Solid Waste Management Health and Safety Risks: Epidemiology and Assessment to Support Risk Reduction

March 2000

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Report #00-01
ACKNOWLEDGEMENTS

This research was sponsored by the Florida Center for Solid and Hazardous Waste Management. Edmund Benson, Mark DeCarlo, Cynthia W. Duffield, Carlos Mangual, Matt Manzione, Joanne Roederer, John D. Schert, Warren N. Smith, Helena Solo-Gabriele, Dorothy C. Sterling, Ram N. Tewari, Ryland Thompson, and Thomas D. Waite are thanked for serving on the project Technical Advisory Committee, and for their suggestions during the course of the research. Ken Hatch is thanked for technical input during the project. Jeff Long, Steve Kropp, and the Florida Bureau of Labor Market and Performance Information are thanked for providing work force data. Chris Goody is thanked for providing computer support. Barbara Smith, Ken Baugh, and the Florida Division of Workers’ Compensation are thanked for providing Workers’ Compensation data. Special thanks go to Andrew Wilfork, Kathleen Woods, Kathie Brooks, and the Miami-Dade County Department of Solid Waste Management for assistance during the research project. Sean Bennie, Mihai Burca, Dybendu De, Khalila Ffrench, Sally Garson, Kelvin Gary, Naira Hosein, Salvador Jurado, Nick Khoury, Rachel Loveman, Joseph McGill, Gabriele Milian, Carlos Morales, Elia Nunez, Eric Olsen, Jaynelle Pemberton, Saradhia Pericles, Ignacio Revilla-Alonso, Maximo Serrano, Judy Solaun, Petronella Uytdewillegen, Alfonso Wangvalle, Clark Wilson, Hong Xu, and Mike Zygnerski are gratefully acknowledged for surveying solid waste collectors in the early morning.
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LIST OF NOTATION

λ = parameter of Poisson distribution, equal to mean number of incidents over planning period;

α_n = parameter of gamma prior distribution for Poisson parameter λ

β_n = parameter of gamma prior distribution for Poisson parameter λ

n_1, n_2, … n_i = data points

\bar{n}_i = mean of the data

I = number of data points

Z = incident size

X = total loss

p(n | α_n, β_n, n_1, n_2, … n_i) = discrete probability distribution given α_n, β_n, and data points n_1, n_2, … n_i

P(n) = probability distribution of incident numbers

F(z) = probability density function of incident size z

F(x) = probability density function of loss x

m and s_m^2 are the prior mean and variance of normal distributions for the injury numbers per year,

Δs_m^2 = 0 if s_m^2 = ∞, Δs_m^2 = 0 if s_m^2 ≠ ∞,

α and β are parameters of a gamma distribution for 1/σ^2,

I is the number of actual data point,

\bar{x}_i is the data average of injury numbers per year

s^2_x is the variance of the observed injury numbers per year, which equals to (x_i* - \bar{x}_i)^2,

x_i is the ith data number.
LIST OF ACRONYMS

NIOSH : National Institute of Safety and Health

OSHA: Occupational Safety and Health Administration

PDF: Probability density function

LWDI: Lost of workdays injury

MSW: Municipal Solid Waste

Ocode: Occupation code

PPR: Prevalence proportional ratio

SIC: Standard Industry Code

CLI: Collection, landfill, and incinerator

NOC: Non-specific
This report presents the findings of a study to evaluate and reduce occupational risks to Florida municipal solid waste (MSW) workers, and to ascertain what is known concerning risks to residents of communities near to MSW landfills. The study consisted of (1) comprehensive literature reviews concerning risks to MSW workers, and to communities near MSW landfills; (2) Workers’ Compensation (WC) data analysis and predictive Bayesian probabilistic assessment of injury characteristics, WC costs and injury frequencies; (3) development of recommendations for reducing injuries and deaths; and (4) educational outreach to MSW facilities and governmental agencies. Results of the overall study indicated high rates of mortality, injury, and disease among MSW collectors. In particular, the driver/helper occupational group suffered an average of 9.8 WC cases of greater than seven calendar lost work days (LWD) per 100 workers annually, 7.4 times higher than the rate for the general workforce in Florida. Actual numbers of injuries were found to be an order of magnitude higher than the numbers of WC claims. This finding agreed with survey results of this study and indicates high chronic morbidity. Mortality of MSW drivers and helpers was estimated at 90 ± 30 deaths per 100,000 workers per year, ranking between rates reported for the second and third deadliest occupations nationally. For the assessed 10% of injuries which became WC cases (>7 LWD), an average annual cost of $12.6 million (1998 basis) was found for Florida. Total costs, including those compensated by employers and borne by workers and communities, may be much greater. Consistent with other studies, skin conditions (rashes), respiratory, and gastrointestinal ailments were reported frequently by collectors in the present survey. Safety recommendations included team-training techniques for crews, public education efforts regarding safe passing of trucks by motorists and disposal of waste, accountability of route supervisors for injuries, redesign of safety vests, warning lights and signs on trucks, and testing of container weight by collectors before lifting. Concerns regarding liability within the solid waste industry were found to be a major obstacle to the flow of information regarding accident prevention. Risks to populations proximal to MSW landfills are largely unknown. General recommendations included research on non-methane airborne emissions from MSW landfills.
EXECUTIVE SUMMARY

This document presents the findings of a study to determine occupational risks to workers in the municipal solid waste (MSW) management industry in Florida, and to investigate risks to populations proximal to MSW facilities. Year 1 of the study focused on risks to workers. The study consisted of (a) a comprehensive review of the literature to determine the state of existing knowledge, and (b) a quantitative risk assessment, exploiting information acquired in the literature review as well as data collected for the project. Year 2 of the study focused on development of health and safety recommendations and review of community exposure and risk surrounding landfills. Year 2 included (a) development of health and safety recommendations and educational outreach program based on statistical analysis of Workers' Compensation (WC) data, and a health and safety survey to 251 waste collectors and four supervisor or safety officers, and (b) literature review of exposures and health effects of solid waste in communities.

LITERATURE REVIEW ON OCCUPATIONAL EXPOSURES AND RELATED HEALTH OUTCOMES IN MUNICIPAL SOLID WASTE WORKERS

A detailed review of the existing literature on the occupational health effects experienced by solid waste workers was conducted. The review concentrated on the peer-reviewed published medical, epidemiologic, and toxicologic literature, as well as available governmental reports. Although not necessarily directly relevant to the Florida solid waste industry, the international literature was reviewed as well, from both developed and less developed nations. This review focused on the available research into the exposures, and the possible and reported health effects of the solid waste worker; however other information sources were reviewed, including those pertaining to the hazardous waste worker.

The following general issues can be surmised from this review of the literature:

1. Relatively little research has been published on either the exposures or the possible health effects of the solid waste industry worker;
2. The existing literature has significant methodologic flaws;

Nevertheless, there are some general conclusions that can be drawn:

1. Solid waste workers are exposed to significant levels of physical, chemical and biological toxins;
2. Solid waste workers do suffer from health effects due to their occupational exposures;
3. In particular, injury, and musculoskeletal, dermal, and respiratory health effects, both acute and chronic, are relatively well documented among solid waste workers;
4. Engineering controls, monitoring of exposures, education, personal protection, and other interventions appear to be under-utilized in protecting solid waste workers from exposure and health effects;
Furthermore, this review of the literature does suggest specific recommendations for reducing the exposures and occupational health effects experienced by the solid waste worker:

1. Additional research is needed to further characterize the exposures and health effects of the solid waste workers;
2. In particular, multi-site, controlled retrospective and prospective epidemiologic studies with appropriate exposure and objective health effect measures should be performed, as well as intervention studies to reduce known exposures;
3. In the meantime, there is much to learn from the existing body of literature and regulation, especially for the hazardous waste worker, which can lead to preventive interventions for the solid waste worker.

RISK ASSESSMENT

The risk assessment conducted in Phase 2 was based on Florida Workers’ Compensation (WC) data, Occupational Safety and Health Administration (OSHA) 200 data for one public and one private facility in Florida, and on results of the comprehensive literature review. The assessment comprised three parts. First, a statistical analysis of Florida WC data was conducted to characterize principal risk categories. Second, a quantitative assessment of WC claim costs was conducted for specific injury and occupation categories. Third, a quantitative probabilistic assessment of the annual numbers of musculoskeletal and dermal injuries to MSW workers was conducted, based on literature information, WC data, and OSHA 200 data for two collection agencies in Florida. Incidents reportable in OSHA 200 logs (requiring more than a single administration of first aid) were considered. Workers’ Compensation data was the principal data collected and used, because it is considered representative of the range of MSW operations throughout Florida. OSHA 200 data was used, along literature information and with estimated confidence levels, to help quantify the number of injuries not resulting in WC claims.

The statistical analysis of WC data characterized claims according to accident type, injury type, occupation, body location, cause, gender, time, day, season, year, and county. The database obtained from the Florida Division of Workers’ Compensation included cases of greater than seven calendar lost work days (LWD). No distinction was made between public and private employers. Claims data for 1993 through 1997 reported under Standard Industrial Codes (SICs) 4212 and 4953 were analyzed as a group (SIC 4953/4212), considered to represent most collection, incinerator, and landfill workers. For SIC 4212 (Local Trucking Without Storage), only claims filed by employers considered to be municipal solid waste collectors were included in the analysis. All claims under SIC 4953 (Refuse Systems), potentially including a small number of claims by hazardous waste workers, were analyzed. Claims under SIC 5093 (Scrap and Waste Materials) were analyzed as a separate group, considered to represent the recycling industry. It was noted that SIC codes are assigned according to the principal activity of
the employer as a whole, and may or may not represent the activity of individual employees reported as such.

To assess injury, mortality, and claim rates per 100 (or 100,000) workers, it was necessary to estimate MSW worker numbers for various occupational categories, based on data compiled by the Florida Bureau of Labor Market and Performance Information. It was estimated that there were 10,500 MSW workers in Florida in 1997. Of these, 4200 were reported under SIC 5093. Of the remaining workers (SIC 4953/4212), at least 2400 were reported as drivers and helpers. These estimates are considered subject to ±30% reporting error, and have been increasing steadily since 1993.

Results of the risk assessment phase of research indicate that MSW workers suffer high rates of musculoskeletal and dermal injuries. Respiratory disease, identified through literature review as a principle exposure, was not reported to any significant extent in WC data obtained for this study. Therefore, no quantitative risk assessment was possible for disease. In this study, disease is used as a more specific term relative to illness, which may include injury. General conclusions regarding mortality and injury rates include:

1. The mortality rate for Florida MSW collectors was estimated at 90 fatalities per 100,000 workers, from 1993 to 1997. Nationally, only two occupations have higher estimated fatality rates. Collector deaths were often caused by a vehicle, either the collection truck or a passing automobile.
2. The expected number of musculoskeletal and dermal injuries to collectors was assessed at 3400 annually, or 57 injuries per 100 (±30) collectors per year, accounting for variability and uncertainty using advanced predictive Bayesian techniques. That is, considering that some workers may experience multiple injuries in a year, each year almost half of all MSW workers may expect to suffer either a musculoskeletal or dermal injury during the year. No such estimates of actual injury numbers are available for other occupations for comparison.
   However, these numbers are an order of magnitude higher than the numbers of WC cases of greater than seven calendar lost work days, in agreement with survey results of this study, and indicate a high level of chronic morbidity in Florida MSW collectors; and
3. There is a 5% believed probability that more than 90 musculoskeletal or dermal injuries per 100 (±30) MSW workers will occur during any year.

General conclusions regarding rates and costs of Workers’ Compensation cases of greater than seven calendar lost work days (LWD) include:

1. From 1993 to 1997, the annual rate of Workers’ Compensation cases per 100 workers in Florida increased significantly, while the rate for the general Florida workforce has fallen;
2. For the assessed 10% of Florida MSW worker injuries that became Workers’ Compensation cases of greater than seven calendar lost work days (>7 LWD), an average cost of $12.6 million per year (1998 basis) was assessed, with a 5% probability of exceeding $47 million in any year; and
3. True costs of occupational injury and disease in MSW workers entails many costs not paid by Workers Compensation, borne by employers, workers and their families, and by communities, including lost salary if fewer than seven calendar days of work are missed, costs of mortality in excess of approximately $100,000, indirect costs, and non-economic costs.

Conclusions regarding WC cases (>7 LWD) under SIC 4953/4212 included:

1. Drivers/helpers were injured most frequently per capita of all MSW occupational groups, suffering an average of 9.8 ± 3 Workers’ Compensation cases (>7 LWD) per 100 workers annually, 7.4 times higher than the rate for the general workforce in Florida;
2. Strains and sprains to the lower back, particularly by lifting, were the most frequently reported injury for all occupational groups;
3. Other frequent injuries among drivers and helpers included lacerations, particularly of fingers and often by glass, fractures, particularly in the foot, and contusions, particularly to the knee; and
4. Relative to the general workforce, vehicular injuries were proportionally higher among collection, landfill, and incinerator workers as a group.

Conclusions regarding WC cases (>7 LWD) under SIC 5093 (recycling) included:

1. Strains and sprains to the lower back, particularly by lifting, were the most frequently reported injury;
2. Other frequent injuries to recycling workers included contusions and fractures, both often by being struck by a falling or flying object, and lacerations, all in varied body locations; and
3. Relative to the general workforce, recycling workers reported higher proportions of burns, injuries resulting from being caught in or between objects or equipment, injuries resulting from being cut, punctured, or scraped, and injuries resulting from being struck by objects and equipment.

Initial findings regarding reasons for occupational injury and disease in MSW workers include:

1. High rates of musculoskeletal and dermal injuries in MSW workers appear related to (i) heavy and continuous lifting by drivers and helpers on collection routes, causing back strains and sprains, (ii) moving equipment parts, causing contusions and fractures, (iii) the presence of sharp material in MSW causing lacerations of fingers and other body parts, (iv) potential exposure to infectious aerosol and water-borne agents in MSW causing occupational illnesses and infectious disease, and (v) the potential for vehicular injuries to collectors collecting both sides of the street around large collection vehicles and passing motorists, both having limited visibility; and
2. Although occupational disease was not reported significantly in data obtained for this study, a study of reported illness in Danish workers indicated a 50% higher
prevalence of occupational disease in MSW workers relative to the general Danish workforce. In particular, gastrointestinal disease was 2.0 times more prevalent, infectious disease was 6.0 times more prevalent, and allergic respiratory disease was 2.6 times more prevalent in reported data for MSW workers. Reported Danish MSW worker injury rates corresponded well with results of the assessment of Florida data, indicating that Florida workers may experience similarly high occupational illness rates. Data reported elsewhere indicates that MSW may have an infectivity similar to medical waste and sewage sludge.

DEVELOPMENT OF RECOMMENDATIONS FOR SAFETY IMPROVEMENTS

The third phase of study consisted of developing recommendations for reducing injuries and deaths among MSW collection workers, based on Phase 1 and 2 results, county-level analysis of WC data, and a survey of 251 MSW collectors and four supervisors at three public and one private collection facility in Florida. Recommendations were not meant to be comprehensive, but to supplement existing, non-proprietary information, available, for example, from the National Institute for Occupational Safety and Health (NIOSH). Initial results of the graphical/statistical analysis of WC claims for the industry indicated a high rate of WC claims in Miami-Dade County. However, county-level analysis indicated that such rates may be attributable to a greater use of the Workers’ Compensation mechanism for compensating injuries, by public waste collection operations in Miami-Dade County. Generality of the results of the survey and county-level WC data analysis are limited by potential differences in privatization and collection methods across the State. Throughout the study, rates of injury and mortality were difficult to derive accurately due to uncertainty in the numbers of workers of different job classifications in Florida. Several factors contributed to this uncertainty, including lack of a centralized system for such data collection, the assignment of SIC codes in individual accident reports and worker data according to the principal business activity of the employer, and the association of principal business activity variously with either the parent company name or with subsidiary names.

Collectors were targeted over other worker groups due to their predominance in the workforce and in injury and death statistics. The nature, specific causes, and contributory factors, of injuries in Miami-Dade and Broward Counties, public and private sectors, were sorted and analyzed versus those for the State, and a categorical logistic analysis was conducted. Capture rate (number responding divided by the number approached) and participation rate (number responding divided by the number available) for the collector survey were 97% and 92%, respectively. Factors related to high injury rates were queried in this survey, including worker literacy and native language and associated difficulty of communicating risks to workers, level of training provided to temporary workers by temporary agencies, enforcement of safety regulations and procedures by agencies and employers, total volume of waste collected, building density, population density, public vs. private operation, vehicle age, street width, mechanization,
race/ethnic differences and associated environmental justice issues, training, experience, age, and gender.

Conclusions generated on the basis of the literature search, WC data analysis, quantitative risk assessment, and the survey of waste collectors include:

1. Survey results were generally consistent with Workers' Compensation data in terms of patterns of injuries; both indicated strain/sprain, contusion, laceration, and fracture as major injuries, with the survey revealing higher proportions of contusions and lacerations (injuries that may not as often result in lost work days);

2. Working conditions were the first concern of collectors in terms of health and safety. They attribute injuries and diseases principally to improper disposal of waste, weather conditions (especially wet, slippery, low visibility conditions, and hot, humid conditions in Florida), and carelessly passing motorists; and

3. Occupational diseases may be a problem for MSW collectors, as indicated by potential exposures, by Danish research, and by the high rate of disease issues reported in the survey. A high incidence of rashes was indicated by survey responses, suggested by some responders to be related to the wearing of gloves.

Recommendations to reduce injuries and deaths among MSW collectors were generated, as for conclusions, on the basis of literature review, WC data analysis, quantitative risk assessment, and waste collector surveys. Changes in the vehicle-based collection method presently employed (e.g., pneumatic conveyance) may eventually reduce occupational risks. Regarding the present system, several recommendations were developed.

**Collection Vehicle Design**

Items to consider regarding engineering design improvements for collection vehicles include:

1. Design of vehicle with respect to loading area, side versus rear, to reduce the incidence of workers pinned against trucks by passing motorists and being backed over by the collection vehicle,

2. Devices to increase communication between driver and the collectors, such as (a) microphones/speakers and video equipment on the outside of trucks and inside cabs, and (b) cellular phones/radios for frequent communication between the supervisor/base and the driver,

3. Design of sweeper devices with respect to shielding of the compaction area, and additional shielding, to reduce exposure of workers to objects, aerosols, and liquids,

4. Further study of reported accumulation of malodorous airborne garbage emissions inside cabs, and of better ventilation/sealing of cabs to minimize such exposure,
5. Flashing lights and signs on the upper sides and backs of trucks to warn motorists (similar to those used on school buses), and
6. Increased automation of collection systems.

Workers and Administration

Recommendations regarding work procedures and administration include:

1. Collectors should briefly test the weight of each container before lifting, to prepare for the load,
2. Collectors should not mount trucks while moving,
3. Trucks should be cleaned and inspected daily,
4. Route supervisors, in addition to safety officers, should be accountable for injuries on their respective routes,
5. Route supervisors should visit routes frequently and discuss proper/improper technique with workers on the spot,
6. Written safety procedures should be widely distributed, reviewed, and enforced,
7. Incentives for safety compliance should be maintained and advertised,
8. Workers should be instructed not to pick up containers weighing over 50 lbs. or obviously containing hazardous materials, but to leave an informative tag on the container for the resident,
9. Compensation method (payment by the hour rather than by the route) should be evaluated relative to injury frequency, and
10. Scheduled medical surveillance and monitoring of workers should be implemented.

Training

Principal recommendations regarding collector training included:

1. Training in teamwork and communication techniques within crews should be conducted,
2. Continuous training in proper lifting and carrying techniques, constituents of MSW, potential hazards of exposure to aerosol contaminants, and techniques for inclement weather, should be augmented, and
3. MSW collection agencies should assume responsibility for health and safety training of temporary workers, and ensure training equivalent to that provided for permanent workers, and
4. All training should be documented.

Applicable Personal Protective Equipment

Recommendations regarding safety equipment included:

1. Reflective safety vests should be redesigned, or incorporated into uniforms, to prevent catching on trucks, and
2. ANSI-approved boots adapted to local weather conditions should be mandatory, and
3. The effect of gloves on the occurrence of rashes should be investigated.

Public Education

Multi-lingual mailings or inclusions with waste collection bills should be distributed to residents regarding:

1. Procedures for passing collection vehicles, including special caution in inclement weather and low-visibility situations,
2. Allowable waste constituents, maximum disposal and container weight, and
3. Hazards of waste collection.

EDUCATIONAL OUTREACH

Results of the study presented in Chapters 1 through 3 were used in the course of an educational outreach program. The outreach phase consisted of four tasks. First, a mailing list of approximately 200 public and private MSW collection agencies in Miami-Dade and Broward Counties, and counties and other governmental agencies throughout Florida, was developed. Second, a brochure including key project findings and recommendations was developed, and distributed accordingly. The intended audience was solid waste collection and safety managers. Special emphasis was on relevant information not typically available to facility-based professionals, and new recommendations developed as a result of this study. Recommendations included in the pamphlet were not intended to be comprehensive, but to supplement existing literature and knowledge. Material on risks found for the State as a whole will be used to motivate recommendations.

The third outreach task was distribution of the Final Report and educational pamphlet. First, a mailing to the approximately 200 public and private agencies on the mailing list, the Florida Division of Safety, the U.S. Occupational Safety and Health Association, Florida Association of Counties, Florida League of Cities, and the Florida Center for Solid and Hazardous Waste Management, was made. In addition, key findings, the final report, and the educational pamphlet, were posted to the project website. Finally, presentation of project results was made to the Advisory Board of the Florida Center for Solid and Hazardous Waste Management, representing solid waste industry, government, and academic sectors in Florida.

The final educational task included media outreach, conference presentations, website maintenance, and peer-reviewed publications. Results presented in Chapter 2 were released at the end of Year 1 to: Associated Press, one national network and two local television stations, three newspapers, two radio stations, two trade journals, one municipality, one trade association, one union, and a planning consultant. A second University of Miami press release was developed after comments were received from the TAG and participating MSW collection agencies, and the final report was finalized. Risk
assessment and WC data analysis results of Chapter 2 were presented at two national
conferences. A project website was maintained to disseminate findings, including a Fact
Sheet on "The Occupational Exposures & Risks of Florida Municipal Solid Waste
Workers." WC data analysis was published in Waste Management & Research, and risk
assessment results are under review for publication in Risk Analysis: An International
Journal. A paper describing the summary results of the survey presented in Chapter 3
was prepared, and sent to participating agencies for review, for publication as
appropriate. The literature review given in Chapter 1 was submitted for publication in
American Journal of Industrial Medicine.

LITERATURE REVIEW ON EXPOSURES AND HEALTH EFFECTS OF SOLID
WASTE IN COMMUNITIES

Modern landfills are designed to collect leachate and methane gas, and MSW
incineration plants are designed to utilize high temperatures, and scrubbers and other
pollution control devices, to control emissions. However, studies have shown that
leachate may contaminate groundwater due to faulty design and/or construction; there is
the possibility of migration of VOCs through the synthetic and compacted clay liners;
and air pollution is possible even with extensive control devices. Moreover, malodorous
airborne emissions can be detected at significant distances from landfills, and such
emissions are not required to be monitored except for methane and average non-methane
organic compounds (NMOC) content.

There is very little scientific literature available on the exposures and health
effects in communities surrounding Municipal Solid Waste (MSW) disposal sites. In the
case of landfills, the main exposure sources would be biogas and leachate. In municipal
solid waste incineration, solid waste incineration, exposures could result from exposure
to air-borne emissions and solid residues (ash and slag). For composting facilities, there
is the potential for exposures to disease vectors, pathogens, methane gas and malodorous
gases.

To evaluate the health impact of MSW waste sites, the hazardous waste literature
was reviewed for both workers and the surrounding communities. There is an overlap
between these two industries due to illegal dumping and misclassification of wastes. The
physical and biological exposures of hazardous and MSW waste sites appear similar.
Although quantitatively less, several studies have found that emissions from MSW sites
may have chemical properties similar to those of emissions from hazardous waste sites.

Hazardous waste poses several potential chemical, physical, and biological
hazards. Short-term human health effects that have been investigated in relation to
residential proximity to hazardous waste sites, include reproductive effects and
developmental effects in children. Long-term effects, such as cancer, have also been
looked at, and some positive correlation has been found. Another important human
health effect is the significant psychological impact due to perception of exposure and
health risk that proximity to these sites has had on communities.
Municipal solid waste disposal sites present potential physical, chemical and biological hazards that can parallel those of hazardous waste sites. Chemical and biological hazards are associated with the inappropriate disposal of the waste itself and with emissions from the sites. These hazards have been found to be associated with both acute and chronic human health effects in solid waste workers. Reported occupational health effects have included dermatological, respiratory, cardiovascular, gastrointestinal, and neurologic effects.

Epidemiology has been the major source of information on the health effects associated with living near MSW sites. These studies are limited because of several factors including the small study populations, recall bias, lack of actual exposure data, and lack of necessary latency periods for chronic exposures and diseases. Studies have shown that there is a possibility that living in proximity to these sites may increase the risk of cancer and reproductive effects. However due to the flaws in these studies, the estimation of these risks is still questionable and warrants further investigation.

Primary prevention of exposure to avoid subsequent health effects in workers and communities surrounding solid waste facilities is a recommendation of this review. At the same time, research involving collection of data on organic and inorganic airborne emissions from MSW landfills and transfer stations should be performed to ascertain potential exposures to neighboring community populations. Also, research should be performed stressing the collection of individual exposure data to establish or refute the suggested associations between waste exposure and acute and chronic health effects. For a variety of reasons, these studies would be most effectively performed in solid waste workers. However, it is highly recommended that future studies look more closely into the environmental justice concerns associated with the location of these disposal sites. Communities that can benefit from the Environmental Justice focus include those with low socioeconomic status and those that have a high disease burden. It would be useful to set up surveillance systems in these communities since they may provide an adequate population sample for valid epidemiological studies to be conducted.

CONCLUSIONS AND RECOMMENDATIONS

The principal conclusion of this study was that solid waste collection involves substantial occupational risk in terms of injury, mortality, and perhaps disease. Methods used for residential solid waste collection should be evaluated with regard to collector safety and health. Regarding the current system of waste collection, improvements in safety procedures, equipment, training, and other factors are recommended. Still, collectors surveyed valued their position, and none suggested automation as an alternative to manual collection. Although occupational disease was not adequately studied due to limitations of the Workers’ Compensation database, skin conditions (rashes), respiratory conditions (e.g., asthma, cough, allergy), and gastrointestinal ailments were reported most often by collectors surveyed. The survey also indicated a desire on the part of collectors for additional training and supervision. Risks to populations proximal to MSW landfills are largely unknown. In particular, monitoring of emissions other than methane and non-methane organic compounds (NMOCs) is not required, and data on specific non-methane emissions have not been found.
As discussed in detail in the individual Chapters, there are important limitations to the conclusions that can be drawn from the data presented in this report. In particular, the analysis of the Florida Workers' Compensation data is limited by the lack of denominator data (i.e., the actual numbers of solid waste workers in Florida), as well as issues of misclassification and reporting bias. Several factors contributed to uncertainty in denominator data, including lack of a centralized system for such data collection, the assignment of SIC codes in individual accident reports and worker data according to the principal business activity of the employer, and the association of principal business activity variously with either the parent company or with subsidiary names. Furthermore, occupational disease rates are largely unknown due presumably to lack of reporting by workers. Chronic diseases in particular by definition do not appear for some time, and the etiology of these chronic diseases is difficult to attribute to waste collection duties. The MSW collector survey is limited by the inherent bias of self-reported data without objective confirmation, as well as the relatively small number of participants (both in terms of workers and industry groups). Concerns regarding liability within the solid waste industry were found to be a major obstacle to the flow of information regarding accident prevention. Such barriers included (a) highly restrictive policies regarding provision of State Workers' Compensation data (anonymous as to worker identity), (b) confidentiality of OSHA/SAF 200 data of public and private agencies, and (c) lack of sharing of written safety materials by any of approximately 40 public and private waste collection agencies contacted. Nevertheless, the conclusions drawn by the Investigators are supported by the review of the international scientific literature of solid waste worker risks and exposures included in this report. These data are important because they represent the first such studies of the range of occupational exposures and potential health risks among Florida's solid waste workers. Although not conclusive, these studies indicate the need for further exploration of the occupational exposures and potential health risks among Florida's solid waste workers.

Several general recommendations were generated on the basis of findings. First, laws should be written to motivate the open disclosure of information related to health, safety, and environmental risks of conducting business. That is, when an accident occurs that results in a court case, previous sharing of information and data regarding risks with stakeholders and interested parties should be rewarded rather than penalized in compensatory decisions. Simply stated, ignorance of risks of all kinds should not be bliss, but should be eliminated to the extent possible so that individuals and society can make informed decisions regarding relative risks incurred in daily living. Estimates of health and safety losses in monetary units should be developed, to motivate accident prevention efforts. Second, it is recommended that the public be educated regarding the hazards of waste collection. In particular, residents should be informed as to maximum weights allowable for disposal, allowable items and substances for disposal, and proper techniques for passing collection vehicles in automobiles. Third, several research needs involving data collection are apparent. Data on airborne emissions from landfills, including potential carcinogens and reproductive toxins, should be collected. Data on health effects in landfill workers should be collected. And, data on incidence of occupational disease should be collected for MSW workers of all types. In Florida, better
data on populations of workers by job classification are needed, to aid in the analysis of all injury and disease data. Also in Florida, oversight, consultation, and education regarding health and safety practices within public agencies should be continued at a level that assures worker safety. The role of the Florida Department of Labor and Employment Security, Division of Safety should be emphasized in light of the findings of this study.

**SOURCES OF ADDITIONAL INFORMATION**


1. REVIEW OF LITERATURE ON OCCUPATIONAL EXPOSURES AND RELATED HEALTH OUTCOMES IN MUNICIPAL SOLID

Lora E. Fleming
Judy A. Bean
Melissa Danits

Current waste management has significant potential for human health and safety risks, and environmental contamination. Workers in waste management operations are the primary affected population at risk for exposure to waste hazards. Although the potential human risks and monetary costs are high, there is little useful information available to solid waste managers for reducing such risks.

This is a review of the available peer-reviewed and government literature pertinent to the exposures and health effects of solid waste workers. The information is divided by job type and disposal strategy. A discussion of the data limitations, research considerations, and future recommendations are offered related to this body of literature.

1.1 BACKGROUND

An enormous amount of solid waste is produced each year in the United States. Since 1960, the volume of municipal solid waste has increased by 250%: from 88 million tons to over 208 million tons in 1995 (Keep America Beautiful, Inc., 1996). When examined more carefully, this figure is equivalent to 4.34 pounds of trash per person per day in the United States. The US Environmental Protection Agency (EPA) projects that by the year 2000, the amount of municipal solid waste generated will be up to 223 million tons, with a projected 262 million tons by 2010 (Keep America Beautiful, Inc., 1996; EPA, 1988). In the State of Florida, from July 1995 to June of 1996, a total of 23.8 million tons of municipal solid waste were collected; this amounts to 9.02 total pounds per person per day (Florida DEP, 1998a).

The materials in municipal solid waste include non-hazardous wastes from households, commercial establishments, institutions, markets, and industries. In highly industrialized countries, the composition of this waste can range from vegetable and putrescible matter (20-50%) to paper and carton (15-40%), to plastics (2-10%), to metals (3-13%), to glass (4-10%) (Cointreau-Levine, 1998).

1.1.1 Brief History

The issue of solid waste has received considerable governmental attention for the last three decades. In the United States, the federal government passed the first major piece of regulation legislation regarding municipal solid waste: the 1965 Solid Waste Disposal Act (Keep America Beautiful, Inc, 1996.). In the early 1970's, the industry
began its transition from open dumping to controlled landfills (Cointreau-Levine, 1998). In 1976, the Resource Conservation and Recovery Act (RCRA) (Public Law 94-580) was enacted. The principle behind this law was the upgrading of solid and hazardous waste management technology and practices (Anderson, 1987). Since that time, a gradual development in technology has contributed to the refinement of the procedures necessary to lessen environmental pollution and human health effects related to solid waste.

Over the past twenty years, the industry has seen increases in facility regulation in an attempt to decrease the number of work-related risks. Several issues are central to the study of solid waste. In order for researchers to establish a relationship between solid waste and potential health outcomes, a universally accepted operational definition of solid waste must exist. Unfortunately, in the literature, the term “solid waste” is used in several different ways with a myriad of definitions. Most individuals think of waste as "any useless byproduct, refuse, garbage or trash" (Anderson, 1987). Florida Statutes have been employed. Florida Public Law defines solid waste as:

sludge unregulated under the federal Clean Water Act or Clean Air Act;
sludge from a waste treatment works, water supply treatment plant, or air pollution control facility; or garbage, rubbish, refuse, special waste, or other discarded material, including solid, liquid, semi-solid, or contained gaseous material resulting from domestic, industrial, commercial, mining, agricultural, or governmental operations (P.L.62-701. Section 102).

From this definition, "solid waste” is comprised by law of materials that are a mixture of liquids, gases, and solids. In addition, a small amount of hazardous waste is allowed under the definition of solid waste (Keep America Beautiful, Inc., 1996). This hazardous portion of solid waste is proposed as one of the primary reasons for the political opposition and attention that the solid waste industry faces today (Anderson, 1987), as well as the shear volume produced and how to dispose of it.

Municipal solid waste is the subset of solid waste, as defined above, generated by the community. The sources of municipal solid waste can include residential, commercial, institutional, construction and demolition, municipal services (such as street cleaning), and treatment sites (such as municipal solid waste incinerators). In 1996, 55% of all municipal solid waste in Florida was generated by the commercial sector (FL DEP 1998b).

However, municipal solid waste is generally considered to exclude agricultural and industrial wastes (Tchobanoglous et al, 1993). It is governed by a myriad of local regulations and definitions (incorporating such issues as moisture content). Therefore, the composition of municipal solid waste and its contents can vary from facility to facility, and even from day to day (Tchobanoglous et al, 1993).

1.1.2 Hazardous Waste

Although the main focus of this review is on the municipal solid waste industry, hazardous waste and the implications of associated physical and chemical exposures to hazardous waste workers may also be relevant. The physical hazards associated with exposures to hazardous wastes can be similar to those encountered by solid waste
workers. Due to the potential inclusion of hazardous material in municipal waste, the solid waste worker may be in jeopardy of chemical exposures that are similar to the hazardous waste worker (although presumably at lower levels of exposure). Therefore, there are aspects of the hazardous waste industry from the point of view of the worker which are pertinent to this paper.

In 1974, the EPA estimated that 90% of all hazardous wastes were improperly disposed of in open pits, surface impoundments, vacant land, farmlands, and water bodies (EPA, 1974). In response to this problem, Congress passed the Resource Conservation and Recovery Act (RCRA) in 1976 and then the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, or Superfund) in 1980. CERCLA provides the federal government with the authority to clean up releases of hazardous substances, to carry out investigations, to test and monitor sites, and to implement clean-up procedures (Zirschky et al., 1987). By Florida Statutes, the legal definition of hazardous waste is: a solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical or infectious characteristics may: (A) cause, or significantly contribute to an increase in serious irreversible, or incapacitating reversible, illness; or (B) pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed (P.L.94-580, Section 1004).

In a California study by Bomberger et al. (1988), hazardous wastes were estimated to constitute only 0.3% by weight of solid municipal waste. One study suggested that the primary industries producing these wastes are primarily chemical, equipment and metals manufacturing, motor transport, and utility companies (Westat Inc., 1984).

1.1.3 Developing Nations and Hazardous Waste

In developed countries, such as the United States, hazardous wastes are "strictly regulated to be source segregated and separately managed in secured transport, processing, and disposal facilities" (Cointreau-Levine, 1998). In contrast, in developing countries, an even higher level of hazardous wastes may be observed in municipal solid waste, despite the lower level of commercial, industrial, and institutional activity, due to the lack of or disorganized regulatory framework and enforcement system. Often, bloodied bandages, cotton swabs, and syringes from hospitals are mixed in with the municipal solid waste of a developing country. Also common are hazardous solvents, adhesives, plating materials, and pesticides from industries, as well as hazardous asbestos from construction and demolition sites (Cointreau-Levine, 1998).

1.1.4 Medical Waste

The issue of medical waste has received a great deal of attention, particularly in the last decade. A hazardous waste survey conducted in 21 Latin American countries found that most of the hazardous medical wastes were being co-disposed with general municipal solid waste in open dumps and controlled landfills (de Koning et al., 1994). But this
problem is not isolated to developing countries. In developed countries, due to the shift in the medical community towards disposable medical supplies (including needles and other sharps), and the stricter regulations on incineration, infectious wastes are now a significant component of municipal solid waste streams. The Florida Department of Environmental Protection (DEP) estimates some 40,000 "generators" (i.e. hospitals) of infectious waste producing 52,000 tons/year of biomedical wastes, with hospitals the largest generator (FLDEP, 1998b). This number fails to include in-home healthcare, hospice, and illicit intravenous drug user sources, all possible sources of improper disposal procedures.

1.1.5 Sanitation

Human waste (feces) is common in solid waste. Most of this waste arrives through soiled disposable diapers (SDD) (Cointreau-Levine, 1998). In high-income countries, 1% of the dry weight of the municipal solid waste is estimated to come from SDD. This amounts to nearly 2 million tons of diapers disposed of per year. Nearly one third of these diapers are soiled with feces (Peterson, 1974). In developing countries, an even higher percentage of human waste is in the municipal solid waste due to inadequate sanitation (Cointreau-Levine, 1998). In higher income countries, the majority of human waste is handled in separate sewage and septic tanks; in less developed countries, it is not uncommon to find seepage from septic tanks left at open dumps due to a lack of treatment facilities.

1.1.6 Waste Management

Various methods are employed to deal with the huge amount of waste that is produced in the world. The methods employed by different communities vary according to their unique needs, and economic and environmental conditions. However, the five primary options are: source reduction, recycling, composting, landfilling, and waste-to-energy (combustion or incineration) (Keep America Beautiful Inc., 1996). In an approach known as "integrated waste management," an individual community employs several of these options based on what is most efficient, cost effective, safe, and environmentally beneficial for that particular community. Source reduction relies on the individual society to reduce the amount of material that eventually is discarded as garbage. Recycling reconverts raw material into new products through a complex process. During composting, organic waste materials decompose, forming a nutrient rich soil-additive as the end product called “compost.” Landfilling utilizes a minimum amount of space to dispose of waste in a safe, closely monitored area. Combustion creates steam or electricity derived from the burning of waste (Keep America Beautiful, Inc., 1996). In 1994, 62% of US municipal solid waste was landfilled, 17% recycled, 16% converted to energy, and 1% incinerated (Franklin, 1994).

1.2 HUMAN HEALTH EFFECTS

A global relationship has been identified between solid waste handling and exposures, and increasing health risk. Human exposure may take place at nearly every step along the way: from the generation of waste to its disposal. Once disposed of, the
waste is likely collected and taken to sanitary landfills, incinerators, resource recovery plants, or composting facilities (Pahren, 1987). Thus, the population at greatest risk for highest and most concentrated exposures is the solid waste industry worker.

Few epidemiologic or medical studies of solid waste workers have been conducted. Although mortality data directly related to accidental on-the-job death are required to be reported due to Occupational Safety and Health Administration (OSHA), mortality from chronic disease associated with occupational exposure to solid waste would not be reported. Furthermore, morbidity data (both injury and disease) are infrequently collected outside of workers' compensation systems. Therefore, potentially a great deal of mortality and morbidity data are unreported. The following is a review of the available literature on the spectrum of exposure, and the possible health hazards related to solid waste industry workers.

1.2.1 Potential Exposures by Job Type

Refuse Collectors

Table 1.1 is a summary of the reported exposures and related reported health effects associated with waste collectors.

<table>
<thead>
<tr>
<th>Reported Exposures</th>
<th>Reported Health Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel Exhaust</td>
<td>Eye irritation, asthma, decreased lung function, upper respiratory tract irritation, lung cancer</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>No documented health effects; potential cardiovascular, neurologic, asphyxiation</td>
</tr>
<tr>
<td>Polycyclic Aromatic Hydrocarbons</td>
<td>No documented health effects; potential carcinogenic</td>
</tr>
<tr>
<td>Dust</td>
<td>Eye irritation, organic dust toxic syndrome (ODTS), non-allergic pulmonary disorders, impaired lung function</td>
</tr>
<tr>
<td>Microorganisms</td>
<td>Dry cough, exercise induced dyspnea, asthma, chronic bronchitis, ODTs, chest tightness, fever, chills, flu symptoms</td>
</tr>
<tr>
<td>Endotoxin</td>
<td>Fever, chest tightness, airway irritation, headache, joint and muscle pain, nausea, fatigue, non-allergic pulmonary disorders, impaired lung function, acute gastrointestinal symptoms</td>
</tr>
<tr>
<td>Gram-negative bacteria</td>
<td>Inflammation of airways, diarrhea, nausea</td>
</tr>
<tr>
<td>Fungal spores</td>
<td>Allergic alveolitis, asthma</td>
</tr>
<tr>
<td>Aerosols from waste</td>
<td>Eye and nose irritation, nausea, vomiting</td>
</tr>
<tr>
<td>Chemicals improperly disposed of</td>
<td>Burns, fires, explosions, eye and skin irritation</td>
</tr>
<tr>
<td>Sharp and broken objects</td>
<td>Lacerations, punctures, abrasions</td>
</tr>
<tr>
<td>Heavy traffic</td>
<td>Pedestrian accidents, broken bones, bruising, death</td>
</tr>
<tr>
<td>Machinery</td>
<td>Crushed body parts, broken bones, lost limbs, musculoskeletal aches, twisted muscles, sprains, permanent disability</td>
</tr>
<tr>
<td>Heavy lifting</td>
<td>Disorders of the neck, shoulder and back, tendon diseases, extreme pain, lumbar disc prolapse, increased pulmonary ventilation</td>
</tr>
<tr>
<td>Unknown exposure</td>
<td>Coronary heart disease, myocardial infarction, angina, insufficiency</td>
</tr>
</tbody>
</table>

In the United States, typically for a manually loading truck, a crew of 2 or 3 persons is
common. In many cases, the driver and helpers alternate roles. A crew of 1 or 2 persons is sufficient for mechanically loading trucks. Typically, a manually loading collector picks up about 5 tons/day, while a mechanically loading collector picks up 11 tons/day. Each day, a crew produces two to three truckloads, averaging 3 to 4 tons per load. The average collection route is 2 to 4 miles per day (Hara et al., 1997; Tchobanglous et al., 1993).

Refuse is required to be fully contained within a plastic bag or in a covered bin. The weight and size of each bag or container of refuse is also regulated by occupational health and safety regulations (Cointreau-Levine, 1998). The various shifts employ approximately 75% of the men on a 7 am to 3 pm schedule, and the rest have varied hours, depending on season and workloads. Collections take place usually six days per week in all types of weather, traffic and neighborhoods. On average, the crew spends 4 to 5 hours per day loading. However, a "ready- and-go-home" scheme has been documented. This phenomenon implies that workers may return home after they collect their daily amount of refuse. Although this allows more time off, the associated increased speed of work often results in injury (Verbeek et al., 1993).

The engineering design of the truck itself leaves the crew vulnerable to many potential health hazards. For example, the location of the exhaust pipes on most trucks directs the fumes toward to work area. This potentially results in overexposure to carbon monoxide (Cimino, 1975). Because garbage collectors work in the street, they are exposed to polycyclic aromatic hydrocarbons (PAH) in motor vehicle gas as they work (Hara et al., 1997). Refuse collectors are exposed to high levels of dust, and foreign bodies are a constant problem due to the lack of air circulation in the disposal area. It is also not uncommon for collectors to find volatile or flammable products discarded in the refuse. Utilization of older equipment poses another potential hazard (Cimino, 1975).

Since the commercial vehicles weigh in excess of 30,000 pounds unloaded, and potentially 50,000 pounds when fully loaded, drivers are allegedly trained regarding how differentials in weight can affect the braking distance (Campbell, 1993). Training is also necessary with regard to traffic associated with specific routes. There is documentation regarding poor visibility due to vehicle design. One study indicated that there are very large blind areas at the right side of trucks which caused countless right turn traffic accidents (Campbell, 1993).

As a result of traffic, loaders frequently work in the middle of the street. Obviously, peak traffic hours and inclement weather add to potential hazards. Frequently, the loaders have been observed to be inattentive and even negligent, riding on the running board of the truck, or collecting from two sides of the street at the same time. Lack of caution and awareness potentially leads to serious injury for the loader as in the following documented scenario: standing behind the truck as it backs up with dirty side-view windows and a disconnected backup alarm due to noise (Campbell, 1993; NIOSH, 1997). Loaders occasionally retrieve articles from inside the hopper, often resulting in injury from the machinery. Newer vehicles may be equipped with a hesitation cycle on the compactor and/or an additional safety stop device. The "diversity and nature" of
equipment and the solid waste handled may also cause problems, i.e. a wide range of objects of variable weight and volume (Bourdouxhe et al., 1993).

**Incinerator Workers**

Table 1.2 is a summary of the reported exposures and related reported health effects associated with incinerator workers.

**Table 1.2. The Documented Exposures and Related Health Effects for Incinerator Workers**

<table>
<thead>
<tr>
<th>Reported Exposures</th>
<th>Reported Health Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dust</td>
<td>Respiratory irritation, gastric cancer, lung cancer</td>
</tr>
<tr>
<td>Exploding chemicals or aerosol cans</td>
<td>Acute and chronic respiratory disorders, burns, death</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Cough, gastric cancer</td>
</tr>
<tr>
<td>Fungal spores</td>
<td>Respiratory distress</td>
</tr>
<tr>
<td>Fecal coliforms</td>
<td>Respiratory distress</td>
</tr>
<tr>
<td>PAH</td>
<td>Lung cancer, increased atherosclerotic plaques, ischemic heart</td>
</tr>
<tr>
<td>Dioxins (PCDDs and PCDFs)</td>
<td>Disease</td>
</tr>
<tr>
<td>Loud machinery</td>
<td>Increased triglycerides</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>Long term hearing disorders</td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>No documented health effects; potential neurologic</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>No documented health effects; potential respiratory</td>
</tr>
<tr>
<td>Heavy metals</td>
<td>No documented health effects; potential cardiovascular, neurologic, asphyxiation</td>
</tr>
<tr>
<td>Respirable quartz</td>
<td>No documented health effects; potential neurologic, hematologic, renal</td>
</tr>
<tr>
<td>Benzene and other solvents</td>
<td>No documented health effects; potential respiratory</td>
</tr>
<tr>
<td>Unknown exposure</td>
<td>No documented health effects; potential neurologic, carcinogenic Hypertension, proteinuria</td>
</tr>
</tbody>
</table>

Modern municipal waste incinerators are designed for heat recovery. In this type of system, the three main areas are the front-end system, the thermal part, and the discharge area. The front-end is typically referred to as the “tipping hall.” It is composed of an unloading shed, a refuse pit, a loading crane and a vibrating feeder. The thermal part of the system consists of a drying gate, combustion gate, gate movement, burnout gate and boiler section. The discharge area deals with both solid and gaseous discharge and ensures proper distribution of the excess heat from the combustion (Poulson et al., 1995).

The initial stage of incineration is the actual unloading of the refuse from municipal trucks to the waste storage areas. The next stage may involve the transfer of waste from the pit to the shredders, and then often to a magnetic separator to remove iron. However, municipal solid waste may or may not be sorted before incineration. Some facilities employ a technique called "mass burning." Mass burning may be preceded by removal of hazardous items, but it does not involve shredding of the waste material (Berenyi, 1996). In both methods, the refuse is then transferred to the furnace (via a conveyor belt) by overhead cranes, or at smaller facilities, by a front-end loader (Berenyi, 1996; Mozzon et
An incineration facility may have one or several furnaces at a site. Each boiler has an approximate capacity of 300-400 tons per day (tpd) with an average power output of 32 megawatts of electricity (Berenyi, 1996). The temperature is usually regulated via air flow through the furnaces (Angerer et al., 1992). According to Berenyi (1996), the average design capacity of an incinerator is 789 tpd with an ash residue of about 176 tpd.

During incineration, municipal waste combustion (MWC) residues are generated at many points. In general, three categories of ashes are produced during incineration: bottom ash, air pollution control (APC) residues, and combined (i.e. the combination of bottom ash and APC residues). Bottom ash consists of the solids retained on furnace grates after combustion, and the solids that pass through the grates. Fly ash is made up of the particles that rise from the furnace during burning (Berenyi, 1996). Fly ash is considered the most hazardous part of the residue, due to the concentrations of leacheable and potentially airborne heavy metals and organic compounds it contains (Hjelmar, 1993). Fabric filters and/or electrostatic precipitators (ESPs) remove trapped particulates and residues generated by acid gas scrubbers. These particulates and residues are the components of APC residue. Some plants use ESPs to remove particulates before wet scrubbers (Wiles, 1996). Other pollution control equipment may include spray dryers used to remove acid gas compounds, and/or baghouses, for the removal of particulate matter (Zemba et al., 1996).

Incinerator workers have many potential chemical exposures including: dust, polycyclic aromatic hydrocarbons (PAH), other polycyclic compounds, nitrous oxides, sulphur dioxide, heavy metals, and carbon monoxide (Rumbold, 1997; Gustavsson, 1989). Microorganisms have also been detected in the air at incineration plants (NEA, 1986). The potential for constant exposure to microorganisms at the incinerator plant exists due to various operations such as conveying, shredding, and screening (Pahren, 1987). Ware (1980) found that in the case where incinerators were packed beyond capacity, packed too tightly, or the operating temperatures were too low, microorganisms can survive. Incomplete combustion potentially leaves residues that enhance the breeding of flies and rats (Anderson, 1987). Shane et al. (1990) also found that the scenario of incomplete combustion can result in the production of a several thousand-fold increase in PAHs. Dioxins have been documented in the exhausts from municipal waste incinerators (Karasek and Hutzinger, 1986). Specifically, polychlorinated dibenzo-p-dioxins (PCDDs) and furans (PCDFs) were reported in municipal solid waste incineration because they are byproducts formed during combustion (Zemba et al., 1996; Ruokojarvi et al., 1995). Increased levels of PCDDs and PCDFs were reported in the blood of exposed vs unexposed municipal waste incinerator workers by Schecter et al (1995). Of note, several studies have found significant amounts of mutagens in the urine of incinerator workers compared to unexposed workers such as water supply workers, even controlling for smoking (Ma et al, 1992; Angerer et al, 1992; Scarlett et al, 1990).

Haynes and Law (1978) reported that bottom ash and stack emissions from
municipal incinerators may be hazardous due to heavy metals such as arsenic, cadmium, lead, antimony, and mercury in the stack air and/or fly ash. Other studies have detected copper, nickel, selenium, beryllium, tin, and zinc in both the stack emissions and the collected ashes from municipal waste (Nriagu and Pacyna, 1988; Korzun and Heck, 1990; Mumma et al., 1990; Roffman and Roffman, 1991). Mumma et al. (1990) also found respirable quartz and solvents such as benzene in various concentrations in fly ash. A study conducted by Malkin et al. (1992) demonstrated that the lead present in incinerator ash is capable of increasing blood lead levels in incinerator workers compared to controls (mean blood levels 11.0 ug/dl vs 7.4 ug/dl); in this study, an increased blood lead was associated with never wearing protective devices and cleaning the precipitators frequently.

Incinerator workers are under a constant threat of potential fire, due to the possibility that waste may overflow from the pit area. Independently, the pit area poses a potential health threat due to the fact that oxygen levels are often not sufficient to support life if an individual were to fall into the pit (Cimino, 1975).

Compost Workers

Table 1.3 is a summary of the reported exposures and related reported health effects associated with compost workers.

**Table 1.3. The Documented Exposures and Related Health Effects for Compost Workers**

<table>
<thead>
<tr>
<th>Reported Exposures</th>
<th>Reported Health Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fungal spores</td>
<td>Pulmonary diseases, allergic alveolitis, invasive aspergillosis, lung tumors</td>
</tr>
<tr>
<td></td>
<td>Nausea, diarrhea,</td>
</tr>
<tr>
<td>Gram-negative bacteria</td>
<td>Upper airway irritation, headache, fatigue, nausea, diarrhea</td>
</tr>
<tr>
<td>Dust</td>
<td>Headaches, nausea</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>Nausea, vomiting</td>
</tr>
<tr>
<td>Sulfur compounds</td>
<td>No documented health effects; potential respiratory effects</td>
</tr>
<tr>
<td>Microorganisms</td>
<td>No documented health effects; potential respiratory effects</td>
</tr>
<tr>
<td>Mycotoxins</td>
<td>No documented health effects; potential respiratory effects</td>
</tr>
<tr>
<td>Bioaerosols</td>
<td>No documented health effects; potential respiratory effects</td>
</tr>
<tr>
<td>PAHs</td>
<td>Skin irritation</td>
</tr>
</tbody>
</table>

For the purpose of composting, municipal solid waste may or may not be sorted before they are delivered to the plant. If sorted, only the convectable portion of the waste arrives at the facility (Kim et al., 1995; He et al, 1995). Workers are present at the composting site at least for the purpose of surveillance, maintenance, and repairs, even though the procedures may be designed to be fully automated (Kim et al., 1995). Several different techniques may be employed with regard to composting, in particular windrow composting, aerated static pile composting, and in-vessel composting. One, referred to as a "simple system," involves large rows, called “windrows,” formed on packed soil or asphalt, and turned by specialized machinery or scabbards (Haug, 1980; Beyers, 1998). Aerated static pile composting involves the mechanical introduction of ambient air using
an air plenum system, without the necessity of turning the organic mixture (Beyers, 1998). A more automated and expensive approach known as in-vessel composting uses large vessels as reaction chambers, accelerating the process of aerobic composting (Kim et al., 1995; Beyers, 1998).

Composting is considered a biological process. If prepared properly, compost should eliminate most pathogens, therefore working with the waste prior to composting should lead to the greatest potential exposure to biological pathogens (Epstein, 1993). However, the end products may be contaminated by both microorganisms and their toxic byproducts, such as mycotoxins (Kim et al., 1995). Lacey et al. (1990) reported bio-aerosols present in air samples. In one study Aspergillus, a fairly ubiquitous fungal spore, has been measured to be airborne at composting plants, especially at the sludge site (Clark et al., 1983; Olver, 1994). Heida et al. (1995), found Penicillium species during air sampling at compost sites, as well as high concentrations of gram-negative bacteria. Of note, a study by Lebret (1985) detected aromatic, aliphatic, and chlorinated hydrocarbons in the air at composting facilities; trace amounts of heavy metals, pesticides, dioxins, PCBs, and other organics have been found in compost with the possibility of worker exposure, especially through dust (Epstein, 1993).

Landfill Workers

Table 1.4 reviews the reported exposures and health effects for landfill workers.
Table 1.4. The Reported Exposures and Related Health Effects for Landfill Workers

<table>
<thead>
<tr>
<th>Reported Exposure</th>
<th>Reported Health Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dangerous roads</td>
<td>Overturned vehicles, crushed drivers, broken bones, death</td>
</tr>
<tr>
<td>Bad visibility in trucks</td>
<td>Pedestrian accidents, broken bones, death</td>
</tr>
<tr>
<td>Methane</td>
<td>Explosions, fires, burns</td>
</tr>
<tr>
<td>Operation of equipment</td>
<td>Spinal injuries, degeneration of vertebrae, lower back pain, musculoskeletal disorders</td>
</tr>
<tr>
<td>Dust</td>
<td>Cough, chronic bronchitis</td>
</tr>
<tr>
<td>Bacteria</td>
<td>Cough, chronic bronchitis</td>
</tr>
<tr>
<td>Bioaerosols</td>
<td>Lower respiratory tract infection, gastrointestinal symptoms</td>
</tr>
<tr>
<td>High noise levels</td>
<td>Auditory impairment</td>
</tr>
<tr>
<td>Coliforms and fecal streptococci</td>
<td>No documented health effects; potential infections, gastrointestinal</td>
</tr>
<tr>
<td>Volatile organic compounds</td>
<td>No documented health effects; potential neurologic effects</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>No documented health effects; potential asphyxiation, neurologic effects</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>No documented health effects; potential asphyxiation</td>
</tr>
<tr>
<td>Ammonia</td>
<td>No documented health effects; potential asphyxiation</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
<td>No documented health effects; potential respiratory effects</td>
</tr>
<tr>
<td>Microorganisms</td>
<td>No documented health effects; potential respiratory effects</td>
</tr>
<tr>
<td>Fungal spores</td>
<td>No documented health effects; potential respiratory effects</td>
</tr>
<tr>
<td>Unknown exposure</td>
<td>Skin irritation, itchy eyes, sore throats, ischemic heart disease, hypertension</td>
</tr>
</tbody>
</table>

The size of landfill sites vary, therefore the number of employees per site varies accordingly. Smaller sites may employ only one part-time operator (Rahkonen et al., 1987). Job details on larger sites may range from check station attendant(s) who are responsible for receiving and recording the waste; a stopper who is responsible for supervising the unloading of waste; and an equipment operator(s) who is responsible for spreading and compacting the waste.

The design of a modern landfill includes liners, leachate collection and removal systems, methane gas controls, and environmental monitoring systems. Depending on local regulations, wastewater treatment plants, recycling facilities, and energy production plants may be incorporated into the landfill site (Keep America Beautiful, Inc., 1996). The bottom and sides of a landfill are lined with layers of clay or plastic for the purpose of collection of any liquid. An associated network of drains then collects this liquid, termed the "leachate," conveying it to a recovery point for treatment or disposal. A typical site includes an area for waste disposal, that is then further divided into a series of individual cells. A smaller area of the waste site, referred to as the "working face," is where dumping is done on a daily basis (Keep America Beautiful, Inc., 1996). "Daily cover" is typically required to be spread over the newly dumped waste at the end of every working day to minimize the odor and vermin infestation. This cover may consist of soil, foam material, sheets of synthetic material, disposed carpeting, compost, shredded tires, or other materials.

For the few individuals required to operate a landfill, many potential hazards exist.
The decomposition of municipal waste produces methane gas and carbon dioxide. Methane is potentially explosive. Thus, fires and explosions are a potential danger at landfill sites (Anderson, 1987). Besides the landfill workers, emergency workers such as firefighters, police and members of special disposal squads are at risk for potential exposures due to unexpected spills, explosions and fires during emergency response (Landrigan, 1983).

Nitrogen, ammonia, hydrogen sulfide, hydrogen, and volatile organic substances are usually present at sanitary landfills (SCS Engineers, 1981). Landfill workers are also potentially exposed to high levels of dusts containing microorganisms spread during dumping or moving of waste, or when debris is blown by the wind or equipment (Pahren, 1987). Coliforms and fecal streptococci were found in the air at several landfill sites in concentrations equal to that of sewage treatment plants. Fungi, including Aspergillus, Penicillium, Cladosporium and yeasts, have been identified in the air samples (Rahkonen et al., 1987). The drivers who dump the waste at the landfill sites are at risk due to hazardous roads resulting in overturned vehicles (Cimino, 1975).

Recycling Workers

Table 1.5 lists the reported exposures and health effects associated with recycling.

Table 1.5. The Reported Exposures and Related Health Effects for Recycling Workers

<table>
<thead>
<tr>
<th>Reported Exposures</th>
<th>Reported Health Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homeless recyclers</td>
<td>Bicycle accidents, pedestrian accidents, physical disputes</td>
</tr>
<tr>
<td>Sharp objects</td>
<td>Punctures, lacerations</td>
</tr>
<tr>
<td>Dust</td>
<td>Itchy eyes, acute nose and eye problems, ODTS, chest tightness, asthma, chronic bronchitis, cough, sneezing</td>
</tr>
<tr>
<td>Endotoxin</td>
<td>Chronic bronchitis, cough, asthma, exercise induced asthma, severe lung problems</td>
</tr>
<tr>
<td>Noise from equipment</td>
<td>Hearing impairment</td>
</tr>
<tr>
<td>Bacteria</td>
<td>No documented disorders; potential infections</td>
</tr>
<tr>
<td>Fungal spores</td>
<td>No documented disorders; potential respiratory effects</td>
</tr>
<tr>
<td>Unknown exposure</td>
<td>Spinal injury, sprains, itchy and irritated skin, nausea, diarrhea, vomiting</td>
</tr>
</tbody>
</table>

Recycling facilities are often referred to as "materials recovery facilities" (MRF). These facilities enable the recovery of secondary materials such as paper, carton, metal, and glass from solid waste (Cointreau-Levine, 1998). Many waste recycling systems are based on the collection of source-separated or source-sorted waste. The equipment, work routines and thus the potential exposures of employees are governed primarily by the degree of separation of the waste received by a plant (Poulson et al., 1995). If the waste is poorly separated, then the employees physically sort materials, transferring them from the tipping floor to the conveyor belts for further more intensive sorting. If the wastes are completely sorted, then the facilities are more automated (Poulson et al., 1995). For example, primary-sort mechanisms using devices (such as magnets, trommels, eddy currents, ballistic classifiers and cyclones) are used at many recycling facilities. This
equipment is employed to break metals, paper, glass, plastic, and yard waste into separate streams (Campbell, 1993).

Recycling is a labor intensive industry. Materials-handling appears to be the chief concern with regard to employee safety. Specifically, glass breakage poses a major hazard. Workers are also exposed to high levels of organic dust (Sigsgaard et al., 1994a; Sigsgaard et al 1994b). This organic dust contains microorganisms (i.e. total viable bacteria, total viable gram-negative bacteria, and viable fungi) and microbial agents (i.e. endotoxin) (Poulson et al., 1995). Workers may also be exposed to several sources of noise such as separators, balers and shredders (Malmros et al., 1990).

One group of recyclers in the community, referred to as "urban recyclers," is comprised of mainly homeless individuals, mostly male. Their collection vehicles are usually bicycle baskets or shopping carts. They are self-employed and their routine consists of rummaging through other people's refuse. Their routes are usually comprised of residential neighborhoods, most likely the same route as a garbage truck. It is not unusual for an individual to physically enter a trash receptacle and manually explore several bags of garbage. Obviously, individuals may often encounter sharp edges of cans and/or broken bottles or other objects. Depending on the amount of recycleables collected, vision may be obscured by cans and bottles, and thus urban recyclers are also at risk for involvement in traffic accidents (Rendleman and Feldstein, 1997). Of note, in less developed countries, urban recyclers represent a large group of people of all ages with similar exposures who live and work near urban solid waste dumps (Cointreau-Levine, 1998).

**Maintenance Workers**

Within the realm of collection, recycling, incineration, and composting, there are workers who are responsible for equipment and plant maintenance. Although this population of workers has not been studied, the inference from a review of the general occupational medicine literature is that this group of individuals are at high risk for many of the previously mentioned exposures, and are often ignored in training and education programs.

**Hazardous Waste Workers**

It is important to recognize that in particular the mechanics of the job of a solid waste industry worker compared to a hazardous waste worker may share some similarities. Although the potential exposure levels of these two groups of workers may be different, several of the common approaches to disposal are nearly identical. Based on the literature and the definition of solid waste under the law, the amount of hazardous waste that a municipal waste worker is actually exposed to is open to speculation. Therefore, all of the potential exposures and hazards associated with the hazardous waste worker must be examined, assuming that at some level the solid waste worker is possibly at risk for these same conditions.
The jobs involved with the hazardous waste industry include individuals involved in discovery, evaluation, feasibility study, and cleanup and inspection of sites, as well as the collection, manifesting, and disposal of currently generated wastes. Administrative positions are inspectors, auditors, lawyers, and contract officers, while other jobs may include clerical positions, professional and scientific positions, equipment operators (drillers, trenchers, backhoe, fork-lift), laborers, maintenance workers, and managers. A wide variety of workers are involved specifically with the transport of industrial hazardous wastes. Drivers are usually responsible for the loading and unloading of the waste that they transport (Gochfield et al., 1990).

Overall, hazardous waste is handled in one of three ways: treatment, storage, or disposal. Waste may be treated via biological decomposition and high-temperature incineration. It may be stored in holding tanks and other above-ground containers; or it may be disposed at a landfill or surface impoundment site (EPA, 1988; Travis and Cook, 1989). The mechanics of landfill sites and incineration sites are the same as the techniques described in the previous sections.

Hazardous waste workers perform difficult and unpredictable duties that are affected by weather and other geographical variations. Every hazardous waste site is required by EPA and OSHA to have a site-specific Safety and Health Plan (Mitchell, 1998). OSHA standards also require workers in hazardous waste removal, containment, or emergency response to receive scheduled health and safety training (Abatemarco et al., 1995). Legislation mandates that employees must wear protective equipment, although this gear may restrict movement and vision. Individuals involved with the remediation of a site often work in confined spaces, and may engage in the hydroblasting of residues. Remediation workers may also work directly with contaminated water and soil (Gochfield et al., 1990). Other hazards besides chemical exposure may include fire, oxygen deficiency and heat stress (Abatemarco et al., 1995).

A typical hazardous waste site may have bags, drums, tanks, and lagoons containing mixtures of unknown contents with no labels or incorrect ones. This situation can potentially result in ruptures, fires and explosions (Favata, 1990). The hazardous waste worker is potentially directly exposed to hundreds of substances, many of unknown composition at the time of exposure (Gochfield et al., 1990). One study documents workers wading in chemical waste in order to break up solidified chemical with hammers and axes. These workers shoveled chemicals into barrels, and also thinned out other chemicals by adding methyl ethyl ketone for incineration purposes (Callender et al., 1997).

In 1986, a study of a hazardous waste site by the California Department of Health Services found sulfur gas exposure due to anaerobic bacterial activity, as well as high levels of hydrogen sulfide and volatile organics in air samples (Favata, 1990).

With regard to the incineration of hazardous waste, carbon dioxide and water are the main products of combustion. However, the combustion of chlorinated waste produces hydrogen chloride, a highly corrosive compound. Other documented incineration byproducts include oxides of metals, sulfur and nitrogen (Travis and Cook,
1989; Fleming et al., 1999). As already discussed with municipal incinerators, incomplete combustion may result in the formation of dioxins and furans, as well as carbon monoxide (EPA, 1988).

1.2.2 Potential Occupational Health Effects by Job Type

The data on solid waste workers and related health effects are limited. The data from the studies discussed below are often flawed due to small study size, recall bias, lack of a good control population, and sparse statistics, as discussed in detail below. Another problem is that the studies have mainly focused on acute injury, not chronic disease. Due to the virtual lack of long term studies and lack of follow up, chronic disease data are almost nonexistent, as indicated in the text below.

Refuse Collectors

The refuse collectors are at a high risk of injury (see Table 1). With regard to the waste industry, Campbell (1993) proposed that the collection of municipal waste represents the greatest and most diverse set of hazards of all waste management aspects. The US Bureau of Labor Statistics reported that garbage collectors have the seventh most dangerous job in the nation; from 1992-1996, 111 garbage collectors were killed while working in the US (Memishi, 1998). In a US National Institute of Occupational Safety and Health (NIOSH) National Traumatic Occupational Fatalities (NTOF) Surveillance System study from 1980-1992, 450 workers aged 16 years or older died in incidents related to refuse collection (NIOSH, 1997).

A. Injury

A Danish study conducted from 1989 to 1992 found that the incidence of occupational injuries among waste collectors was 99 per 1000 employees compared to only 17 per 1000 employees in the total work force (Arbejdstilsynet, 1995; Poulsen et al, 1995a). This translates to a rate of injury 5.6 times higher among waste collectors compared to all other Danish workers. A study by Bourdouxhe et al. (1993) reported an even higher rate of injury among waste collectors: 74% of the waste collectors in municipality companies and 57% in private enterprise. A similar trend was observed in a Brazilian study that found an incidence rate of 70 injuries per 100 waste collectors per year; the lower limbs suffered the greatest injury, including cuts, contusions, and excoriations (Robazzi et al., 1993; Robazzi et al, 1997). An older study by Cimino (1975) compared the frequency (reported disabling injuries/1 million man hours) and the severity (days reported lost per 1 million man hours) rates for the sanitation workers of New York City compared to a number of other industries. Sanitation workers had a 5 times greater rate of reported injury compared to underground miners (148.0 vs 29.42), although the severity of the sanitation workers’ injuries was less than for the miners (1205 vs 4846).

Dangerous equipment combined with inappropriate employee work practices, such as riding on the step on the back of the truck, can result in the individual being caught between the truck and a wall or other object. Other behaviors, such as reaching hands and
arms into the hoppers, have resulted in serious injuries. Individuals have lost fingers or arms after accidentally getting a sleeve caught in the machinery. Many collection employees work during peak traffic hours; associations have been made between heavy traffic and worker accidents. In the NIOSH NTOF study mentioned above, 303 (67%) of the 450 refuse collector fatalities were vehicle associated; of these deaths, 110 (36%) occurred when the worker was run over by the refuse collection vehicle after slipping and falling, while 20 (18%) occurred when the refuse collection vehicle backed up (NIOSH, 1997). Cimino (1975) reported that over 50% of the injuries occurred during lifting, dumping, or walking with a load, with back injuries predominating. According to a study by Ivens et al. (1998), the most frequent type of injury reported by waste collectors was back (15%), knee (12%), and hand (12%); the back and knee injuries were reportedly predominantly related to twisting. Frequently, injuries occurred when a worker was hit by or bumped into goods, vehicles or objects, or when they fell or overloaded themselves. Injury was often linked with high working speeds, and the carrying of multiple bins. As noted above, waste collectors often adopt hazardous work strategies in order to save time.

B. Musculoskeletal

The occupation of waste collector entails a great deal of heavy lifting, as well as pushing and pulling of garbage bins and containers. Studies also document work above shoulder level, frequent exertion of force, static contractions, and extreme joint positions. These studies have directly linked these behaviors with an increased risk of musculoskeletal disorders of the neck, shoulders and back (Hagberg and Wegman, 1987; Stock, 1991; Sommerich et al., 1993). Similar disorders were reported in a study on Danish waste collectors which found the most frequent musculoskeletal disorders to be: tendon diseases, muscular pain, lumbar disc prolapse, low back pain, and shoulder and neck pain (Arbejdstilsynet, 1995; Poulsen et al, 1995a). An elevated relative risk of 1.9 (95% Confidence Interval=1.6-2.2) for developing musculoskeletal problems among waste collectors compared to the total workforce was observed with an incidence rate of 3.5 injuries/1000 employed per year. Another study conducted in 1987 in Amsterdam (Verbeek et al., 1993) among all municipal waste workers, found that the incidence of disability as a result of musculoskeletal disorders was highest in refuse collectors (15 injuries/1000 person years). A Canadian study (Bourdouxhe et al., 1993) observed a very high rate of back and shoulder injury in waste collectors due to overloading. Frequent ankle sprains due to falls were also seen. In this study, this situation was attributed to haphazard work behavior and inexperience.

C. Dermatologic

For the waste collector, due to a considerable amount of manual handling, dermal contact is nearly unavoidable. One Danish study reported an elevated relative risk of 1.6 (1.2-2.0) for skin problems in waste collection workers compared to all Danish workers with an incidence rate of 1.3/1000 employed/yr (Arbejdstilsynet, 1995; Poulsen et al, 1995). Gaube et al. (1986) detected Streptococci, enterobacteria, and other microorganisms on the hands and clothing of waste workers. Careless disposal of
pesticides, herbicides, paints, solvents, assorted cleansers, acids, and other volatile and flammable compounds resulted in severe burns and skin irritation elicited by crushing and splashing (Campbell, 1993, Cimino, 1975; Gellin, 1985).

The most common skin abnormality observed in one study (Gellin, 1985) was callus formation on the palms and/or palmar digits, usually due to the refusal to wear gloves, particularly in younger worker populations. This study demonstrated that the formation of calluses was a response to repetitive mechanical trauma. However, the formation of calluses was never a documented reported injury. The investigators hypothesized that this meant that the workers regarded calluses as an accepted consequence of the job.

Punctures, lacerations and abrasions from glass, metal, plastic and wooden objects are frequently reported by refuse collectors (Gellin, 1985). Needlestick punctures have also been reported among this group. The improper disposal of medical waste, from both residential and medical facility sources, is most likely responsible for the reports of needlestick injuries by waste collectors. In a study by Turnberg and Frost (1990), among waste workers who responded 21% reported having ever been stuck or scratched by a waste hypodermic needle; 6% of these respondents reported the needle contact within the last year. Needles evoke fear of contamination by hepatitis viruses, AIDS or other potentially fatal infections (Campbell, 1993). However, documentation of these diseases as occupational health effects is lacking. Solid waste workers in the United States are currently estimated to have a risk of contaminated puncture that is 1/1000th the risk level of hospital nurses (World Health Organization, 1996).

D. Mucous Membrane

Sigsgaard et al. (1994a) reported a significantly high prevalence (27%) of reported eye problems related to garbage handling. In a study of U.S. waste collectors, eye injuries accounted for 10% to 25% of the total injuries reported (Gellin, 1985). In addition to the sharp objects described above, the concentrations of chemicals, bioactive dusts and other potentially irritating compounds in waste in direct contact with the face/eyes may be responsible for irritation and inflammation (Anderson et al., 1992). A Japanese study based on self report, observed a relationship between the exposure to automobile exhaust with nose and eye irritation. The reported symptoms were exhibited most frequently in high traffic areas with highest automobile exhaust exposures (Ishizaki et al., 1987).

E. Respiratory

Workers in waste collection have also demonstrated elevated levels of respiratory disorders. This occupation is physically strenuous, resulting in workers breathing through their mouths rather than their noses. Individuals who breath through their mouths have higher pulmonary ventilation rates than those who breathe through their noses (Cointreau-Levine, 1998).
One Danish study reported an elevated relative risks of 2.6 (1.8-3.9) for allergic respiratory disease and 1.4 (0.9-3.9) for other respiratory diseases in waste collection workers compared to all Danish workers with incidence rates of 0.58/1000 employed/yr and 0.53/1000 employed/yr respectively (Arbejdstilsynet, 1995; Poulsen et al, 1995). Of interest, infectious diseases were also significantly elevated among these waste workers with a relative risk of 6.0 (3.6-10.0) and an incidence rate of 0.36/1000 employed/yr.

A study in Geneva reported the occurrence of chronic bronchitis 2.5 times more frequently in waste collectors than an age matched control group (Rufener-Press et al., 1975). Similarly a cross sectional study by Hansen et al (1997) comparing 1515 male Danish waste workers with 423 park workers found significantly increased reported prevalence of 2.3 (1.3-4.3) for chronic bronchitis that increased in a dose response fashion with increasing concentrations of selected microbial parameters; asthma was not increased although the prevalence of reported cough and wheezing were. A study by Sigsgaard et al. (1990) which looked at ten workers who handled garbage, concluded that direct contact with garbage could induce dry cough with exercise induced dyspnea, asthma, and organic dust toxic syndrome (ODTS). A suggested hypothesis was that the level of exposure to microorganisms was responsible for these symptoms. A follow up study in 1994, which examined 72 garbage handling workers compared to 129 water-supply workers, showed a high prevalence (14%) of upper respiratory tract symptoms, specifically chest tightness, fever, chills and flu symptoms. Similar results from studies in laboratory settings confirmed these symptoms. Rylander et al. (1987) had volunteers inhale aerosolized, purified endotoxins. Subjects reported fever, chest tightness and airway irritation (6-8 hours after inhalation) and unspecified symptoms such as headache, joint and muscle pains, nausea, and fatigue.

Several studies have linked exposures to mold spores from species such as Aspergillus and Penicillium detected in the refuse, with allergic pulmonary diseases such as asthma and allergic alveolitis (Clark, 1986; Malmros et al., 1990; Malmros et al., 1992). Also, due to the fact that endotoxins can elicit a histamine release, the simultaneous exposure to endotoxin and mold spores, as is frequent in the waste collection environment, may result an increase in allergic effects (Norn et al., 1986, 1990). Several studies have also suggested an association between exposure to high levels of dust containing endotoxins with occupational non-allergic pulmonary disorders and impaired lung function (Poulson et al., 1995). Gram negative bacteria, also found in high concentrations in municipal waste, can cause inflammation of the airways when inhaled (Rylander and Bergstrom, 1993).

Asthma, decreased lung function, upper respiratory tract irritation, and even lung cancer have been linked to exposure to diesel exhaust, a constant exposure for waste collectors (Ishizaki et al., 1987; Scheepers and Bos, 1992a, 1992b; Swanson et al., 1993). Swanson et al. (1993) examined a population that included many different occupations, including waste collectors, and found an increased risk of lung cancer for men working more than 10 years, especially black men; she postulated an association of lung cancer risk with exposure to diesel exhaust.
F. Cardiovascular

Minimal data are available which associate cardiovascular effects with refuse collection. However, in 1975 study by Cimino, coronary heart disease was nearly twice as common in waste collectors as compared to "general laborers"; furthermore, waste collectors had twice as many myocardial infarctions. In a population of approximately 11,500 New York City sanitation men, an average of 103 new cases of myocardial infarction, 78 new cases of angina and insufficiency, and 31 deaths from CHD, each year were found. These findings were compared to those in three other group studies, and the results were reconfirmed.

G. Gastrointestinal

Several reports document a high frequency of gastrointestinal (GI) problems among waste collectors. A study by Nielson et al. (1994) found that garbage collectors may be exposed to the aerosols emitted from the refuse in garbage disposal bags. Due to the high levels of bacteria and endotoxin in the percolate from the waste, these investigators linked workers' report of acute gastrointestinal symptoms (onset as quickly as one half hour) to these exposures. Diarrhea and nausea are well established problems among workers exposed to high concentrations of airborne gram negative bacteria (such as sewage workers and compost workers) (Lundholm and Rylander, 1980 and 1983; Zuskin et al., 1993). In another study (Ivens et al. 1997), among refuse collectors nausea and diarrhea were frequently reported, associated with organic and residual waste (prevalence proportion ratio (PPR)=1.45) and mixed household waste (PPR 1.43). Loaders in particular reported the most nausea (PPR=1.51). These workers indicated specific factors in their work environment as the cause of their GI problems: the smell of rotten waste. These odors may be linked to some of the sulphur-containing volatile organic components found in waste, previously reported to elicit gastrointestinal symptoms with occupational exposures (Glass, 1990; Anderson et al., 1992, Wilkins, 1994).

H. Neurological

No studies to date have reported an association between waste collectors and neurological impairment.

Incinerator Workers

As seen in Table 2, workers at incinerator plants are exposed to a variety of toxic compounds. Some of these exposures come from the actual waste, but many come from the combustion process and its byproducts. The process of incineration has received a great deal of attention, perhaps due to the fear of environmental pollution and population exposures. A body of literature related to the procedure of incineration, as well as information on the chemical emissions and their related concentrations exists (Fleming et al, 1999). However, the health hazards experienced by the incineration worker population
have received significantly less attention, despite existing data that warrant further investigation.

A. Injury

The US Bureau of Labor Statistics reported that transportation accidents are the leading cause of workplace accidents at landfills and incineration operations (Memishi, 1998). Although none of the available literature directly mentioned any incinerator-related accidents, incidents were described in the hypothetical sense. Situations of accidental fires were noted in relation to the pit area (Cimino, 1975). In addition, potential fatal accidents in the event that an individual fell into the pit area were mentioned.

B. Musculoskeletal

None of the available literature mentioned an association between incinerator workers and musculoskeletal problems.

C. Dermatologic

A relationship between skin disorders and incineration workers is usually not mentioned in literature. However, one study by Scarlett et al. (1990) hypothesized that the dermal route of exposure did impact abnormalities due to a protective effect found when workers wore gloves verses a lack of protective effect when workers wore only masks. Marty (1993) sites this finding as extremely important for occupational research, noting that dermal exposure may have an even greater impact than the route of inhalation on these workers’ health.

Incinerator workers are at risk for burns resulting from exploding chemicals or aerosal cans (Cimino, 1975). Particularly at risk are the stationary fireman, employed specifically for emergency events such as fires and explosions.

D. Mucous Membrane

A relationship between incinerator workers and problems with mucous membranes has apparently not been investigated since no literature was found on this topic.

E. Respiratory

The bulk of the health related literature associated with incinerator workers is related to respiratory disorders. A retrospective cohort study of incinerator workers in Rome found that workers reported a high frequency of respiratory symptoms (Rapiti et al., 1997). Crook et al. (1991) observed odds ratios that indicated an increased risk for incineration employees of cough (OR = 2.1; 1.1-4.2). These symptoms may be caused by high bacterial counts that are often detected at incinerator plants (Crook et al. 1987; Mansdorf et al., 1982; Duckett et al., 1980). High airborne exposure levels of fecal
coliform and fungal concentrations were also measured at incinerator plants which may be related to respiratory distress (Crook et al., 1987; Duckett et al., 1980).

Exposure to dust is often noted at incinerator plants in relation to respiratory symptoms. In a Danish study, the levels of organic dust for many work processes at incineration sites exceeded occupational limits (Mozzon et al., 1987; Mansdorf et al., 1982; Duckett et al., 1980). Similar results were reported at a Swedish incinerator plant (Petersson and Vikstrom, 1984).

Stationary firemen, employed at incinerator plants for emergency reasons, had more episodes of respiratory disease than the total New York Sanitation workforce. They also had more periods of disability due to acute and chronic respiratory disorders (Cimino, 1975). However, study of municipal waste incinerator workers by Bresnitz et al. (1992) found that changes in pulmonary function were predominantly related to smoking.

The association between lung cancer and occupational exposure to polycyclic aromatic hydrocarbons (PAHs) is established in other workforces. An excess of lung cancer has been found in several occupational groups exposed to combustion products, including a Danish study of incineration workers compared to national and local populations (SMR=3.55; 1.62-6.75) (Gustavsson, 1989). These investigators proposed a possible relationship between working at the incineration plant and an increased risk of lung cancer due to the fact that exposure to dusts with high PAH content, as well as other combustion products, varied according to work task (Petersson and Vikstrom, 1984). Of note, Rapiti et al (1997) found an insignificantly reduced mortality for Italian municipal waste incinerator workers (SMR=0.55; 0.93-6.35) compared to the general population.

F. Cardiovascular

Some studies have proposed an increase in ischemic heart disease in incinerator workers. Gustavsson (1989) hypothesized that the increase he noted was due to the PAHs enhancing the growth of atherosclerotic plaques. Research has also established a relationship between increased triglycerides in blood, and exposure to dioxins and dibenzofurans (Oliver, 1975; Uzawa et al., 1969). A study by Bresnitz et al. (1992) found a 34% higher prevalence of hypertension compared to the expected prevalence in the United States population as reported by the National Center for Health Statistics (Schoenborn, 1988). This finding is related to the high prevalence (31%) of urinary abnormalities in the population, specifically proteinuria.

G. Gastrointestinal

Few studies link the risk for gastrointestinal problems with occupational exposure to incineration plants. However, one study of incinerator workers revealed that workers reported a high frequency of gastrointestinal symptoms (Rapiti et al., 1997). This study, which was retrospective in nature, detected an almost threefold excess risk of stomach cancer compared to the general population based on 4 cases (SMR=2.79; 0.94-6.35). In
one Swedish study, an increased risk of gastric cancer in sewage plant employees was observed (Friis et al., 1993). The investigators proposed that the increase of gastric cancer among incinerator workers may be due to the inhalation of volatile pathogens, bacterial toxins and organic dust (Rapiti et al., 1997).

H. Neurological

The literature linking auditory disorders and incinerator plants is scant. Of note, several studies have documented excessive noise at incinerator plants (Sobeih, 1988). Ahrenholz (1986) found noise levels well above OSHA's action level.

Landfill Workers

The working environment at landfills varies greatly from site to site, yielding varying reports of associated health effects, as can be seen in Table 4. In a study of the employees at a New York City landfill, there were a vast number of harmful substances and unsafe conditions. However, on account of the variable nature of the refuse at the site, all of the potential exposures were impossible to categorize; thus, no conclusions regarding health outcomes could be drawn (Gelberg, 1997). According to one reviewer, exposures at landfill sites are less dramatic, and any resulting illnesses would be "subtle, insidious, and delayed in their onset." Landrigan (1983) suggested that inhalation was the principle mode of exposure, followed by transcutaneous absorption.

A. Injury

According to Cimino (1975), due to the nature of the roads surrounding landfill sites, driving is dangerous and vehicles occasionally overturn. Individuals not secured by a seat belt run the risk of being overrun by a falling vehicle. A 1984 Professional Safety article reported that falls from vehicles were the second highest cause of indemnity days at a landfill site (Campbell, 1993). The US Bureau of Labor Statistics reported that transportation accidents are the leading cause of workplace accidents at landfills and incineration operations (Memishi, 1998).

Due to the multiple gases emitted at a landfill site, specifically methane, fire is a risk. These types of fires can be very dangerous because they are difficult to control since the engineering of a site allows the fire to go below the surface (Campbell, 1993).

B. Musculoskeletal

Of the few studies conducted on landfill employees, several directly associate vibration from the operation of heavy equipment to serious injuries. German studies, in particular, have linked spinal injuries (specifically a higher than average degeneration of the vertebrae) to landfill equipment operators exposed to intense vibration of the hands and arms (Wilhelm, 1989). A study of landfill workers in Liguria (Italy), also reported lower back pain as a common symptom (Kanitz et al., 1995). Gelberg (1997) cited a
Finnish study that detected a high disease prevalence of musculoskeletal disorders among dump workers (Tuomi et al., 1991).

C. Dermatologic

Perhaps due to the limited number of employees at landfill sites, health endpoint data are sparse. Thus, there is little information that directly links dermatological disorders to landfill employees. A study of New York City landfill employees reported a significantly higher prevalence (24.8%) and risk (OR 2.07; 1.11-3.84) of work-related dermatologic symptoms than the control group in the study (Gelberg, 1997). Specifically, the employees who worked on the active dumping area at the landfill reported experiencing more skin problems.

D. Mucous Membranes

No studies have examined the relationship between landfill workers and mucous membrane complications. However, some studies that employ self-reported questionnaires address these types of disorders. For example, workers at a New York landfill site, especially the workers at the active dumping area and the operators, reported frequent itchy eyes and sore throats (Gelberg, 1997).

E. Respiratory

Volatile organic compounds are often present in solid waste decomposition gases due to their high vapor pressures and their low solubilities (Cointreau-Levine, 1998). The decomposition gases at landfill sites contain a number of potentially toxic and carcinogenic volatile organic compounds. A study of a landfill site in Canada in 1991 detected at least 35 volatile organic compounds, all in appreciable concentrations. These included many suspected, some known, carcinogens such as benzene, vinyl chloride, methylene chloride, and chloroform (Goldberg et al., 1995). Bioaerosols detected at sites have the capacity to penetrate the lower respiratory tract (Rahkonen et al., 1987). This study also detected coliforms and fecal streptococci in the air at the landfill sites they sampled in Finland. In Finland, as the size of the landfill increased, so did the risk of exposure to dust particles and bacteria. A Canadian study found a positive association between landfill exposure and chronic bronchitis and daily cough (Hertzman et al., 1987).

Gelberg et al (1997) reported a significant increased risk for respiratory symptoms for landfill workers compared to their offsite counter parts (OR 2.14; 1.35-3.38); this was especially true exposure of the landfill active bank and the landfill compost site, as well as for operators, as opposed to other landfill workers.

F. Cardiovascular

Rarely does the literature mention cardiovascular disorders in association with landfill employees. However, Gelberg (1997) discussed one cross-sectional Finnish study
which found that municipal waste workers at dump sites have a high prevalence of cardiovascular disorders, specifically ischemic heart disease and hypertension (Tuomi et al., 1991).

E. Gastrointestinal

Only one study reported gastrointestinal related disorders associated with landfill employees. This study was on New York City Sanitation employees; the conclusion was that individuals working at landfill sites reported GI symptoms related to refuse dumping (Gelberg, 1997).

F. Neurological

The issue of noise has been frequently addressed with regard to landfills. The controversy surrounding this concern is typically related to neighboring populations and the nuisance of the noise, rather than the damage to the employees. A NIOSH health hazard evaluation found that noise levels at a Brooklyn landfill site were high (NIOSH, 1984). Landfill workers at a New York City site also reported hearing impairment. Noise levels from the operation of heavy equipment at the landfill exceeded Occupational Safety and Health Administration limits (Gelberg, 1997). Rahkonen et al. (1987) reported that the sound insulation of the cabin of the compactor had the greatest significance for its sound level. Depending on the amount of insulation, noise frequencies detected ranged from 250Hz to 1000Hz.

Compost Workers

As observed in Table 3, studies on composting plant employees reveal increased health problems related to occupation (Lundholm and Rylander, 1980; Diaz, 1980). Since composting is a relatively newer approach to waste management, numerous uncertainties exist regarding health hazards related to pathogens, trace metals, and organic contaminants (Gillett, 1992; Harrison and Richard, 1992; Chaney and Ryan, 1993; Epstein, 1993). Unfortunately, little data on composting facilities, their employees, and the related health outcomes are in the literature. The studies that are available involve limited subjects, and only a small number of facilities. These studies are primarily concerned with air sampling, and thus, the results focus on subsequent air concentrations instead of health effects. Hence, disease and injury data are insufficient.

A. Injury

No studies reviewed injury data associated with composting.

B. Musculoskeletal

None of the studies reviewed documented a relationship between compost workers and musculoskeletal problems.
C. Dermatologic

To date, only one study made any mention of this issue. In this study, a self report questionnaire concerning composting in an indoor facility that did not necessarily incorporate proper ventilation to their facility was employed. The results indicated that skin irritation was often reported by compost workers (Clark et al., 1983).

D. Mucous Membrane

There was no mention of mucous membrane problems among compost workers in the available literature.

D. Respiratory

According to one study, compost workers most often complain about odors and dust particles causing upper airway irritation (Clark, et al., 1983). Clark (1986) documented that during composting Aspergillus and Penicillium are some of the most abundant fungi. A study by Heida et al. (1995) found fungal spore concentrations of Aspergillus and Penicillium only slightly below hazardous levels. Such exposures have been linked with subsequent pulmonary disease (Belin, 1985; ACGIH, 1989). A case study of one employee at a composting facility described allergic alveolitis with invasive aspergillosis (Vincken and Roels, 1984). Additionally, Aspergillus strains and structural analogs produce aflatoxins which may be present at composting facilities (Deportes et al., 1997); aflatoxins are known to be mutagens and heptacarcinogens, and have been associated with lung tumors (Stark, 1980; Burg and Shotwell, 1984; IARC, 1993).

E. Cardiovascular

There was no available literature reporting cardiovascular health effects with composting.

G. Gastrointestinal

Household garbage, which is crushed and milled with other materials at composting plants, is a significant source of Gram-negative bacteria. Nausea and diarrhea were linked to the presence of large amounts of Gram-negative bacteria and/or bacterial endotoxins in the air of composting plants (Lundholm and Rylander, 1980). Malmros et al. (1991) reported that gastrointestinal problems occurred significantly more frequently in compost workers than water supply plant workers, most likely due to the high levels of Gram-negative bacteria present at the composting plant. Lundholm and Rylander (1980) reported that 4 out of 13 compost workers at a plant reported symptoms such as headache, fatigue, nausea and diarrhea.

The process of composting yields carbon dioxide, water vapor and heat as
byproducts. Headaches and nausea were associated with anoxic conditions at sites that have high levels of carbon dioxide (Cointreau- Levine, 1998). Krauss et al. (1992) identified several compounds at a composting site that were considered an odor nuisance. Several of these were sulphur compounds, which have been hypothesized to evoke GI reactions. Odor also often results when an anaerobic condition exists (Keep America Beautiful Inc., 1996); this type of situation could also potentially elicit GI symptoms.

E. Neurological

There are no associations found in the available literature between compost workers and neurological effects.

Recyclers

As seen in Table 5, studies on the recycling industry indicate that workers have an excess risk of work-related health problems. The degree of that risk seems to be related to the amount of direct contact that a recycling employee has with the refuse (i.e. whether or not the refuse is sorted before it arrives at the facility) (Poulson et al., 1995). The available data on this population are very limited, although future research activities are proposed due to an increase in recycling practices.

A. Injury

Few accidental injuries associated with recycling employees are reported. The US Bureau of Labor Statistics reported that scrap metal workers were fifth on the list of the 99 worst industries for occupational injuries and illnesses in 1996 (Memishi, 1998); these workers reportedly had a lost workday injury and illness rate of 11.1 per 100 full-time workers. For the population called "urban recyclers" discussed above, numerous episodes were reported in one study with a prevalence of 32% reported on the job injuries with 46% of the reported injuries being lacerations (Rendleman and Feldstein, 1997). The injuries resulted from broken glass and cans, and trauma from entering and leaving trash containers, as well as disputes over territory with other recyclers, fights with garbage collection employees, and fights with individuals attempting to seize their shopping carts. Accidents between bicycle and shopping carts, and automobiles were described, these often resulting in severe injury and sometimes death.

B. Musculoskeletal

A high prevalence of ergonomic problems associated with recycling was seen. A study by Ettala et al. (1989) directly addressed musculoskeletal problems in recovery facilities. Employing a 5 point Likert scale, workers were asked to rate the risk of developing these problems. These Finnish workers rated back injuries a “5” (i.e. the most risky), indicating that they believed that waste sorting frequently resulted in spinal injury. Poulson et al. (1995) reviewed a Danish study by Petersen (1988) which found similar results. Homeless recyclers often reported sprains from jumping in and out of trash
receptacles (Rendleman and Feldstein, 1997).

C. Dermatologic

Perhaps due to the direct contact with refuse experienced by recycling employees, skin disorders are a frequent health outcome of this occupation. One cross-sectional study on recycling plant employees found a significant odds ratio for itching skin, 14.7 (1.5-132.2) (Malmros et al., 1991). Frequent episodes of irritated, itchy skin were reported by recycling workers on a questionnaire compared with water supply workers with an annual prevalence of 23% (Sigsgaard et al., 1994a).

"Urban recyclers" are a great risk for skin problems due to the nature of their work. Often, these individuals climb into trash receptacles to retrieve glass and metal objects. Their job detail includes grabbing objects with bare hands, and they often do not wear shoes. In this process, bottles get broken and cans pierce bags, frequently cutting the skin of the workers. Thus, lacerations were the most frequently reported injury (Rendleman and Feldstein, 1997).

D. Mucous Membrane

Although no study has directly addressed a relationship between mucous membrane problems and recovery facility employees, a few mention this association. A significant odds ratio of 3.8 (1.6-9.4) for itching eyes was reported in a Danish study on recycling workers compared to water supply plant workers (Malmros et al., 1991). Sigsgaard et al. (1994a) found that garbage recycling workers reported on a questionnaire that they were prone to acute nose (14%) and eye problems (27%) compared to water supply workers.

E. Respiratory

Perhaps due to the long-term disability related to chronic pulmonary diseases, research has given this issue a fair amount of attention (Poulson et al., 1995). Danish studies report a significantly higher risk of chest tightness (OR = 5.43; 2.01-14.64) and organic dust toxic syndrome (ODTS) (OR = 17.19; 1.86-158.52) in recycling plant workers than a reference population of water supply workers (Sigsgaard et al., 1994a; Sigsgaard et al 1994b). Although only 12 employees were studied, Petersen (1988) found that workers complained of asthma, chronic bronchitis, coughing and sneezing. All of these workers were involved in the manual sorting of waste.

Results from another study of only 15 subjects, indicated that nine workers developed severe lung problems (8 with asthma and 1 with chronic bronchitis) (Malmros et al., 1991; Malmros et al., 1992). Six of the asthma cases reported continued exercise-induced asthma two years after having left their jobs. The investigators hypothesized that exposure to high levels of endotoxins was responsible for these disorders, since similar relationships have been established in other industries such as cotton mills, pigs and
poultry farms, and animal feed mills. Plant modifications decreased airborne levels of bacteria, but not of fungi (Poulson et al., 1995; Malmros et al., 1992). Endotoxin exposure was linked to acute pulmonary effects and impaired lung function (Rylander, 1987). In six recovery facilities in the United States, the airborne bacteria and fungi concentrations inside the facilities were approximately one order of magnitude higher than the levels outside of the facility, with a wide range of pathogenic organisms identified (EPA, 1988). In a medical waste recycling plant in the US, reportedly workers contracted tuberculosis from washing and disinfecting tubs used to transport the medical waste (Memishi 1998).

E. Cardiovascular

No association between recycling and cardiovascular disease risk were mentioned in the available literature.

G. Gastrointestinal

To date, no study has directly addressed gastrointestinal problems and recycling facility employees. A cross-sectional Danish study in 1989 of 23 employees reported a high odds ratio for gastrointestinal problems (OR = 7.3; 2.5-21.3) (specifically nausea, diarrhea, and vomiting) compared to water supply plant workers (Malmros et al., 1990). Urban recyclers reported GI problems resulting from eating scavenged food (Rendleman and Feldstein, 1997).

H. Neurological

Little data on exposure to noise for recycling workers were found, although many potential sources of noise at recycling plants (i.e. separators, balers and shredders), exist. Noise levels from the processing equipment at such facilities exceeded OSHA action levels for worker protection (EPA, 1988). Noise levels that exceed 90dB were reported at waste recycling plants (Mansdorf et al., 1982).

1.3 OTHER ISSUES

1.3.1 Seasonality

Several studies of solid waste workers hypothesize that there is an increase in injury and health hazards related to the seasons of the year. Two studies in Finland found higher levels of dust, bacteria and fungal levels at landfill sites in the summer, possibly due to the wind and heat (Rahkonen et al., 1987, 1990). A study by Nielson et al. (1997) confirmed this with the detection of significantly lower concentrations of endotoxins and microorganisms in the winter. These results may be related to the findings reported in a study of Danish waste collectors in which more nausea was reported in the summer compared to a non-exposed control group (Ivens et al., 1997). This study also found that diarrhea was most frequent in the summer season. In a Danish study of the municipal
waste workforce, injury rates peaked in May and September (Ivens et al., 1998).

With regard to PCDDs and PCDFs, however, a reverse seasonal trend may exist. Marty (1993) found that concentrations of PCDDs and PCDFs in work areas were consistently higher in the winter months. He hypothesized that this trend was due to better building ventilation in the summer, but did not rule out that incinerators may produce more dioxins in the winter season.

Several studies also indicate a trend related to day of the week and injury occurrence. Ivens et al. (1998) report that more injuries occur on Mondays and Thursdays. This study reconfirmed a similar trend found in a prior Danish study that also detected increased injury on Mondays, especially in September (Aarhus Renholdningselskab, 1992). A Brazilian study found Mondays and Tuesdays, after only a few hours of work, associated with the most injuries (Robazzi et al., 1993; Robazzi et al., 1997).

### 1.3.2 Work Experience

As with many workplace studies of a wide range of professions, younger and less experienced workers are at greatest risk of injury on the job. Furthermore, they are not only more frequently injured, the injuries themselves are often more serious. Older, more experienced workers are usually more aware of the possible hazards of their working environment. All these factors were seen by Ivens et al (1998) in her study of injuries among 667 domestic waste collectors in Denmark.

### 1.3.3 Protective Equipment

An ongoing assumption exists that the use of protective equipment by solid waste industry workers reduces associated negative health outcomes (Levine, 1990). The available literature yields mixed reports as to whether or not there is a significant protective effect with the use of personal protective equipment. The EPA and the Agency for Toxic Substances and Disease Registry (ATSDR) did a study in 1988 which revealed that the levels of contaminants at an incinerator site did not pose a significant threat to workers if they wore their proper protective equipment (EPA/ATSDR, 1988; NIOSH, 1985). In line with these findings, Gelberg (1997) reported that wearing hearing protection significantly decreased reported hearing difficulty and ringing in the ears of sanitation employees in New York City. However, he did not find any protective effect for work-related respiratory and dermatologic symptoms when employees wore protective masks.

A study by Scarlett et al. (1990) found nearly identical results: gloves decreased the risk of detectable levels of urinary promutagens for incinerator workers, but wearing masks had no influence on risk. In a study by Gellin (1985), although heavy gloves were provided to all collection workers surveyed, many refused to wear them, and thus were subjected to increased skin injury. A study of incinerator workers found that individuals tended to wear protective gear either "always" or "never" (Malkin et al., 1992). This
study proposed that within the industry there are workers who are careful and take precautions in their work, and another group that had no concern for these issues.

Although none of the literature on municipal waste workers addressed the issue of heat stress with regard to protective gear, it is cited as a frequent and potentially severe health hazard encountered by hazardous waste workers (Favata et al., 1990). Hazardous waste workers wear vapor-barrier clothing, which prevents evaporative heat loss to the environment. The combined synergistic result of the effect of increased heat load and decreased heat dissipation is known as “heat strain.” According to Ferguson and Martin (1985), heat stress is the most common problem while working in personal protective equipment, especially when temperatures exceed 80°F. If similar protective clothing is worn by municipal workers, the potential hazards should be the same.

1.3.4 Hazardous Waste and Its Relationship to the Solid Waste Industry

The hazardous waste industry is regulated under different laws than the solid waste industry. However, as already noted, this distinction by regulatory bodies does not necessarily ensure that hazardous waste disposal is kept separate from solid waste. In fact, Anderson (1987) cites that commercial and institutional wastes have been routinely dumped with household waste in the same incinerator, landfill, or sewer system. These smaller commercial and institutional enterprises, which may not be regulated due to their small volumes, generate the same types of wastes that are regulated as hazardous waste when produced by Industry. Thus, the municipal waste worker is theoretically exposed to some of the same chemicals (albeit at presumably lower levels) as the hazardous waste worker, without the same regulation and protection.

A study conducted in 1986 by the California Department of Health Services illustrates the similarities in exposures and degree of health hazards between hazardous waste workers and solid waste workers (Gochfeld, 1990). The results of this study indicated that municipal waste workers had more skin and respiratory symptoms than the hazardous waste workers. Higher median urinary phenol levels, a measure of benzene exposure, were seen in municipal workers (5 mg/L) than in hazardous workers (4 mg/L). Unfortunately, this study did not draw any conclusions regarding the implications of such results for the health of municipal waste workers. Rather, the investigators interpreted their results as showing that hazardous waste workers were not heavily exposed to the chemical substances they encounter. However, results such as these emphasize a definitive need for further research regarding the overlap between these two industries in terms of similar exposures and health effects.

Hazardous waste workers are ultimately protected by the OSHA Standard 29 CFR 1910.120. Under this standard, medical surveillance examinations are mandated (Gochfeld, 1990; NIOSH, 1985; Levine, 1990). Medical surveillance systems, including a baseline pre-exposure exam, periodically examine workers at risk of exposure to hazardous materials for the purpose of early recognition and control of exposures. Furthermore, workers in hazardous waste removal, containment, or emergency response are required to receive health and safety training (Komaki et al., 1978). These trainings
incorporate aspects of hazard identification, the use of personal protective equipment, safe work practices, and medical surveillance. Lectures may also include aspects of empowerment to raise the employees' awareness centering on the importance of maintaining a safe work environment, as well as education about worker protection regulations, and a review of employer responsibilities.

Obviously, these regulations and associated educational seminars are focused on worker protection. One study explains the pertinence of these initiatives by describing the multiple chemicals workers are potentially exposed to, and the limitations of traditional preventative strategies in protecting these workers (Abatemarco et al., 1995). Thus, the average hazardous waste worker in the United States is, in general, better trained and better equipped than most industrial workers potentially exposed to hazardous materials, including the solid waste industry worker.

The literature on the solid waste industry documents multiple exposures to multiple agents. However, it would appear that there are far less interventions and protective strategies mandated for the solid waste worker. Furthermore, there is a lack of information on health outcomes, and maybe more importantly, intervention and initiatives for worker protection.

1.3.5 Limitations of Research

A review of the available literature illustrates many shortcomings in research design, which in turn further limits the knowledge of the waste industry and associated definitive health outcomes. Many of the reviewed studies had fundamental design flaws such as: a lack of control population, lack of exposure data (such as inadequate knowledge about the timing and order of the contamination and environmental exposure), scientific uncertainty about the impact of low-dose exposures, and the often inconclusive nature of findings, the latter probably due to small sample size and low power. Although, rarely mentioned as a problem, the underestimation of injury and disease probably exist due to under-reporting, especially for disease.

Many studies' results may have been influenced by a classic epidemiologic bias known as the “Health Worker Effect” (Monson, 1990; Checkoway et al, 1988). This refers to the fact that working populations tend to be much healthier than the general population, and that often the individuals who become ill in their jobs leave. Therefore, cross sectional studies performed at a single point in time on working populations (i.e. the majority of the existing studies of solid waste workers), will tend to underestimate the amount of disease, since truly diseased individuals will have left the workplace. Another issue with cross-sectional studies is that they can only produce prevalence data, not incidence data. Another bias seen in some of the reviewed studies is the so-called “Hawthorne Effect” in which the presence of the investigators can change the behavior of the study population. For example, Ma et al. (1992) suspected that workers who believed they were at high risk of occupational exposures to toxicants began to take measures to reduce their exposure, such as wearing protective gear, during the course of the study. This suspicion by the investigator was based on the fact that the prevalence of urinary
mutagens significantly declined with each successive sampling.

Several studies conducted personal and environmental monitoring and sampling. However, for the most part, only brief periods of time were sampled, and thus, the results may not be representative of normal conditions. Other studies only sampled one site. For example, a study by Gelberg (1997) examined only one landfill site in New York City. Thus, the generalizability of these results was low because this landfill may not be representative of most landfill sites in New York or most cities. Furthermore, although a control group was included, workers and the individuals in the control group were not matched; significant socioeconomic differences were found between the two groups, causing potential confounding. As noted above, many other studies did not include any control or comparison groups.

The study of the New York City landfill, as well as many others, employed a self-reported questionnaire; thus no objective measure of illness was made. Recall bias and low response rates are problems frequently associated with this type of study design. Turnberg and Frost (1990) believe that their low response rate (47%) of waste workers to their questionnaire resulted in higher estimates of exposure (i.e. only those people who wanted to report a problem responded). Recall bias is often a problem in retrospective study designs, as those with more serious injuries are more aware of risk circumstances and more likely to report them than lesser injured individuals (Ivens et al., 1997). Another bias seen in these studies is reporting bias, especially when investigators have attempted to rely solely on official reporting databases such as workers’ compensation systems; these databases have many hidden barriers to reporting, especially for diseases as opposed to acute injury, such that they represent only the “tip of the iceberg” of the disease profile for an industry.

Often, studies attempt to simulate a waste facility, such as an incinerator plant, landfill site, composting facility or recycling plant, in order to estimate possible occupational exposures. Although laudable attempts several shortcomings exist in this type of design. Laboratory tests may not accurately mimic field conditions. For example, Cains and Eduljee (1997) point out that the data derived from their artificial incinerator underestimated the formation rates of PCDDs and PCDFs by failing to account for "in flight" enhancement due to favorable mass transfer and the high catalytic activity of freshly formed ash. However, the concentrations of heavy metals in leachates from laboratory tests are normally much higher than the metal concentrations in the leachates from the ash monofills (Wiles, 1996).

Researchers often offer explanations for the lack of disease data. Landrigan (1983) suggested that rarely would health effects be acute and overwhelming as in the case of an emergency worker inhaling toxic smoke during a dump fire. He hypothesized that more typically, exposures were less dramatic, and thus, illnesses would be more gradual in onset. Lowrance (1981) stated a similar theory; he said that with regard to the waste industry, other than direct contact poisoning, health effects would likely be subtle and chronic, and have long latency periods before detection. Gelberg (1997) discussed the
difficulty in hypothesizing about health outcomes due to heterogeneous nature of the materials. The research on occupational exposures related to the waste industry is often made more difficult due to simultaneous chemical exposures. This complicates the data interpretation because it is more arduous to isolate which substance is causing what problem (Anderson, 1987).

### 1.3.6 Community Studies

A body of literature exists on studies related to communities and their exposures and health outcomes related to municipal waste. However, this subject was outside the scope of this project. The bulk of this literature is focused on communities surrounding incinerator and landfill sites. As seen with hazardous waste sites, public resistance to the siting of municipal incinerators is stiffening due to a perceived threat to public health, natural ecosystems, and quality of life (Reams, 1996; Fleming et al., 1999). Community opposition to the establishment of landfills seems to be related to their unsightliness and the threat of groundwater pollution (Scarlett et al., 1990). Other factors such as fear of property devaluation, environmental equity concerns, and economic risks further influence community resistance (Fleming et al., 1999; Fosella, 1998).

Schwartz et al (1998) performed an ecological study in Florida to evaluate the possible association between pancreatic cancer and solid waste; in addition to high income and cigarette smoking, a significant correlation was found \((r=0.47)\) between county of residence at the time of diagnosis of pancreatic cancer and solid waste production, particularly the subcomponent of yard trash \((r=0.42)\). Nevertheless, according to a review by Valberg et al. (1996), modern day facilities do not contribute measurably to the health risks in the community. Many investigators emphasize that a cause-effect relationship cannot be definitively concluded from studies on community exposures and related health outcomes (Marty, 1993; Fleming et al, 1999). The reasons for this include population mobility, disease latencies, variable and low exposures, and health outcomes manifesting as chronic conditions.

### 1.4 FUTURE RESEARCH RECOMMENDATIONS AND CONSIDERATIONS

This section will discuss specific recommendations actually found in the literature, as well as recommendations suggested by this intensive review of the literature concerning the health of solid waste workers. Table 1.6 is a summary of the known and possibly implicated health effects by job category according to the available literature.
Table 1.6. Known and Possible Health Effects Listed by Job Category

<table>
<thead>
<tr>
<th>Health Problem</th>
<th>Waste Collectors</th>
<th>Incinerator Workers</th>
<th>Landfill Workers</th>
<th>Compost Workers</th>
<th>Recycling Workers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injuries</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>x</td>
<td>✓</td>
</tr>
<tr>
<td>Musculoskeletal</td>
<td>✓</td>
<td>x</td>
<td>✓</td>
<td>x</td>
<td>✓</td>
</tr>
<tr>
<td>Dermal Membrane</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>?</td>
<td>✓</td>
</tr>
<tr>
<td>Respiratory</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Cardiovascular</td>
<td>✓</td>
<td>?</td>
<td>✓</td>
<td>x</td>
<td>X</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Neurologic</td>
<td>?</td>
<td>?</td>
<td>✓</td>
<td>x</td>
<td>?</td>
</tr>
</tbody>
</table>

✓ = documented in literature; ? = possible association inferred by literature; x = not explored in literature.

### 1.4.1 Recommendations in the Literature

Many investigators recommend the increased use of protective gear. Rahkonen et al. (1987) stated that landfill workers should wear working clothes that give protection against water and dirt and have access to protective gloves, shoes and other protective clothing when needed. He also added that the clothes should be brightly colored and be equipped with reflectors in order to avoid injuries from accidents. Although direct mention of heat stress in this population was not discussed, this study suggested that the clothing should be appropriate for fluctuating temperatures and the periodicity of work. Hygiene recommendations were also made. These investigators recommended the separation of washing facilities from eating facilities to prevent cross contamination. Gellin (1985) stated, based on the results of his study, that waste collectors wear gloves to protect their hands. Heida et al. (1995) suggested that compost workers wear a disposable protection suit with a cap, as well as a high-efficiency particulate filter respirator. Mozzon et al. (1987) recommended that incinerator workers use an air-supplied respirator and other protective equipment, particularly when in contact with precipitators. For recycling workers, particularly urban recyclers, Rendlemen and Feldstein (1997) emphasized the use of personal protective equipment, particularly shin-high impenetrable boots and puncture-proof gloves.

Recommendations concerning future studies of waste collectors were given in many studies. Poulsen et al. (1995a) suggested that information is needed on the actual incidence rates of occupational health problems related to waste collectors. They also recommended that reports on bio-aerosol, endotoxin, and total dust exposures in the work environment of the waste collector are needed. Many studies offered suggestions to prevent injury, particularly with regard to the manual handling of waste involving high workload and high speed subsequently resulting in musculoskeletal problems. Ivens et al. (1997) suggest less manual handling and less walking on stairs, ramps, and basements; in a separate study, Ivens et al (1998) recommend particular attention the education of younger and less experienced workers concerning musculoskeletal hazards. Poulsen et al.
(1995a) hypothesized that the implementation of new waste collection systems and new equipment would not only improve the work conditions, but result in less injury. NIOSH (1997) has produced a series of detailed recommendations in terms of training, education, and engineering controls of equipment to prevent refuse collectors from death and injury. The American National Standards Institute (ANSI), as well as the National Solid Waste Management Association (NSWMA), have published Safety Standards for Mobile Refuse Collection and Compaction Equipment which address safe operation and construction of the equipment and include recommendations for worker and pedestrian safety (ANSI 1992; NSWMA, 1988).

1.4.2 Additional Recommendations suggested by this Literature Review

In general, few epidemiological studies have been conducted on the health of solid waste workers. Furthermore, as previously mentioned, these were plagued with design flaws. One recommendation is that both retrospective and prospective longitudinal studies be conducted, rather than collecting purely cross-sectional data. Furthermore, these studies must be multi-site, employ appropriate control groups, and if possible, examine chronic, as well as acute, health effects. Other critical components are the incorporation of personal and environmental exposure monitoring, and precise diagnostic instruments for objective health effect evaluation (Landrigan, 1983).

In order to establish the chronic health effects and occupationally related hazards associated with the municipal waste industry, follow-up studies of current and former employees are needed (Sigsgaard et al., 1994a; Sigsgaard et al 1994b). Computer databases and multiple information resources are becoming more readily available and accessible (Campbell, 1993). An employee database provides a medium in which any and all pertinent information on individuals can be documented and stored. With this trend towards information technology, increasing information on employee status, employee safety and any related health issues could be easily attained. This type of information would provide fundamental data for the industry to utilize for the purpose of change.

Since definitive information on occupationally related health problems is scarce, current initiatives to reduce health concerns is based almost solely on empirical considerations. In a Health Hazard Evaluation performed by NIOSH, the basic health and safety protections of solid waste workers were found to be practically non-existent (Arenholz, 1986). A review by Ivens et al. (1997, 1998) also assumed that many injuries could be prevented or less serious if training and education were increased, especially for young and/or inexperienced workers. Of note, Memishi (1998) noted that many recycling workers in the US are illiterate, which impedes education and training; in such circumstances videotapes, rather than printed materials, should be used. Turnberg and Frost (1990) reported that among their study respondents, only 69% received and job safety training, and only 26% of these learned about special handling such as medical waste. Obviously, increased efforts in reducing personal risk factors and potential occupational exposures would reduce morbidity in the municipal waste worker population.

Furthermore, the municipal waste industry should consider mirroring the practices employed by the hazardous waste industry with regard to regular personal monitoring.
periodical work-place environmental monitoring, medical surveillance, and worker education.

Studies have failed to conclusively establish an etiological association between exposures at municipal landfill sites and disease. However, nearly all of the available studies implicate a potential relationship. Investigations are necessary related to bioaerosols, bacteria, fungi and dust as they potentially instigate negative health effects in landfill workers. Mozzon et al. (1987) suggested utilizing new equipment that incorporated sound insulation and air conditioning in order to provide a safer environment for operators. However, with regard to landfill employees, Gelberg (1997) points out that the bulk of the existing literature pertains to hazardous waste workers and their occupational risk factors. Since little is written about the health and exposures related to the municipal landfill worker, a study that compares these two groups (the hazardous waste landfill worker and the municipal landfill worker) could yield interesting data, as long as an additional non-waste exposed worker group was used.

Since a limited amount of information related to composting and its health outcomes is available, many uncertainties about potential health hazards related to pathogens, trace metals, and organic contaminant exist (He et al., 1995). This is complicated further by the variation in the composition of municipal waste, the source of compost. One recommendation is to further study the leachability and bioavailability of elements from municipal solid waste compost (Tisdell and Breslin, 1995). Researchers also suggest further investigation of volatile organic compounds associated with composting (Kim et al., 1995) and organic dust concentrations (Heida et al., 1995). Obviously, the acute and chronic health effects of composting need to be explored further.

Within the realm of recycling, Rendlemen and Feldstein (1997) recommended new industry regulations for the public such as the separation of all glass containing products and the regulation of labeled, safe and approved containers for needles and syringes. Poulsen et al. (1995a, 1995b) suggested the establishment of occupational exposure limits for airborne microorganisms and microbial toxins. Varying levels of microorganisms, dust, and bacteria were detected in studies, some with associated reports of occupational problems. However, in general, there is limited information exists on the magnitude of risks and the causal factors that pertain to the recycling industry. Thus, based on the information available on the potentially dangerous exposures related to recycling, research needs to be conducted in order to establish a causal relationship.

Although the bulk of the literature reviewed related to incinerator plants, few epidemiologic studies on the health effects related specifically to exposure to incinerator waste were found. Bresnitz et al. (1992) implied that the random sampling of personal and environmental conditions may produce results that are more representative of the normal conditions at a plant. Further investigation of PCDDs and PCDFs and their emissions, the role of exposure to organic dust, and bacterial endotoxin at incinerator plants is necessary in order to understand how to reduce them and eliminate any health effects caused. Information which characterizes the quantities, concentrations and
chemical forms of pollutants that are emitted from incinerator stacks is necessary for the purpose of environmental and health insights (Hasselriis and Licata, 1996). Epidemiological surveillance is paramount as the industry has and may continue to become further dependent on incinerator plants as landfill storage space decreases (Reams and Templet, 1996).

1.5 CONCLUSIONS

In conclusion, a review of the literature concerning solid waste workers provides an incomplete knowledge base; rarely are plausible links between exposure and health confirmed. Despite factors such as research design flaws, small study populations and lack of follow-up, based on known exposures and existing studies one is left with the following possible health risks for the solid waste worker. In particular, musculoskeletal, dermal, and respiratory health effects, both acute and chronic, are relatively well documented among solid waste workers. Furthermore, engineering, monitoring, education, personal protection, and other interventions appear to be under-utilized in protecting solid waste workers from exposure and health effects.

Certainly, in this society the disposal of solid waste is a concern. Yet because of the deficient information on the types, volumes, and characteristics of these wastes, many unanswered questions regarding the risk of occupational injuries and irreversible chronic health effects for the solid waste worker still exist. Nearly every study and review article characterizes the lack of epidemiological studies and urges further investigation on the relationship between waste and health. In particular, multi-site, controlled retrospective and prospective epidemiologic studies with appropriate exposure and objective health effect measures should be performed, as well as intervention studies to reduce known exposures.

Considering the magnitude of uncertainties related to an indefinite number of chemical exposures and concentrations which could potentially result in morbidity and mortality, and the risk of injuries specifically related to worker environment and practices, further investigations and interventions are warranted. In the meantime, there is much to learn from the existing body of literature and regulation (especially for the hazardous waste worker) that can lead to preventive interventions for the solid waste worker.
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2. ASSESSMENT OF RISKS TO MUNICIPAL SOLID WASTE WORKERS

James D. Englehardt
Huren An

Section 2 of this report comprises an assessment of the occupational health and safety risks to municipal solid waste (MSW) workers in Florida. The rationale for the study can be seen not only in the findings presented in Section 1, but also in recent rapid escalation in both the amounts of MSW generated in Florida and the per capita generation rates. In 1996, 23,745,910 tons of municipal solid waste (MSW) were collected and recycled or disposed in the state (Bureau of Solid and Hazardous Waste 1998), corresponding to a generation rate of 3295 lb./cap.-yr. This rate can be compared to the rate of 2200 lb./cap.-yr. reported for Florida in 1990 (Tchobanoglous et al., 1993). While population is increasing at a 1.3% annual rate, per capita solid waste generation has increased at more than double that rate since 1990. Based on reported generation quantities (Bureau of Solid and Hazardous Waste 1998), the annual rate of increase in solid waste generation in Florida has been 4.13% over the period 1990 through 1996. At this rate, new solid waste collected in Florida would fill the Tampa Bay basin, as delivered in compaction vehicles, in 76 years.

Growth in MSW generation in Florida has driven a growth in the industry, and in the number of MSW workers. Table 2.1 lists work force populations reported by the Florida Department of Labor and Employment Security, Bureau of Labor Market and Employment Information, for three Standard Industrial Codes (SICs). The SIC 4953 includes employees of firms engaged primarily in the operation of refuse systems, and may include small numbers of hazardous waste workers and recycling workers. Numbers shown for SIC 4212, Local Trucking Without Storage, are only those workers reported as refuse collectors. The SIC 5093, Scrap and Waste Materials, was considered to represent the recycling industry, although recycling workers employed by firms engaged primarily in solid waste collection (e.g., BFI Industries) or disposal would be reported under 4212 or 4953, respectively. According to Occupational Health and Safety Administration (OSHA) guidelines, workers employed by firms engaged primarily in producing compost would be reported with other fertilizer industry workers under SIC 2875. The number of compost workers per se could not be identified in the data as reported, due the small number of such workers and the uncertainty as to reported SIC. However, the total number of fertilizer workers averaged only 1047 over the five-year period, and compost workers were considered to represent an insignificant fraction thereof. Estimated total MSW workers are therefore estimated as the total of other workers, as shown in the Table 2.1.
Table 2.1. Estimated MSW Work Force Populations

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4212 (refuse collectors, excluding other trucking)</td>
<td>573</td>
<td>615</td>
<td>617</td>
<td>646</td>
<td>662</td>
</tr>
<tr>
<td>4953 (primarily collection, landfill and incinerator workers)</td>
<td>5004</td>
<td>5197</td>
<td>5139</td>
<td>5727</td>
<td>5631</td>
</tr>
<tr>
<td>5093 (recycling industry workers)</td>
<td>3418</td>
<td>3798</td>
<td>4274</td>
<td>4172</td>
<td>4152</td>
</tr>
<tr>
<td>2875 (compost, excluding other fertilizer)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Total MSW and recycling workers (est.)</td>
<td>8995</td>
<td>9610</td>
<td>10,030</td>
<td>10,545</td>
<td>10,445</td>
</tr>
</tbody>
</table>

It is likely that the costs of managing the burgeoning MSW stream in Florida are rising more rapidly than waste quantities, considering health care cost increases (Memishi 1998 a). Escalating health care costs are currently considered the greatest inflationary force on the costs of U.S. commerce in general, and the rate of injury and mortality in the MSW industry is substantially higher than for the general workforce. Between 1972 and 1993, the National Institute for Occupational Safety and Health (NIOSH) reported that costs for providing workers’ compensation increased from $6 billion to $57 billion nationally, an annual growth rate of 12.5% (National Institute for Occupational Safety and Health, 1998). Recent news reports indicated that U.S. garbage collectors experienced 48.8 deaths per 100,000 workers in 1996, making it the seventh most deadly occupation nationally (Memishi 1998 b). This rate is higher than that of taxicab drivers (32/100,000), the tenth deadliest profession.

Although the literature review of Section 1 indicated that little is known concerning risks to workers in the growing MSW industry, articles on particular aspects were found, and various field data are available. Principal data sources include Workers’ Compensation data, as reported to the Florida Department of Labor and Employment Security, Division of Workers’ Compensation, by individual facilities, and OSHA 200 logs, maintained (by law) but not reported unless requested. Workers’ Compensation data includes only injuries and occasional illnesses that are (a) recognized by the employee as job-related, (b) reported to the employer, and (c) reported as a claim against Workers’ Compensation insurance. OSHA 200 data includes all accidents reported to the employer, but is not generally available to researchers, except by special relationship with employers. Data collected by the National Institute for Occupational Safety and Health (NIOSH) on potential health hazards at individual work sites, collected in response to requests from employers, workers, and state agencies, is publicly available. However, NIOSH data is specific to the site, time, and hazard under investigation. NIOSH also operates the National Traumatic Occupational Fatalities Surveillance System (NTOF), the purposes of which are to identify occupational injury fatalities by cause and compare rates among industries at the national level. Such fatality rates at the state level among subsets of the worker population, such as Florida MSW workers, are not high enough for many purposes of analysis.

Although literature information and data on risks to MSW workers is spotty, predictive Bayesian (Englehardt, 1995) and information-theoretic (Englehardt and Lund,
1992) risk analysis techniques have been developed recently, which allow leveraging and integration of available information rigorously. For example, the compound Poisson model can be used to evaluating cumulative losses over a planning period (Englehardt, 1997 a). Accordingly, probability distributions for numbers of impairments over a planning period, and magnitudes, of health impacts are evaluated. From these, distributions for cumulative health impacts, for given categories of occupation and impairment, are computed. Component distributions are developed using both subjective information and indirect data, as well as direct numerical data. Resulting probability distributions evolve in shape depending on the level of information available, becoming narrower if more is known about the particular risk.

The objectives of the study presented in this section were to:

1. Identify the injuries and diseases most frequently reported by MSW workers in Florida, and the specific occupational groups to which these injuries and diseases correspond, and identify other influential factors,
2. Assess the risks, in terms of annual incidence rates as well as some measure of total health-related losses (e.g., in monetary units), to MSW workers in Florida, and
3. Develop a fact sheet describing principal risks and potential countermeasures, to aid in risk reduction.

The study population comprised Florida MSW workers, excluding secretarial and administrative staff. Two categories of injury were studied: those for which compensation was received by the worker through Workers’ Compensation insurance, and those reportable in OSHA 200 Logs. Reportable OSHA 200 incidents include those for which more than a single administration of first aid is required. Less serious injuries were not assessed. Workers were categorized in the data as to principal business activity of the employer (e.g., refuse systems) by Standard Industrial Code (SIC); therefore results are reported in terms of SIC code rather than by implied business activity of the worker, as discussed in Section 2.1.2. Injury rates per 100 workers were based on best estimates of worker populations for SIC codes, and for subgroups thereof (e.g., drivers and helpers), implying associated uncertainty as discussed in Section 2.3. No attempt was made to distinguish injury, mortality, or disease rates between public and private employers in the first year of study. Assessment of risks to populations proximal to landfills and other MSW operations was outside the scope of study in the first year, as well.

2.1 METHODOLOGY

Methods used to evaluate health and safety risks to MSW workers in Florida Quantitatively comprised:

a) Two site visits to a waste collection operation,
b) Collection of Florida Workers’ Compensation data, OSHA 200 data from two individual MSW collection operations, one public and one private,
c) Collection of Florida MSW workforce population data for industry and job categories,
d) Statistical analysis of Florida Workers’ Compensation data to identify principal risk categories, and
e) Predictive Bayesian risk analysis to assess principal risks quantitatively.

Methods for each subtask are described in the following sections.

2.1.1 Site Visit

During the project, the investigators conducted two site visits, in collaboration with the Florida Division of Safety, to a private South Florida waste collection operation. To maintain open lines of communication with this firm, which cooperated willingly with the researchers, the identity of the firm were not disclosed in research results. The Health and Safety officer for the operation was interviewed extensively, and the past two years of OSHA 200 logs were obtained. Extrapolation of information obtained from this firm to other MSW operations in Florida was done only indirectly in a Bayesian probabilistic procedure. On the first visit, investigators accompanied the Division of Safety representative on a safety inspection, noting potential hazards. On the second visit, investigators followed trucks on several household waste, yard waste, and recycling collection routes to identify potential risks to waste collectors. Potential hazards were noted.

2.1.2 Data Collection

Workers’ Compensation data were provided by the Florida Department of Labor and Employment Security, Division of Workers’ Compensation. Subsequent to the initial request, such data were made confidential. Due to the date of the initial request, all data requested were provided. Data acquired included Workers’ Compensation claims for cases of more than seven calendar lost work days (LWD), reported under standard industrial codes (SICs) 4953, 5093, 4212 and 2875, for the period 1993 through 1997. Data fields included injury nature, injured body location, accident type, disability type, worker’s occupation, accident date, age, gender, and monetary values awarded.

It should be noted that the data obtained for this study were not collected for this study, but for purposes of legal and medical compensation. In particular, workers were categorized in the data according to the SIC code best representing the employer’s principal business activity. Individual workers may or may not be engaged in this particular activity. Moreover, SIC codes may be assigned separately to each company owned by a larger corporation (e.g., Waste Management), or may be assigned consistently for such a corporation at a national or regional level (e.g., BFI). Therefore, results are reported in this document according to SIC code rather than by the implied business activity of the worker. For example, a worker at a recycling facility operated by an employer engaged primarily (at either the corporate or company level) in refuse disposal and reporting to OSHA as such would be referenced by SIC 4953 (Refuse Systems).
SIC code 4953 is defined as “Establishments primarily engaged in the collection and disposal of refuse by processing or destruction, or in the operation of incinerators, waste treatment plants, landfills, or other sites for disposal of such materials,” including:

- Acid waste, collection and disposal of,
- Ashes, collection and disposal of,
- Dumps, operation of,
- Garbage: collecting, destroying, and processing,
- Hazardous waste material disposal sites,
- Incinerator operation,
- Landfill, sanitary: operation of,
- Radioactive waste material, disposal of,
- Refuse systems,
- Rubbish collection and disposal,
- Sludge disposal sites,
- Street refuse systems, and
- Waste material disposal at sea.

SIC code 4212 represents firms engaged in local trucking without storage. Many such firms are courier and delivery services. Because waste collectors represented only a small fraction of such workers, data for refuse collectors was sorted manually for analysis. Collection worker cases were identified by the name of the firm or public agency, and the occupation category.

It was considered that collection workers could not be distinguished in the data from other MSW workers, due to the way SIC codes are assigned to employers as discussed previously. Therefore, SIC codes 4953 and 4212 (sorted for refuse collectors) were analyzed as a whole. Such workers are referred to in this report by the reference SIC 4953/4212.

SIC 5093 represents “establishments primarily engaged in assembling, breaking up, sorting, and wholesale distribution of scrap and waste materials,” including:

- Automotive wrecking for scrap-wholesale bag,
- Bottles, waste-wholesale,
- Boxes, waste-wholesale,
- Fur cuttings and scraps-wholesale,
- Iron and steel scrap-wholesale
- Junk and scrap, general line-wholesale,
- Metal waste and scrap-wholesale,
- Nonferrous metals scrap-wholesale,
- Oil, waste-wholesale,
- Plastic scrap-wholesale,
- Rags-wholesale,
- Rubber scrap-wholesale,
• Scavengering-wholesale,
• Scrap and waste materials-wholesale,
• Textile waste-wholesale,
• Wastepaper, including paper recycling-wholesale, and
• Wiping rags, including washing and reconditioning-wholesale.

Such workers are considered to represent the recycling industry. Workers at recycling centers operated by employers engaged principally in other activities were analyzed accordingly.

Work force populations for SICs 4953, 5093, and 4212, for 1993 through 1997, were obtained from the Florida Department of Labor and Employment Security, Bureau of Labor Market and Performance Information (Long 1998). In addition, the number of workers in each of 20 specific occupations within SIC 4950, and in each of 15 occupations in SIC 4210, were provided for 1994. From these data, workforce population estimates for MSW workers, and for occupational categories thereof, were estimated as described in Section 2.3. Total work force data for Florida was obtained from Florida Department of Labor and Employment Security, Division of Workers’ Compensation Worldwide Web page.

2.1.3 SAS Statistical Analysis

The SAS® version 6.12 statistical software package was used to analyze Workers’ Compensation data. Injury nature, body part, summarized body location, accident type, summarized accident type, and disability type were each identified by a Florida Workers’ Compensation Standard code in the data. A listing of the codes and their meanings is given in Appendix B. Fatalities were identified by means of the disability code field. The distribution of injury by the following characteristics were investigated:

a) Injury type,
b) Injured body location,
c) Accident type,
d) Occupation,
e) Year,
f) Season, and
g) Day of the week

Recycling workers reported under SIC 5093 were analyzed separately, representing the recycling industry. For the analysis by specific occupation, occupations studied were classified according to the occupational description given in the data as:

a) Driver/Helper,
b) Laborer,
c) Administrative personnel,
d) Mechanic,
e) Equipment operator,
g) Others

Incidence rates were estimated on the basis of worker population estimates for each occupational category. Population estimates were averaged over the period 1993 through 1997 for which WC data was obtained. Such estimates for subcategories (a) through (g), above, of the SIC code groups studied are described in detail Section 2.3, and are considered subject to approximately 30% reporting error. Estimated incidence rates were summarized and compared to national rates. Rates for occupational subgroups are subject to the error contained in worker population estimates. Principal injuries were identified, and cause categories for each principal injury type were investigated, to provide information regarding accident prevention. Because illness and disease were not reported significantly in the Workers’ Compensation or other data, occupational illness was not assessed quantitatively. Such risks were discussed qualitatively only, on the basis of literature studies and the experience of the Investigators.

2.1.4 Risk Assessment Methods

Two scales of risk assessments were conducted. First, quantitative assessments of risks for particular job and injury type categories, based on Florida Workers’ Compensation data, were conducted. These were done both in terms of numbers of injuries, and in monetary units, based on the Workers’ Compensation data. Second, risks for two general categories of health risk, musculoskeletal and dermal injuries, were conducted based on literature information, Florida Workers’ Compensation data, and OSHA 200 data for one large public and one large private facility in Florida. These assessments were only possible in terms of the number of injuries, given currently available information. Methods for each are described in the following sections.

2.1.4.1 Assessment of Particular Occupational Risks Based on Workers’ Compensation Data

The numbers of Workers’ Compensation cases per year, and the resulting Florida Workers’ Compensation costs, were assessed for major injury types identified in the SAS© analysis. These assessments were conducted using a predictive Bayesian version of the compound Poisson model. That is, the number of injuries over a planning period was assumed to have a Poisson distribution, on the basis of theory and experience. A predictive Bayesian adaptation of the basic compound Poisson model, diagrammed in Figure 2.1, was used in cases where less than 30 data points were available. The variable $N$ is the number of injuries of a particular type over the planning period, $Z$ is the magnitude of the health impairment for individual incidents of that type, and $X$ is the total (uncertain) health loss accumulated over the period. Dotted lines portray distributions with varying information content. Broader distributions represent less available information.
Figure 2.1. Predictive Bayesian compound Poisson model for total loss over a period.
The magnitude of individual injuries was measured in monetary units, and assumed equal to the total monetary cost of the incident charged to Workers’ Compensation insurance. These costs comprised total indemnity, including some, but not all, wages paid for lost time, medical costs, and any settlement awarded in compensation for a permanent disability or other claim. Death benefits are generally capped at just over $100,000. Such costs, as described in more detail in Section 2.5.2, “The Nature of Claim Size Distributions” are considered to represent only a fraction of the societal cost of occupational injuries.

For the analysis of Workers’ Compensation data, ample data on the cost of individual incidents were available. Therefore, a Bayesian analysis was not necessary. Histograms of frequency versus Workers’ Compensation claim size were constructed on log-log scales. To determine histogram bin sizes, the minimum claim size, $Z_0$, was assumed to be $50, and the maximum claim size, $Z_{\text{max}}$, was set at $10 million. Histograms were evaluated for fit against several parametric distributional forms known to apply to incident sizes, including the Pareto, lognormal, gamma, and exponential. Fits of the empirical probability density functions (PDFs) were evaluated visually against the parametric forms, as this method has proved more satisfactory than the Chi-square and Kolmogorov-Smirnov goodness-of-fit tests for evaluating incident size data (Englehardt, 1997 b). The lognormal distribution was found to fit all Workers’ Compensation data. Parameters of the three-parameter lognormal distribution were estimated by the method of maximum likelihood. Estimated values are given in Appendix C.

Only five data points, corresponding to each of five years of data, were available to estimate the expected annual number of incidents. Therefore, the predictive Bayesian approach was used, assigning a probability distribution to the expected number of injuries per year. This expected injury number is the one parameter, $\lambda$, of the Poisson distribution, and is equal to the mean or expected annual number of injuries. This Poisson mean was assumed to have a Gamma prior distribution, with parameters $\alpha_n$ and $\beta_n$.

A marginal predictive distribution of incident number that accounts for uncertainty in $\lambda$ by assuming a gamma prior distribution for $\lambda$ follows, based on Aitchison and Dunsmore (1975):

$$p(n | \alpha_n, \beta_n, n_1, n_2, ... n_I) = \frac{(n + \alpha_n - 1 + I \bar{\eta})!}{n!(\alpha_n - 1 + I \bar{\eta})!} \left[ \frac{1}{\beta_n + I + 1} \right]^n \left[ 1 - \frac{1}{\beta_n + I + 1} \right]^{(\alpha_n + I \bar{\eta})}$$

(2.1)

In Equation 2.1, $n$ is the number of incidents over a planning period, $p(n|\ldots)$ is the discrete probability distribution of incident number given $\alpha_n$, $\beta_n$, and data points $n_1, n_2, \ldots n_I$, $I$ is the number of data points, and $\bar{\eta}$ is the mean of the data. It was considered that no significant subjective information was available for these analyses with which to estimate expected annual numbers of injuries. Therefore, non-informative prior
distributions for $\lambda$ were assumed, as follows. The gamma priors for expected injury numbers, other than strains/sprains, were assumed with low confidence to have a mean equal to the mean of the data, plus 20% to account for under-reporting. Parameters $\alpha_n$ and $\beta_n$ of the gamma prior were then specified by the method of moments, with a value of $\alpha_n = 2$ indicating low confidence. The ratio $\alpha_n/\beta_n$ is equal to the mean of a gamma distribution. Therefore, $\beta_n$ was set equal to two divided by the subjectively-estimated value of the parameter $\lambda$. Because estimates were specified with low confidence, results of these analyses were determined primarily by the reported data. All parameter estimates are listed in Appendix C.

Probability distributions for total Workers’ Compensation costs were computed as the product of the (random) number of incidents in Florida annually, and the (random) cost of individual incidents. The Monte Carlo method was used to compute the final distributions for various injury categories. For each Monte Carlo simulation, 10,000 iterations were performed. Mean, standard deviation, and 5% exceedance values for the total cost associated with each injury/job category were thus computed. Then, each such Monte Carlo simulation was repeated thirty times, to obtain an estimate of the numerical error incurred in simulation. The resulting probability distributions, and associated percent exceedance probabilities, were presented to describe the potential costs of various injuries to various occupational categories, and the associated variability.

2.1.4.2 Integration of Literature Information and Data to Assess Musculoskeletal and Dermal Injury Frequencies

In the final phase of risk assessment, predictive Bayesian methods were used to integrate the understanding of risks acquired by means of the literature search, with the numerical information contained in the Florida Workers’ Compensation data. To do this, it was necessary to account for the fact that Workers’ Compensation data represented only claims against such insurance. Many injuries are reported to the employer and recorded in OSHA 200 logs (private facilities) or Florida SAF 200 (public facilities), but not filed as Workers’ Compensation claims. Only injuries requiring more than a single administration of first aid are required to be reported in OSHA 200 logs or SAF 200. Some injuries may not even be reported by the worker, due to concerns relating to employment, residency, and other social factors. Literature studies, in contrast, typically comprise surveys of all health impacts reported anonymously by workers at a point in time (cross-sectional study). Such surveys tend to indicate all health effects, albeit without indicating incidence rates on an annual or other basis.

On the basis of the literature search, the Investigators identified three principal categories of health risk to MSW workers: respiratory, dermal, and musculoskeletal injuries and diseases. The respiratory category included many chronic conditions such as coughing and wheezing that can generally be described as illnesses. Because chronic illness and disease do not appear in reported data to any significant extent, respiratory conditions were not quantifiable even by Bayesian techniques. Dermal and musculoskeletal were more typically reported. Therefore, these categories were assessed as described in this section. Because no indication of the severity of such injuries was
found in literature studies, risks were assessed only in terms of the numbers of such
injuries on an annual basis. The assessment focused primarily on injuries requiring more
than first aid. It was assumed that over-reporting approximately compensated under-
reporting in the data.

The Poisson distribution has been shown theoretically and empirically to be the
distribution for the number of events over a period, given stationarity and independence
of event frequency over the period, and given that events are infrequent enough that no
two events can occur simultaneously (Ross 1985). Over a year's time, it was considered
that the number of collector injuries in Florida might violate the latter premise of the
Poisson distribution. Hoel, et al, (1971) noted that (a) the sum of all events over multiple
time periods would be distributed Poisson, and (b) for large number of time intervals, the
same sum would be distributed normal by the Central Limit Theorem. Thus, for large
incident numbers, the (discrete) Poisson distribution converges to the (continuous)
normal. The same result applies to the negative binomial distribution, and was used in
this work to analyze collector injuries.

Total numbers of musculoskeletal and dermal injuries were first assessed using
Equation 2.1 based on Poisson assumption. To account for the possibility that injury
numbers were high enough to violate the premise of the Poisson distribution, normally
distributed injury numbers were assumed for comparison. The mean of the normal
distribution was assumed also to be distributed normal, with mean and variance as \( m \) and
\( s^2_m \), respectively. The inverse of the variance was assumed gamma \((\alpha, \beta)\) distributed,
written such that \( \alpha/\beta \) was equal to the mean, and the variance was \( \alpha/\beta^2 \). Therefore,
moment estimators for \( \alpha \) and \( \beta \) could be found from empirical relationships for the mean
and variance of \( 1/s^2 \). The predictive Bayesian version of the normal distribution was then
Student t distribution as follows, based on Aitchison and Dunsmore (1975):

\[
pdf(x \mid I, m, \bar{x}, s_m^2, s_x^2, \alpha, \beta) = \frac{1 + (x - e)^2}{d \times f}^{-1/2}
\]

\[
\frac{Beta\left(\frac{1}{2}, \frac{d}{2}\right) \sqrt{d \times f}}{\beta(\frac{1}{2}, \frac{d}{2}) \sqrt{d \times f}}
\]

(2.2)

in which:

\[
d = 2\alpha + I - 1 + \Delta(s^2),
\]

(2.3)

\[
e = \frac{m + I s_m^2}{1 + I s_m^2}, \text{ and}
\]

(2.4)
In Equations 2.2 through 2.5,

1. **Beta** function,

2. \( m \) and \( s_m^2 \) are the prior mean and variance of normal distributions for the injury numbers per year,

3. \( \Delta s_m^2 = 0 \) if \( s_m^2 = \infty \), \( \Delta s_m^2 = 0 \) if \( s_m^2 \neq \infty \),

4. \( \alpha \) and \( \beta \) are parameters of a gamma distribution for \( 1/\sigma^2 \),

5. \( I \) is the number of actual data point,

6. \( \bar{x}_i \) is the data average of injury numbers per year

7. and \( s_{x_i}^2 \) is the variance of the observed injury numbers per year, which equals to \((x_i - \bar{x}_i)^2\), \( x_i \) is the \( i \)th data number.

Investigators involved in the literature review were interviewed to determine estimated incidence rates for musculoskeletal and dermal injuries, and associated confidence levels. These estimated rates were estimated with low confidence, based on prevalence rates in Danish and other populations. Thus, it was estimated with low confidence that annual numbers of musculoskeletal injuries per 100 MSW workers were between 0.4 and 25, with an expected value of approximately 10. Dermal injury rates were estimated at between 0.13 (minimum) and 5 to 12 (maximum) per 100 workers per year. Thus, estimated expected values of 10 and 6 injuries per 100 workers were interpreted by the risk assessors for musculoskeletal and dermal injuries, respectively, on the basis of the literature review. The prior distribution of the Poisson parameter \( \lambda \) was assumed to be distributed gamma, with parameters \( \alpha_n \) and \( \beta_n \) estimated using subjective information and associated confidence. The prior for the mean of the normal distribution was assumed as a normal distribution, and the prior for the variance was specified such that the inverse variance has a Gamma distribution. The estimate of the prior mean was based same information as for the Poisson distribution. The prior for the normal variance was estimated such that the standard deviation was approximately three times of that of the Poisson distribution, as will be described. Individual distributions for the annual number of musculoskeletal and dermal injuries occurring in Florida annually were developed. From those distributions, a distribution for the annual sum of musculoskeletal plus dermal injuries was computed by Monte Carlo analysis.
2.2 SITE OBSERVATIONS AND SUPPORTING LITERATURE INFORMATION

Site visits provided first-hand experience with dangers encountered in MSW collection. Such work is extremely heavy, with continual exposure to the risk of back strains and sprains. Workers may be paid by the route, such that they are free to leave for the day upon completion of their allotted territory. This practice encourages rapid work, and may discourage the use of automated equipment. Sharp materials, which may be hidden in plastic bags, pose a continual risk of laceration, especially to fingers. Both household and yard waste may be manually collected, and frequently contain sharp materials. Gloves are provided by employers. However, the gloves become quickly soiled. Therefore, they may not be worn, or may require frequent replacement. Because of the need for frequent replacement, the employer may provide a moderate quality glove manufactured of cloth and leather in an attempt to control cost. Leather gloves providing maximum protection may not be provided.

Refuse collection trucks, including automated front-loaders, automated and manual rear-loading compaction vehicles, and automated side-loading compartmentalized recyclable collection vehicles, are large. Trucks frequently start and stop, with workers mounting and dismounting frequently and crossing relatively narrow residential streets to collect on both sides. Visibility for both the collection truck driver and passing motorists is limited, endangering collectors. These conditions pose the risk of vehicular accidents, personal injuries including contusions and fractures, and fatalities. Statistics developed by the NIOSH Bureau of Labor Statistics (Waste News, 1998) indicate that from 1980 to 1992, 67% of the 450 recorded fatalities among waste collectors resulted from vehicle-related accidents, and from 1992 to 1996, 79% of the 111 deaths were vehicle-related. These potential traffic accidents pose risks to waste collectors, as well as to the population at large.

Other risks were observed that did not appear significantly in the data analyzed. In particular, when bags were loaded into the back of a compaction vehicle, a sweeper mechanism descended to propel bags into the compactor. The sweeper was observed to burst some of the bags, engulfing two workers standing at the rear of the truck in a cloud of aerosol contaminants. While the workers did not appear to notice their exposure, respiratory and gastrointestinal disease may have resulted. Support in the literature for this observation was provided by Hansen and coworkers (1997), who reported a prevalence proportion ratio of 2.3, relative to a control group, for chronic bronchitis in Danish waste collectors. Poulson (1995) reported a prevalence ratio of 1.5 for illness in Danish MSW workers, relative to the general workforce. Also, the investigators were told that garbage trucks at that facility ignite several times per year, as a result of pickup of a hot load. When ignition occurs, the driver must dump the load to extinguish it. Another incident reportedly involved the collision of a truck with a house. This incident was due partially to the practice of fixing the engine accelerator in a depressed position, to accelerate hydraulic loading equipment. When the brakes released, the truck went through the wall. Such incidents illustrate the diversity of hazards encountered, which may not be well-described in coded Workers’ Compensation data.
2.3 FLORIDA MSW WORKFORCE POPULATION ESTIMATES

Estimates of populations of workers at the state level, by occupational description, were difficult to obtain. Total population estimates for SICs 4212, 4953, 5093, and 2875, some of which are shown in Table 2.1, were obtained from the Florida Department of Labor and Employment Security, Bureau of Labor Market and Performance Information. However, because numbers of drivers/ helpers, mechanics, and other categories were available only for upper level SIC code 4950 and 4210, sub-populations for SIC 4212 and 4953 were estimated from the work force data shown in Table 2.1 and 2.2, as follows.

For SIC 4212, there were 615 refuse collectors (of 61,726 workers total) reported in 1994. This figure was adjusted by year in proportion to the increase in the total number of workers in SIC 4212. The SIC 5093 was considered to represent only recycling industry workers, and no further breakdown was attempted for the analysis. The compost worker population was not identifiable within the general population of fertilizer workers, SIC 2875. However, the total fertilizer worker population averaged only 1047 over the period 1993-1997, and compost workers as a subset thereof were not considered to represent a significant fraction of MSW workers in Florida. Compost workers employed by employers engaged principally in other activities, such as operation of refuse systems, were considered in the analysis accordingly.

For SIC 4953, average annual employment, 1993-1997, by occupation was estimated from the occupational breakdown available for SIC 4950, shown in summary in Table 2.2. Refuse collectors reporting under 4950 were attributed entirely to SIC 4953, because SIC 4950, Sanitary Services, comprises only solid and hazardous waste and wastewater utilities, because hazardous waste workers were few, and because the wastewater industry does not employ refuse collectors. Other occupations within SIC 4953 were assumed distributed according to the proportions reported for SIC 4950. In 1994, there were a total of 5197 workers reported under SIC 4953. Thus, the 1167 refuse collectors reported under 4950 represented 22.5% of these 5197 workers reporting under SIC 4953. Then, from 1993 to 1997, employment under SIC 4953 averaged 5340 workers. Workers other than drivers/ helpers (collectors) were assumed distributed as for SIC 4950. Thus, the number of drivers and helpers was estimated at 5340 × (22.5%+9.3%) = 1696; the number of laborers was estimated at 5340 × 2.1% = 112; the number of administrative staff was estimated at 5340 × (4.3%+2.8%+3%+2.1%+2.1%+1.9%+1.2%) = 929; the number of mechanics was estimated to be 5340 × (2.2%+2.2%+2.0%+1.0%) = 395, and the number of equipment operators was estimated to be 5340 × (3.4%+2.2%) = 299.

Given the number of workers reported in job categories representing less than 1.0% of the total number of workers (Table 2.3), and the uncertainty in SIC code reported by employers (as discussed in Section 2.1.2), worker population estimates for subgroups of occupation were considered subject to ±30 % error. This error affects injury and mortality rates reported for occupational subgroups, such as refuse collectors.
Table 2.2. Employment by Occupation for Sanitary Services (SIC 4950) in 1994.

<table>
<thead>
<tr>
<th>Occupation Title</th>
<th>Occupation category in Table 2.3</th>
<th>Employee number</th>
<th>% of Total</th>
<th>Estimated SIC 4953 Worker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total all occupations</td>
<td></td>
<td>6877</td>
<td>100</td>
<td>5197</td>
</tr>
<tr>
<td>Refuse collector</td>
<td>Driver/helper (1)</td>
<td>1167</td>
<td>13.8</td>
<td>1167</td>
</tr>
<tr>
<td>Water and waste treatment plant</td>
<td>Water related</td>
<td>701</td>
<td>10.8</td>
<td>561</td>
</tr>
<tr>
<td>Truck driver, heavy</td>
<td>Driver/helper (1)</td>
<td>590</td>
<td>9.3</td>
<td>483</td>
</tr>
<tr>
<td>General Manager</td>
<td>Administrative (3)</td>
<td>293</td>
<td>4.4</td>
<td>229</td>
</tr>
<tr>
<td>Operating Engineer</td>
<td>Equipment operator (5)</td>
<td>234</td>
<td>3.7</td>
<td>192</td>
</tr>
<tr>
<td>Machinery Mechanics, Water/Power</td>
<td>Water related</td>
<td>193</td>
<td>3.2</td>
<td>166</td>
</tr>
<tr>
<td>General office clerk</td>
<td>Administrative (3)</td>
<td>195</td>
<td>2.8</td>
<td>145</td>
</tr>
<tr>
<td>Bookkeeping, accounting etc</td>
<td>Administrative (3)</td>
<td>205</td>
<td>2.7</td>
<td>140</td>
</tr>
<tr>
<td>First line supervisor, mechanics</td>
<td>Mechanics (4)</td>
<td>153</td>
<td>2.5</td>
<td>130</td>
</tr>
<tr>
<td>Customer service representatives</td>
<td>Administrative (3)</td>
<td>142</td>
<td>2.2</td>
<td>114</td>
</tr>
<tr>
<td>Maintenance Repairer</td>
<td>Mechanics (4)</td>
<td>149</td>
<td>2.2</td>
<td>114</td>
</tr>
<tr>
<td>All other plant and system operator</td>
<td>Equipment operator (5)</td>
<td>148</td>
<td>2.1</td>
<td>109</td>
</tr>
<tr>
<td>Helpers, laborers</td>
<td>Laborer (2)</td>
<td>138</td>
<td>2.1</td>
<td>109</td>
</tr>
<tr>
<td>Secretary</td>
<td>Administrative (3)</td>
<td>144</td>
<td>2.1</td>
<td>109</td>
</tr>
<tr>
<td>Bus, truck, diesel engine mechanics</td>
<td>Mechanics (4)</td>
<td>135</td>
<td>2.1</td>
<td>109</td>
</tr>
<tr>
<td>Accountant and auditor</td>
<td>Administrative (3)</td>
<td>128</td>
<td>2.0</td>
<td>104</td>
</tr>
<tr>
<td>Power generating plant operator</td>
<td>Water related</td>
<td>109</td>
<td>1.7</td>
<td>88</td>
</tr>
<tr>
<td>First line supervisor, production</td>
<td>Administrative (3)</td>
<td>107</td>
<td>1.6</td>
<td>83</td>
</tr>
<tr>
<td>Sales agent, business service</td>
<td>Administrative (3)</td>
<td>85</td>
<td>1.3</td>
<td>67</td>
</tr>
<tr>
<td>Mechanic and repairer helper</td>
<td>Mechanics (4)</td>
<td>71</td>
<td>1.1</td>
<td>57</td>
</tr>
</tbody>
</table>

Table 2.3. Estimated Average Work Force by Occupation (1993-1997)

<table>
<thead>
<tr>
<th>SIC</th>
<th>Occupation Group (code from Table 2.2)</th>
<th>Average employee number</th>
</tr>
</thead>
<tbody>
<tr>
<td>4212</td>
<td>Driver/helper</td>
<td>623</td>
</tr>
<tr>
<td>4953</td>
<td>Driver/helper (1)</td>
<td>1696</td>
</tr>
<tr>
<td></td>
<td>Administrative (2)</td>
<td>(929)</td>
</tr>
<tr>
<td></td>
<td>Laborer (2)</td>
<td>112</td>
</tr>
<tr>
<td></td>
<td>Mechanics (4)</td>
<td>395</td>
</tr>
<tr>
<td></td>
<td>Equipment operator (5)</td>
<td>299</td>
</tr>
<tr>
<td></td>
<td>Misc. jobs, each less than 1.0% of total</td>
<td>1909</td>
</tr>
<tr>
<td>5093</td>
<td>Recycling industry workers</td>
<td>3963</td>
</tr>
<tr>
<td></td>
<td>Total MSW workers, average 1993-1997</td>
<td>8997</td>
</tr>
</tbody>
</table>

2.4 STATISTICAL ANALYSIS OF WORKERS’ COMPENSATION DATA

Results of the statistical analysis of Florida Workers’ Compensation (WC) data for MSW workers, with the exception of compost workers, for the years 1993 through 1997 are presented in the following sections. First, a summary is presented, followed by an analysis of total Workers’ Compensation claim rates for MSW workers. Then, analyses
of principal injury types, principal body locations, principal accident types and disability types, occupational groups principally represented, and distribution of occurrence by age, gender, and region of the state, are presented. Workers reported under SIC 4953, and those reporting under SIC 4212 and considered on the basis of their occupation and employer to be refuse collection drivers or helpers, are referred to with the designation SIC 4953/4212. Such workers are considered to be primarily collection, incinerator, and landfill workers. Workers reporting under SIC 5093 are referred to accordingly.

2.4.1 Summary

Florida Workers’ Compensation data for MSW workers for the years 1993 through 1997 were analyzed statistically to determine the salient features of risks to such workers. Principal findings, described in subsequent sections, are outlined here. All injury rates per 100 workers are subject to 30% error, due to limitations in data on worker populations, and issues of reporting bias and misclassification. For workers in all SICs analyzed:

a) The mortality rate estimated for Florida MSW collectors, 1993 through 1997, was 90 ± 30 deaths per 100,000 workers, equivalent to the third deadliest occupation listed in national data. Every year for which data were available, one or more Florida MSW collectors died; and
b) Over the five-year period, only five cases of dermatitis, two cases of Carpal Tunnel Syndrome, one respiratory disorder, and one case of cancer were reported as WC cases of greater than seven calendar lost work days (LWD).

For SIC 4953/4212 workers:

a) The Workers’ Compensation claim rate (>7 LWD) tended to increase, from 4.3 per 100 workers in 1993, to 8.6 and 6.9 in 1996 and 1997, respectively;
b) An average of 6.2 WC cases (>7 LWD) per 100 workers was found, 4.7 times the rate for the general Florida workforce;
c) Strains and sprains to the lower back, particularly by lifting, were the most frequently reported injury for all occupational groups;
d) Other frequent injuries among drivers and helpers included lacerations, particularly of fingers and often by glass, fractures, particularly in the foot, and contusions, particularly to the knee;
e) Drivers and helpers were injured the most frequently, per capita, of all MSW occupational groups, in addition to being the most populous group;
f) The SIC 4953/4212 worker group in Miami-Dade County reported two-to-three times as many injuries per million tons of MSW collected as workers in other metropolitan counties in Florida;
g) Relative to the general workforce, vehicular injuries were proportionally higher in SIC 4953/4212 workers as a group; and
h) Relative to the general workforce, SIC 4953/4212 workers reported higher proportions of burns, injuries resulting from being caught in or between objects or equipment, injuries resulting from being cut, punctured, or scraped, and injuries resulting from being struck by objects and equipment;
For SIC 5093 workers:

a) Strains and sprains to the lower back, particularly by lifting, were the most frequently reported injury among SIC 5093 workers; and

b) Other frequent injuries included contusions and fractures, both often by being struck by a falling or flying object, and lacerations, all in varied body locations;

Table 2.4 summarizes the most commonly reported Workers’ Compensation cases, by occupation and injury type. Underreporting of illnesses was considered likely.

Table 2.4. Most Frequently Reported Workers’ Compensation Claim Types, by Occupation and Injury

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Injury</th>
<th>Total in 5 years</th>
<th>Average/Year</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drivers/Helpers</td>
<td>Contusion</td>
<td>120</td>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Fracture</td>
<td>70</td>
<td>14</td>
<td>5.2</td>
</tr>
<tr>
<td></td>
<td>Laceration</td>
<td>79</td>
<td>15.8</td>
<td>5.8</td>
</tr>
<tr>
<td></td>
<td>Strain/Sprain</td>
<td>550</td>
<td>110</td>
<td>44.9</td>
</tr>
<tr>
<td>Laborers</td>
<td>Strain/Sprain</td>
<td>31</td>
<td>6.2</td>
<td>2.7</td>
</tr>
<tr>
<td>Mechanics</td>
<td>Strain/Sprain</td>
<td>40</td>
<td>8</td>
<td>3.7</td>
</tr>
<tr>
<td>Equipment Operators</td>
<td>Strain/Sprain</td>
<td>78</td>
<td>4</td>
<td>4.8</td>
</tr>
<tr>
<td></td>
<td>Contusion</td>
<td>20</td>
<td>15.6</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td>Fracture</td>
<td>14</td>
<td>2.8</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>Laceration</td>
<td>12</td>
<td>2.4</td>
<td>1.1</td>
</tr>
<tr>
<td>SIC 4953/4212</td>
<td>Strain/Sprain</td>
<td>112</td>
<td>22.4</td>
<td>7.4</td>
</tr>
<tr>
<td>Workers</td>
<td>Contusion</td>
<td>50</td>
<td>10</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>Fracture</td>
<td>43</td>
<td>8.6</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>Laceration</td>
<td>40</td>
<td>8</td>
<td>2.8</td>
</tr>
</tbody>
</table>

2.4.2 Total incident rates

Florida Workers’ Compensation (WC) rates for cases of greater than seven calendar lost work days (LWD), per 100 workers per year, for SIC 4953/4212 workers, SIC 5093, and the total work force in Florida, are shown in Figure 2.2. An average of 6.2 WC cases (>7 LWD) were found for the SIC 4953/4212 worker group (1993-1997), 4.7 times the rate for the general Florida workforce (1993-1996). The figure also indicates that from 1993 to 1997, incidence rates decreased for total work force, while incidence rates for MSW workers almost doubled. This increasing rate of injury, together with the
rapid escalation in MSW generated in Florida, does not bode well for the public welfare or for the economics of MSW management.
Figure 2.2. Workers’ Compensation claim rates (greater than seven calendar LWD) for SIC 4953/4212 workers, SIC 5093 workers, and all Florida workers.
Although national data for SICs 4953 and 4212 were not available, total incidence rates for sanitary services (SIC 495) have been reported by OSHA. Table 2.5 lists nonfatal occupational injury and illness incidence rates per 100 full-time sanitary service workers, including most waste management workers (U.S. Occupational Safety and Health Administration, 1998).

Table 2.5. Nonfatal Occupational Injury and Illness Incidence Rates per 100 Full-time Worker in Sanitary Service

<table>
<thead>
<tr>
<th>Year</th>
<th>Injuries &amp; Illnesses Total</th>
<th>LWDI*</th>
<th>Injuries Total</th>
<th>LWDI*</th>
<th>Illnesses** Total</th>
<th>LWDI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1989</td>
<td>18.7</td>
<td>10.6</td>
<td>18.2</td>
<td>10.4</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>1991</td>
<td>15.3</td>
<td>7.9</td>
<td>14.9</td>
<td>7.8</td>
<td>0.4</td>
<td>0.1</td>
</tr>
<tr>
<td>1992</td>
<td>16.3</td>
<td>8.3</td>
<td>15.8</td>
<td>8.2</td>
<td>0.5</td>
<td>0.1</td>
</tr>
<tr>
<td>1993</td>
<td>13.7</td>
<td>7.2</td>
<td>13.1</td>
<td>7.1</td>
<td>0.6</td>
<td>0.1</td>
</tr>
<tr>
<td>1994</td>
<td>13.9</td>
<td>7.6</td>
<td>13.4</td>
<td>7.4</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>1996</td>
<td>13</td>
<td>7.1</td>
<td>12.6</td>
<td>6.9</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>mean</td>
<td>15.2</td>
<td>8.1</td>
<td>14.7</td>
<td>8.0</td>
<td>0.5</td>
<td></td>
</tr>
</tbody>
</table>

* Lost workday injuries/illnesses
** Estimated as the difference between total incidence and injuries

In comparison, the Danish Registry of Occupational Accidents and Diseases also found higher occupational risks for solid waste workers. Occupational injury prevalence ratios were found to be 5.6 times higher in such workers relative to the general workforce, and occupational diseases prevalence ratios were 1.5 times higher, in Denmark. Table 2.6 shows the Danish data (Poulson, 1995).
Table 2.6. Danish Reported Injury and Disease Incidence Rates for Solid Waste Workers and Total Work Force (per 100 worker per year)

<table>
<thead>
<tr>
<th>-reported Diseases</th>
<th>Waste Workers</th>
<th>Total Work Force</th>
<th>Relative Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reported Diseases</td>
<td>0.83</td>
<td>0.55</td>
<td>1.5 (1.4-1.7)</td>
</tr>
<tr>
<td>Allergic respiratory diseases</td>
<td>0.058</td>
<td>0.022</td>
<td>2.6 (1.8-3.9)</td>
</tr>
<tr>
<td>Other respiratory diseases</td>
<td>0.053</td>
<td>0.038</td>
<td>1.4 (0.9-3.9)</td>
</tr>
<tr>
<td>With defective hearing</td>
<td>0.051</td>
<td>0.095</td>
<td>0.5 (0.09-0.8)</td>
</tr>
<tr>
<td>Musculoskeletal diseases</td>
<td>0.35</td>
<td>0.19</td>
<td>1.9 (1.6-2.2)</td>
</tr>
<tr>
<td>Skin diseases</td>
<td>0.13</td>
<td>0.084</td>
<td>1.6 (1.2-2.0)</td>
</tr>
<tr>
<td>Infectious diseases</td>
<td>0.036</td>
<td>0.006</td>
<td>6.0 (3.6-10.0)</td>
</tr>
<tr>
<td>Nerves/senses</td>
<td>0.010</td>
<td>0.005</td>
<td>2.0 (0.8-5.3)</td>
</tr>
<tr>
<td>Brain damage</td>
<td>0.031</td>
<td>0.039</td>
<td>0.8 (0.5-1.4)</td>
</tr>
<tr>
<td>Circulation</td>
<td>0.005</td>
<td>0.008</td>
<td>0.6 (0.2-2.5)</td>
</tr>
<tr>
<td>Gastrointestinal</td>
<td>0.014</td>
<td>0.005</td>
<td>2.8 (1.3-6.3)</td>
</tr>
<tr>
<td>Accidents in general</td>
<td>9.46</td>
<td>1.68</td>
<td>5.6 (5.4-5.9)</td>
</tr>
<tr>
<td>Fatal accidents</td>
<td>0</td>
<td>0.003</td>
<td>0</td>
</tr>
<tr>
<td>Amputation</td>
<td>0.022</td>
<td>0.02</td>
<td>1.1 (0.4-2.9)</td>
</tr>
<tr>
<td>Fractures</td>
<td>0.49</td>
<td>0.16</td>
<td>3.1 (2.5-3.8)</td>
</tr>
<tr>
<td>Sprain</td>
<td>4.59</td>
<td>0.57</td>
<td>8.1 (7.5-8.6)</td>
</tr>
<tr>
<td>Wounds</td>
<td>1.87</td>
<td>0.49</td>
<td>3.8 (3.4-4.2)</td>
</tr>
<tr>
<td>Thermal Accidents</td>
<td>0.13</td>
<td>0.67</td>
<td>1.9 (1.3-2.9)</td>
</tr>
<tr>
<td>Soft tissue Accidents</td>
<td>1.44</td>
<td>0.19</td>
<td>7.6 (6.7-8.6)</td>
</tr>
<tr>
<td>Chemical burn</td>
<td>0.087</td>
<td>0.015</td>
<td>5.8 (3.5-9.5)</td>
</tr>
<tr>
<td>Poisonings</td>
<td>0.17</td>
<td>0.012</td>
<td>14.2 (9.9-20.2)</td>
</tr>
<tr>
<td>Unknown type</td>
<td>0.66</td>
<td>0.15</td>
<td>4.4 (3.7-5.3)</td>
</tr>
</tbody>
</table>

Total fatalities were identified in the Workers’ Compensation data (SIC 4953/4212), by disability type. Fatalities for collection drivers and helpers were tallied as 11 from 1993 through 1997. When divided by 2319, the total number of collection drivers and helpers estimated under SICs 4212 and 4953 in Florida (Table 2.3), this corresponds to an annual rate of 90 ± 30 occupational deaths per 100 MSW workers. This rate ranks in between the second and third deadliest occupations listed in U.S. Bureau of Labor Statistics data for the U.S. (Memishi, 1998). Of these 11 deaths, five were identified in the data as related to vehicles. The national fatality rate in 1996 for MSW collectors was 48.8 per 100,000 workers per year, ranking seventh just below fishers (178.4), timber cutters (157.3), airplane pilots (87.7), structural metal workers (85.2), extractive occupations (66.9), and water transportation jobs (60.9) (Memishi, 1998). Fatalities among workers reported under SIC 4953, are shown in Table 2.7 for Florida and the U.S. There were one or more fatalities among Florida MSW collectors during every year for which data were available.
Table 2.7. Fatalities among Workers Reported Under SIC 4953 (only) in Florida and the U.S.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Florida</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>U.S.</td>
<td>27</td>
<td>34</td>
<td>34</td>
<td>51</td>
<td>42</td>
<td></td>
</tr>
</tbody>
</table>
2.4.3. Analysis of Injury Types and Causes

Results of the analysis of Florida Workers’ Compensation data to determine principal injury types and causes are described in the following sections. Figures considered the most interesting to the current study are presented in the text, with remaining figures shown in Appendix C.

2.4.3.1 Analysis of Injury Types

Figure 2.3 gives the distribution of injury types for SIC 4953/4212 occupational group. Musculoskeletal or dermal injuries, particularly strains/sprains (Code 16), contusions (Code 4), lacerations (Code 13), and fractures (Code 8), predominated. Between 1993 and 1997 in Florida, strains and sprains accounted for almost 47.7% of all injuries. Contusions accounted for 10.3%, lacerations for 7.3%, and fractures for 6.6%. All the other injuries were under 1.3%. As shown in Table 2.8, this distribution is similar to that of the general workforce. In contrast, SIC 5093 recycling industry workers showed significantly greater proportions of lacerations, contusions, and fractures, and fewer strains and sprains, than either SIC 4953/4212 workers or the general workforce, as shown in Figure 2.4 and Table 2.8.
Figure 2.3  Types of injuries to collection, landfill, and incinerator workers.
Figure 2.4. Types of injuries to SIC 5093 workers.
Table 2.8  Proportions of Major Workers’ Compensation Claim Types, for MSW Workers and the Total Florida Work Force

<table>
<thead>
<tr>
<th>Injury type</th>
<th>% of Total Injuries SIC 4953 &amp; 4212</th>
<th>% of Total Injuries SIC 5093</th>
<th>% of Total Injuries Total Work Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strains/Sprains</td>
<td>47.7</td>
<td>31.5</td>
<td>45.7</td>
</tr>
<tr>
<td>Contusion</td>
<td>10.3</td>
<td>14</td>
<td>11.2</td>
</tr>
<tr>
<td>Fracture</td>
<td>6.6</td>
<td>12</td>
<td>7.4</td>
</tr>
<tr>
<td>Laceration</td>
<td>7.3</td>
<td>11.2</td>
<td>6.1</td>
</tr>
<tr>
<td>Total</td>
<td>71.9</td>
<td>70.4</td>
<td>68.7</td>
</tr>
</tbody>
</table>

2.4.3.2 Causes of Principal Injury Types

The causes of major injury types were analyzed as shown in Figures 2.5 through 2.9. The causes of strains and sprains are shown in Figure 2.5 and 2.6 for the SIC 4953/4212 and SIC 5093 workers. Strains and sprains were caused mostly by:

a) Lifting, accident code 56 (SIC 4953/4212, 36.5%; SIC 5093, 23.2%),
b) Pushing, accident code 57 (SIC 4953/4212, 6.4%; SIC 5093, 4.5%),
c) Non-specific falls, slips, and trips, accident code 31 (SIC 4953/4212, 6.3%; SIC 5093, 7.1%), and
d) Falls, slips, and trips off walls, cat walks, bridges, and other levels, accident code 25 (SIC 4953/4212, 5.3%; SIC 5093, 7.1%).

Accident code 60 represented non-specific causes. The analysis shows that waste collectors, as expected, suffer the most strains and sprains by lifting.
Figure 2.5. Causes of strains and sprains in collection, landfill, and incinerator workers.
Total Injuries = 112

<table>
<thead>
<tr>
<th>Code</th>
<th>Value</th>
<th>Code</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>machine or machinery</td>
<td>59</td>
<td>using toll or machinery</td>
</tr>
<tr>
<td>15</td>
<td>cut broken glass</td>
<td>60</td>
<td>strain or injury by, noc</td>
</tr>
<tr>
<td>25</td>
<td>from different level</td>
<td>66</td>
<td>object being lifted or handled</td>
</tr>
<tr>
<td>26</td>
<td>from ladder or scaffolding</td>
<td>69</td>
<td>stepping on sharp object</td>
</tr>
<tr>
<td>27</td>
<td>from liquid or grease spills</td>
<td>70</td>
<td>striking against or stepping on, noc</td>
</tr>
<tr>
<td>29</td>
<td>on same level</td>
<td>75</td>
<td>falling or flying object</td>
</tr>
<tr>
<td>30</td>
<td>slipped, do not fall</td>
<td>77</td>
<td>motor vehicle</td>
</tr>
<tr>
<td>31</td>
<td>fall, slip, or trip, noc</td>
<td>79</td>
<td>object being lifted or handled</td>
</tr>
<tr>
<td>45</td>
<td>collision or sideswipe with another vehicle</td>
<td>81</td>
<td>struck or injured, noc</td>
</tr>
<tr>
<td>50</td>
<td>motor vehicle, noc</td>
<td>98</td>
<td>cumulative</td>
</tr>
<tr>
<td>56</td>
<td>lifting</td>
<td>99</td>
<td>others – miscellaneous, noc</td>
</tr>
<tr>
<td>57</td>
<td>pushing or pulling</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2.6. Causes of strains and sprains in SIC 5093 workers.
Distributions of the causes of worker contusions are shown in Figures 2.7 and Figure C.1 in Appendix C. Contusions of SIC 4953/4212 workers were caused primarily by:

a) Striking against or stepping on stationary object, Accident code 68 (13.6%),
b) Falls, slips, and trips injury off walls, cat walks, bridges, and other levels, accident code 25 (11.9),
c) Being struck by falling or flying objects, accident code 75 (11.4%),
d) Falls, slips, and trips on the same level, accident code 29 (6.8%), and
e) Being struck by objects being lifted or handled, accident code 79 (5.7%).

While causes for contusions in SIC 4953/4212 workers were varied, the cause of contusions in SIC 5093 workers was typically being struck by a falling or flying object, accident code 75 (24.0%). Such objects may include recycled containers. As shown in Figure 2.7, falls, slips, and trips from off walls, cat walks, bridges, and other levels, accident code 25, accounted for the second 10.0%.
Total Injuries = 50

<table>
<thead>
<tr>
<th>Code</th>
<th>Value</th>
<th>Code</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>caught in, under or between, noc</td>
<td>66</td>
<td>object being lifted or handled</td>
</tr>
<tr>
<td>18</td>
<td>cut by powered tool</td>
<td>68</td>
<td>stationary object</td>
</tr>
<tr>
<td>25</td>
<td>from different level</td>
<td>70</td>
<td>striking against or stepping on, noc</td>
</tr>
<tr>
<td>29</td>
<td>on same level</td>
<td>75</td>
<td>falling or flying object</td>
</tr>
<tr>
<td>30</td>
<td>slipped, do not fall</td>
<td>76</td>
<td>struck by hand tool or machine in use</td>
</tr>
<tr>
<td>31</td>
<td>fall, slip, or trip, noc</td>
<td>77</td>
<td>motor vehicle</td>
</tr>
<tr>
<td>50</td>
<td>motor vehicle, noc</td>
<td>78</td>
<td>moving parts of machine</td>
</tr>
<tr>
<td>56</td>
<td>lifting</td>
<td>79</td>
<td>object being lifted or handled</td>
</tr>
<tr>
<td>57</td>
<td>pushing or pulling</td>
<td>81</td>
<td>struck or injured, noc</td>
</tr>
<tr>
<td>59</td>
<td>using toll or machinery</td>
<td>87</td>
<td>foreign body in eye</td>
</tr>
<tr>
<td>65</td>
<td>striking moving parts</td>
<td>99</td>
<td>others – miscellaneous, noc</td>
</tr>
</tbody>
</table>

Figure 2.7. Causes of contusions in SIC 5093 workers.
As shown in Figure C.2 in Appendix C, fractures in SIC 4953/4212 workers were caused by:

a) Falls, slips, and trips off walls, cat walks, bridges, and other levels, accident code 25 (12.4%),
b) Being struck by motor vehicles, accident code 77 (8.8%),
c) Being struck by falling or flying objects, accident code 75 (7.1%),
d) Being caught in, under or between machine or machinery, accident code 10 (7.1%),
e) Being caught in, under or between object handled, accident code 12 (5.3%), and
f) Being caught in, under or between non-specific objects, accident code 13 (5.3%).

As for contusions, fractures in SIC 5093 workers were due primarily to being struck by falling or flying objects (23.3%), with 16.3% being caused by falls, slips, and trips off walls, cat walks, bridges, and other levels.

While it was expected that lacerations in SIC 5093 workers would be caused by broken glass containers, broken glass was more often pointed to as the cause for SIC 4953/4212 workers. Otherwise, causes were most often simply reported as being caused by cuts, punctures, and scrapes by non-specific items, accident code 19, for both groups.
<table>
<thead>
<tr>
<th>Code</th>
<th>Value</th>
<th>Code</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>burn, steam or hot fluid</td>
<td>50</td>
<td>motor vehicle, noc</td>
</tr>
<tr>
<td>10</td>
<td>machine or machinery</td>
<td>56</td>
<td>lifting</td>
</tr>
<tr>
<td>12</td>
<td>caught in, under or between object handled</td>
<td>58</td>
<td>reaching</td>
</tr>
<tr>
<td>13</td>
<td>caught in, under or between, noc</td>
<td>68</td>
<td>striking stationary object</td>
</tr>
<tr>
<td>15</td>
<td>cut by broken glass</td>
<td>69</td>
<td>stepping on sharp object</td>
</tr>
<tr>
<td>16</td>
<td>cut by hand tool</td>
<td>70</td>
<td>striking against or stepping on, noc</td>
</tr>
<tr>
<td>18</td>
<td>cut by powered hand tool</td>
<td>75</td>
<td>falling or flying object</td>
</tr>
<tr>
<td>19</td>
<td>cut by miscellaneous</td>
<td>76</td>
<td>struck by hand tool</td>
</tr>
<tr>
<td>25</td>
<td>from different level</td>
<td>77</td>
<td>motor vehicle</td>
</tr>
<tr>
<td>29</td>
<td>on same level</td>
<td>78</td>
<td>moving parts of machine</td>
</tr>
<tr>
<td>31</td>
<td>fall, slip, or trip, noc</td>
<td>79</td>
<td>object being lifted or handled</td>
</tr>
<tr>
<td>45</td>
<td>collision or sideswipe with another vehicle</td>
<td>81</td>
<td>struck or injured, noc</td>
</tr>
<tr>
<td>46</td>
<td>collision with a fixed object</td>
<td>99</td>
<td>others – miscellaneous, noc</td>
</tr>
<tr>
<td>48</td>
<td>vehicle upset</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2.8. Causes of lacerations in collection, landfill, and incinerator workers.
Figure 2.9. Causes of lacerations in SIC 5093 workers.
2.4.3.3. Reasons for High Rates of Musculoskeletal and Dermal Injuries

The high rate of strains and sprains in MSW workers is not surprising, considering worker exposure. In the U.S., the hauled container system and the stationary container system are the two most common waste collection systems. Hauled containers are generally loaded mechanically by one or two person crews, for commercial and institutional accounts. However, stationary containers are still commonly loaded manually by two or three person crews on residential and commercial waste routes. A waste collector may typically handle 4.7-11.2 tons of waste per day [Tchobanoglous, 1993]. The lifting and carrying of loaded containers, the rolling of loaded containers on their rims, and the use of small lifts for rolling loaded containers, often entail both compression and shear forces, which can very easily cause ergonomic problems. Markslag and coworkers reported that holding or walking with a 7Kg waste bag results in a 3240 to 5200 N force being exerted on spine segment L5/S1. Pulling or pushing a container containing 22 to 60 kg of waste results in a 1510 to 2650 N force on L5/S1 (Poulson, 1995). The US National Institute of Occupational Safety and Health (NIOSH) recommends that the force on that particular back segment should be under 3400 N (Waters et al., 1993). Back strains and sprains are not unique to MSW workers, however. Klein and coworkers (1984) reported that back strains and sprains constituted 19.0% to 25.5% of Workers’ Compensation claims. For the Florida SIC 4953/4212 occupational group studied, 20.3% of injuries were strains or sprains to the back.

Dermal injuries were the second most prevalent general category of Workers’ Compensation claim found for the Florida data, after musculoskeletal injuries. Dermal injuries accounted for 22% of the claims. Amounts of potentially sharp materials in MSW are given in Table 2.9. Sharp tin can lids, broken glass, thorns, broken tree limbs, disposable razors, and disposable needles resulting from home health care practices are commonly hidden inside garbage bags. Such materials may puncture bags, and skin, when handled by collectors.

Table 2.9. Amounts of Potentially Sharp Materials in MSW.

<table>
<thead>
<tr>
<th>Composition</th>
<th>Florida 1996 (Total MSW=23.7 Million Tons)</th>
<th>US 1995 (Total MSW = 208 Million Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass</td>
<td>3.5%</td>
<td>6.2%</td>
</tr>
<tr>
<td>Metals</td>
<td>17.1%</td>
<td>7.7%</td>
</tr>
<tr>
<td>Yard Waste</td>
<td>18.5%</td>
<td>14.5%</td>
</tr>
</tbody>
</table>
2.4.4. Injured Body Location Distribution

Figures C.4 and C.5 in Appendix C show the analysis of the general body location of injuries. Lower extremities (code 5) and upper extremities (code 3) were the most vulnerable body parts, as shown in Figure C.4. Back injury (code 6) was also common among SIC 4953/4212 workers, and SIC 5093 workers reported fewer back injuries than other MSW workers (Figure C.5). The distribution of injured body locations was also compared with the total Florida work force, as shown in Table 2.10. The SIC 4953/4212 occupational group reported more injuries to lower extremities, while SIC 5093 workers reported a greater number of injuries to lower extremities, and fewer back injuries, relative to the general work force in Florida.

Table 2.10. Workers’ Compensation Claims, by Body Location, for the General Florida Work Force (1992-1996), and MSW Workers (1993-1997)

<table>
<thead>
<tr>
<th>Body location</th>
<th>General work force (%)*</th>
<th>Collection, landfill, and incinerator (%)</th>
<th>Recycling (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>3.1</td>
<td>3.6</td>
<td>6.7</td>
</tr>
<tr>
<td>Neck</td>
<td>1.1</td>
<td>1.5</td>
<td>1.4</td>
</tr>
<tr>
<td>Upper extremities</td>
<td>23.7</td>
<td>23.1</td>
<td>28.1</td>
</tr>
<tr>
<td>Trunk</td>
<td>6.7</td>
<td>6.1</td>
<td>7.6</td>
</tr>
<tr>
<td>Lower extremities</td>
<td>22.9</td>
<td>26.6</td>
<td>18.4</td>
</tr>
<tr>
<td>Back injury</td>
<td>23.6</td>
<td>23.0</td>
<td>13.5</td>
</tr>
</tbody>
</table>

*data from the Florida Division of Workers’ Compensation webpage.

In Figures 2.10-2.13, as well as Figures C.6-C.9 in Appendix C, a detailed analysis of the particular body parts to which particular injuries occur, is presented. Back strains and sprains in SIC 4953/4212 workers were easily the most frequent injury, as shown in Figure 2.10. Also of note, the following injuries occurred more than 15% of the time to the body part noted, among SIC 4953/4212 workers:

a) Strains and sprains of the lower back (code 42),
b) Contusions to the knee (code 53),
c) Fractures of the foot (code 56), and
d) Lacerations of the fingers (code 36).

Injuries to SIC 5093 workers tended to be relatively evenly distributed among body parts.
Total Injuries = 816

<table>
<thead>
<tr>
<th>Code</th>
<th>Value</th>
<th>Code</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>eye(s)</td>
<td>43</td>
<td>disc</td>
</tr>
<tr>
<td>20</td>
<td>multiple neck</td>
<td>44</td>
<td>chest</td>
</tr>
<tr>
<td>25</td>
<td>soft tissue</td>
<td>45</td>
<td>sacrum and coccyx</td>
</tr>
<tr>
<td>30</td>
<td>multiple upper extremities</td>
<td>46</td>
<td>pelvis</td>
</tr>
<tr>
<td>31</td>
<td>upper arm</td>
<td>48</td>
<td>internal organs</td>
</tr>
<tr>
<td>32</td>
<td>elbow</td>
<td>50</td>
<td>multiple lower extremities</td>
</tr>
<tr>
<td>33</td>
<td>lower arm</td>
<td>51</td>
<td>hip</td>
</tr>
<tr>
<td>34</td>
<td>wrist</td>
<td>52</td>
<td>upper leg</td>
</tr>
<tr>
<td>35</td>
<td>hand</td>
<td>53</td>
<td>knee</td>
</tr>
<tr>
<td>36</td>
<td>finger(s)</td>
<td>54</td>
<td>lower leg</td>
</tr>
<tr>
<td>37</td>
<td>thumb</td>
<td>55</td>
<td>ankle</td>
</tr>
<tr>
<td>38</td>
<td>shoulder(s)</td>
<td>56</td>
<td>foot</td>
</tr>
<tr>
<td>40</td>
<td>multiple trunk</td>
<td>57</td>
<td>toe</td>
</tr>
<tr>
<td>41</td>
<td>upper back</td>
<td>61</td>
<td>abdomen including groin</td>
</tr>
<tr>
<td>42</td>
<td>lower back</td>
<td>90</td>
<td>multiple body parts</td>
</tr>
</tbody>
</table>

Figure 2.10. Strained/sprained body locations (SIC 4953 and 4212)
Total Injuries = 112

<table>
<thead>
<tr>
<th>Code</th>
<th>Value</th>
<th>Code</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>head</td>
<td>40</td>
<td>multiple trunk</td>
</tr>
<tr>
<td>11</td>
<td>skull</td>
<td>42</td>
<td>lower back</td>
</tr>
<tr>
<td>14</td>
<td>eye(s)</td>
<td>44</td>
<td>chest</td>
</tr>
<tr>
<td>18</td>
<td>other facial tissues</td>
<td>45</td>
<td>sacrum and coccyx</td>
</tr>
<tr>
<td>19</td>
<td>facial bones</td>
<td>46</td>
<td>pelvis</td>
</tr>
<tr>
<td>20</td>
<td>multiple neck</td>
<td>48</td>
<td>internal organs</td>
</tr>
<tr>
<td>22</td>
<td>disc</td>
<td>50</td>
<td>multiple lower extremities</td>
</tr>
<tr>
<td>25</td>
<td>soft tissue</td>
<td>51</td>
<td>hip</td>
</tr>
<tr>
<td>30</td>
<td>multiple upper extremities</td>
<td>52</td>
<td>upper leg</td>
</tr>
<tr>
<td>31</td>
<td>upper arm</td>
<td>53</td>
<td>knee</td>
</tr>
<tr>
<td>32</td>
<td>elbow</td>
<td>54</td>
<td>lower leg</td>
</tr>
<tr>
<td>33</td>
<td>lower arm</td>
<td>55</td>
<td>ankle</td>
</tr>
<tr>
<td>34</td>
<td>wrist</td>
<td>56</td>
<td>foot</td>
</tr>
<tr>
<td>35</td>
<td>hand</td>
<td>57</td>
<td>toe</td>
</tr>
<tr>
<td>36</td>
<td>finger(s)</td>
<td>61</td>
<td>abdomen including groin</td>
</tr>
<tr>
<td>37</td>
<td>thumb</td>
<td>65</td>
<td>unclassified</td>
</tr>
<tr>
<td>38</td>
<td>shoulder(s)</td>
<td>90</td>
<td>multiple body parts</td>
</tr>
</tbody>
</table>

Figure 2.11. Strained/sprained body locations (SIC 5093)
**Total Injuries = 113**

<table>
<thead>
<tr>
<th>Code</th>
<th>Value</th>
<th>Code</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>head</td>
<td>37</td>
<td>thumb</td>
</tr>
<tr>
<td>11</td>
<td>skull</td>
<td>42</td>
<td>lower back</td>
</tr>
<tr>
<td>15</td>
<td>nose</td>
<td>44</td>
<td>chest</td>
</tr>
<tr>
<td>19</td>
<td>facial bones</td>
<td>46</td>
<td>pelvis</td>
</tr>
<tr>
<td>25</td>
<td>soft tissue</td>
<td>50</td>
<td>multiple lower extremities</td>
</tr>
<tr>
<td>30</td>
<td>multiple upper extremities</td>
<td>52</td>
<td>upper leg</td>
</tr>
<tr>
<td>31</td>
<td>upper arm</td>
<td>53</td>
<td>knee</td>
</tr>
<tr>
<td>32</td>
<td>elbow</td>
<td>54</td>
<td>lower leg</td>
</tr>
<tr>
<td>33</td>
<td>lower arm</td>
<td>55</td>
<td>ankle</td>
</tr>
<tr>
<td>34</td>
<td>wrist</td>
<td>56</td>
<td>foot</td>
</tr>
<tr>
<td>35</td>
<td>hand</td>
<td>57</td>
<td>toe</td>
</tr>
<tr>
<td>36</td>
<td>finger(s)</td>
<td>90</td>
<td>multiple body parts</td>
</tr>
</tbody>
</table>

Figure 2.12. Fractured body locations (SIC 4953 and 4212)
Figure 2.13. Lacerated body locations (SIC 4953 and 4212)
2.4.5. Distribution of Injuries by Accident Type (Cause)

The distribution of injury by general causal categories for SIC 4953/4212 and SIC 5093 workers is shown in Figures C.10 and C.11 in Appendix C. Strain/sprain (code 6) is most often reported for both groups. Fall and slip injuries (code 4) are also common, though not found in as high a proportion as in the general workforce. The SIC 5093 workers also report being struck or injured by objects or equipment. In Table 2.11, injury rates for the two groups are compared to the general Florida workforce. Of note, the following proportions are high or low relative to the general workforce:

a) Vehicular injuries are higher proportionally among SIC 4953/4212 workers,
b) Vehicular injuries are lower proportionally among SIC 5093 workers,
c) burns are higher proportionally among SIC 5093 workers,
d) Injuries resulting from being caught in or between objects or equipment are higher proportionally among SIC 5093 workers,
e) Injuries resulting from being cut, punctured, or scraped are higher proportionally among SIC 5093 workers, and
f) Injuries resulting from being struck by objects and equipment are higher proportionally among SIC 5093 workers.


<table>
<thead>
<tr>
<th>General cause category</th>
<th>Code</th>
<th>General Florida work force (%)*</th>
<th>Collection, landfill, and incinerator workers (%)</th>
<th>Recycling workers (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burn/scald-heat/cold exposure</td>
<td>1</td>
<td>1.8</td>
<td>1.1</td>
<td>5.6</td>
</tr>
<tr>
<td>Caught in or between</td>
<td>2</td>
<td>3.0</td>
<td>4.3</td>
<td>7.0</td>
</tr>
<tr>
<td>Cut, puncture, scrape</td>
<td>3</td>
<td>3.9</td>
<td>5.1</td>
<td>7.3</td>
</tr>
<tr>
<td>Fall or slip injury</td>
<td>4</td>
<td>28.1</td>
<td>20.6</td>
<td>19.7</td>
</tr>
<tr>
<td>Motor vehicle</td>
<td>5</td>
<td>4.7</td>
<td>9.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Strain or sprain</td>
<td>6</td>
<td>37.8</td>
<td>36.9</td>
<td>23.9</td>
</tr>
<tr>
<td>Striking against/stepping on</td>
<td>7</td>
<td>4.5</td>
<td>4.6</td>
<td>5.3</td>
</tr>
<tr>
<td>Struck or injured by</td>
<td>8</td>
<td>10.5</td>
<td>10.7</td>
<td>19.9</td>
</tr>
</tbody>
</table>

*data from Division of Workers’ Compensation webpage.

2.4.6. Distribution of Disability Types

The distribution of disability types is shown for SIC 4953/4212 and SIC 5093 workers in Figures C.12 and C.13 in Appendix C. Of note, Workers’ Compensation claims to MSW workers are most frequently for temporary total disability, according to reported data.
2.4.7. Injuries of Different Occupations

Injuries occurring to detailed occupational type were analyzed, as presented in Figure 2.14. The figure indicate that drivers and helpers on collection routes sustain far greater numbers of injuries. This injury rate is partly due to their greater population. In Florida, approximately 40% of MSW workers are drivers.helpers as shown in Table 2.3. However, for all injury types, injuries to the driver/helper group represent greater than 60% of the injuries. Therefore, this group is considered a high risk occupational group, as has been highlighted in recent news articles.
Figure 2.14. Distribution of injuries by occupation.
2.4.8. Distribution of Injury by Season and Day

The distribution of injuries by season and day are shown in Figures 2.15 and C.14. Seasonality was not apparent for SIC 4953/4212 workers in Florida (Figure 2.15). However, injuries to SIC 5093 workers were somewhat more prevalent in Summer (31%, Figure C.14). Reasons for higher injuries rates during summer include high temperature and humidity. Bio-aerosols, volatile compounds, and infectious materials are more active during periods of high temperature and humidity. Also, workers suffer in the heat, potentially affecting work performance and hindering the use of personal protective equipment.

The distribution of claims by day of the week is shown for SIC 4953/4212 and SIC 5093 workers in Figures 2.16 and C.15. The SIC 4953/4212 group reports more injuries on Monday. Based on information acquired during the site visit. The heaviest loads of MSW are typically collected on Monday, partly due to the lack of collection on weekends. Because many collectors employed with private firms are paid by the route, more MSW is collected on Mondays as compared with other days of the week. Thus, exposure is greater. Ettala and coworkers (1989) reported a similar finding.

2.4.9. Age and Gender

The distributions of injury by age and gender are shown in Figures C.16 through C.19. The distribution of Workers’ Compensation claims in the general workforce in Florida is shown in Table 5.7 for comparison. The SIC 4953/4212 workers show a high rate of injury in the 30-39 year age bracket, relative to the general workforce.

<table>
<thead>
<tr>
<th>Age</th>
<th>20-29</th>
<th>30-39</th>
<th>40-49</th>
<th>50-59</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of total</td>
<td>26.1</td>
<td>31.2</td>
<td>21.4</td>
<td>12.6</td>
</tr>
</tbody>
</table>
Figure 2.15. Seasonal distribution of injuries to SIC 4953/4212 workers.
Figure 2.16. Daily distribution of injuries to SIC 4953/4212 workers.
2.4.10. Regional Distribution

Injury rates by county in Florida are generally proportional to population and MSW generation rates. However, the rate of Workers’ Compensation claims, per million tons of MSW collected, is shown by county in Figures 2.17 and 2.18. A significant finding of the study was that, independent of the fact that Miami-Dade County generates more MSW than other Florida counties, the rate of injury to SIC 4953/4212 workers per million tons of MSW collected is two-to-three times higher than that of other metropolitan counties in Florida (Figure 2.17). Note that rates in rural counties are not likely to be meaningful, due to the low number and random variation in the number of claims.
Figure 2.17  Injury rates per million tons waste recycled per year by counties (SIC 5093)
Figure 2.18  Injury rates per million tons waste collected per year, by county (SIC 4953/4212)
2.5. BAYESIAN RISK ANALYSIS

Two categories of risk assessment will be described in the following sections. First, a detailed assessment of risks by occupational and injury group will be presented. Because literature studies were not available on such detailed groups, these assessments relied solely on Workers’ Compensation data. As such, dollar values for WC claims of greater than seven calendar lost work days (LWD) were available for two years of data, and were used as a measure of injury severity. Results are presented in terms of numbers of injuries, as well as in terms of total Workers’ Compensation costs. Second, literature information was integrated with the information contained in the Workers’ Compensation data, and OSHA 200 data from one public and one private facility in Florida, to assess risks of the broader groups of musculoskeletal and dermal injuries. Because monetary or other measures of severity were not found in the literature, these assessments were conducted only in terms of numbers of injuries.

2.5.1. Workers’ Compensation Claim Numbers for Specific Occupational and Injury Groups

The frequency of occurrence of various Workers’ Compensation claims by various occupational groups are depicted in Figures 2.19 through 2.20. These probability distributions give the probability of numbers of Workers Compensation claims occurring during a single year for all SIC 4953/4212 workers and SIC 5093 workers. Distributions for additional occupational groups are presented in Appendix E. The injury/occupation groups analyzed are those principal risk groups listed previously in Table 2.4. The predictive Bayesian distributions are versions of the negative binomial distribution, developed from five years of data as described in Section 2.1. They describe not only the expected number of injuries of each type to workers of each occupation annually, but the variability in such numbers. For example, the standard deviation around the mean, and the number of claims for which there is a 5% probability of exceedance annually, are derived from these distributions and given in Table 2.13. Numbers of injuries for which there is a 5% probability of exceedance can be thought of as having a 20-year return period. In addition, probability distributions for the annual numbers of strains and sprains to laborers, strains and sprains to mechanics, strains and sprains to equipment operators, contusions to equipment operators, and fractures to equipment operator are shown in Appendix D.
Figure 2.19. Probability distribution for the annual number of WC claims (greater than seven calendar lost work days) of all types to all SIC 4953/4212 workers.
Figure 2.20. Probability distribution for the annual number of WC claims (greater than seven calendar lost work days) of all types to SIC 5093 workers.
2.5.2. Distributions of Severity of Injury

were developed. Workers’ Compensation costs were used as the measure of severity, as described in Section 2.1.4. Because claims are paid out as expenses are incurred over four years old “mature”. That is, costs reported for claims less than about four years old were developed on the basis of data for 1993 and 1994.

Distributions of the severity of accidents, or incidents, are typically highly skewed, large incidents. Often the Pareto is found to provide the best fit. Workers’ Compensation data, however, was best fitted with the lognormal distribution. That is, the distribution of actual distribution of injury severities probably was.

reflects characteristics of the Workers’ Compensation payment structure. Workers’ Compensation payments comprise indemnities, medical costs, and additional settlements care provider, (b) surgery, (c) hospital care, (d) dental care, (e) prescription drugs, (f) braces and crutches, and (f) other medical supplies when ordered by an approved care provider, (b) surgery, (c) hospital care, (d) dental care, (e) prescription drugs, (f) braces and crutches, and (f) other medical supplies when ordered by an approved

Indemnities include (a) lost wages, if the worker is unable to work for more than seven calendar days on the advice of an approved doctor; (b) compensation if the compensation if the worker is able to work but earns wages less than 80% of those earned before the injury, because of the injury; and (d) compensation for permanent loss of a calendar days, is not included in Workers’ Compensation costs, and this may reduce the Compensation pays $100,000 to a spouse or surviving family member, plus funeral expenses to a maximum of approximately $3000, and possible expenses for retraining of a over $100,000 may decrease the apparent severity (cost) of extremely serious accidents.

Workers’ Compensation costs, as depicted in Figures 2.21 and 2.22, are only a fraction of the total costs of such injuries. NIOSH (1998) referred to a 1991 study that found that only 60% of persons reimbursed for work injuries received Workers’ additional hiring and training costs, disruption of work processes, and reduced coworker productivity under perceived risk. Workers and their families may experience reduced caregiving, and retraining, costs
for home modifications and equipment related to disability, and loss of education for family members. The community may also incur expenses, such as for increased use of social services. Non-economic losses may include changes in family and community roles, and loss of self-esteem of disabled workers.
Figure 2.21. Probability distribution for the cost of individual WC claims (greater than seven calendar lost work days) for all injury types, for SIC 4953/4212 workers.
Figure 2.22. Probability distribution for the cost of individual WC claims (greater than seven calendar lost work days) for all injury types, for SIC 5093 workers.
2.5.3. Annual Workers’ Compensation Costs by Occupation and Injury Type

Probability distributions for the cost of Workers’ Compensation claims, by occupation and injury type, are shown in Figures 2.23 and 2.24. The distributions were computed numerically as the product of the numbers of claims and the cost of individual claims, as described in Section 2.1.4.1. Parameter estimates are listed in Appendix C. Expected annual costs and 5% exceedance costs are presented in Table 2.13. In addition, probability distributions for Workers’ Compensation costs for principal injury categories are shown in Appendix F. It must be remembered that these costs do not reflect the large number of injuries that are not compensated by Workers’ Compensation, the specific costs that are not covered by Workers’ Compensation for injuries that are compensated in part, or non-economic costs.
Figure 2.23. Probability distribution for the annual cost of WC claims (greater than seven calendar lost work days) for all injuries to SIC 4953/4212 workers.
Figure 2.24. Probability distribution for the annual cost of WC claims (greater than seven calendar lost work days) for all injuries to SIC 5093 workers.
2.5.4. Summary of Annual Workers’ Compensation Costs

The results of the assessment of risks in terms of Workers’ Compensation costs for specific occupations and injuries, described in Sections 2.5.1 through 2.5.3, are summarized in Table 2.13. The expected number of injuries, expected number of injuries per 100 workers, expected annual Worker’s Compensation cost, expected cost per 100 workers, and the annual cost for which there is a 5% probability of exceedance in any year, are shown in the table. All probabilities reflect variability in the annual numbers and costs of injuries, as well as uncertainty in the annual numbers of claims due to the five-year period of available and relevant data. Results computed by Monte Carlo simulation are given with computational error bounds. Error bounds represent ± 2 standard deviations, found in 30 simulations.

Results of the assessment of Workers’ Compensation costs for specific occupations and injuries include the following observations. All costs are given in constant 1998 dollars. Note that actual costs, including those borne by employers, workers, and communities, are considered to be significantly higher:

a) Workers’ Compensation costs for cases of greater than seven calendar lost work days (LWD), for MSW workers in Florida, average $12.6 million per year, constant 1998 dollars, and have a 5% probability of exceeding $47 million in any year;

b) An average of 9.8 Workers’ Compensation cases (>7 LWD) per 100 workers annually (1993-1997) was assessed for the MSW driver/helper occupational group (SIC 4212/4953), 7.4 times higher than the rate for the general workforce in Florida (1993-1996). Such claims result in an average cost of $6.54 million annually, representing 52% of the total cost for MSW workers;

c) Strains and sprains are the most frequent, and correspondingly costly, injury type among MSW workers, resulting in a Workers’ Compensation (>7 LWD) cost averaging $4.48 million, or 36% of the total cost;

d) Specifically, Workers’ Compensation (>7 LWD) claims for strains and sprains to MSW collection drivers and helpers result in an expected cost of $3.3 million annually, representing 26% of the total cost. Such costs have a 5% probability of exceeding $12.1 million in any year; and

e) Workers’ Compensation (>7 LWD) costs for contusions to equipment operators at collection, landfill, and incineration facilities average $1.4 million annually, representing 11% of the total cost. This cost was more consistent from year to year than those for other injury/occupation categories (having a 5% probability of exceeding $4.5 million in any year).
Table 2.13. Summary of annual Workers’ Compensation Costs (1998 dollars), and Variability therein, for Florida MSW Workers, by Occupation and Injury Type

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Injury</th>
<th>Expected number</th>
<th>Expected number/100 workers</th>
<th>Expected annual cost*</th>
<th>Expected cost*/100 workers</th>
<th>5% Exceedance Cost**</th>
</tr>
</thead>
<tbody>
<tr>
<td>All SIC 4953/4212</td>
<td>All injuries</td>
<td>342.3</td>
<td>6.41</td>
<td>10.2±0.51</td>
<td>0.19</td>
<td>38.4±1.46</td>
</tr>
<tr>
<td></td>
<td>Strain/sprain</td>
<td>163.3</td>
<td>3.06</td>
<td>4.48±0.23</td>
<td>0.084</td>
<td>16.8±0.63</td>
</tr>
<tr>
<td>SIC 4953/4212 drivers and helpers</td>
<td>All injuries</td>
<td>228.7</td>
<td>9.80</td>
<td>6.54±0.33</td>
<td>0.28</td>
<td>24.6±0.90</td>
</tr>
<tr>
<td></td>
<td>Contusion</td>
<td>24.1</td>
<td>1.03</td>
<td>0.52±0.020</td>
<td>0.022</td>
<td>2.01±0.060</td>
</tr>
<tr>
<td></td>
<td>Fracture</td>
<td>14.1</td>
<td>0.60</td>
<td>0.50±0.014</td>
<td>0.021</td>
<td>1.90±0.048</td>
</tr>
<tr>
<td></td>
<td>Laceration</td>
<td>15.9</td>
<td>0.68</td>
<td>0.015±0.0003</td>
<td>0.00064</td>
<td>0.033±0.0008</td>
</tr>
<tr>
<td></td>
<td>Strain/sprain</td>
<td>110.1</td>
<td>4.72</td>
<td>3.28±0.19</td>
<td>0.14</td>
<td>12.1±0.45</td>
</tr>
<tr>
<td>SIC 4953/4212 laborers</td>
<td>Strain/sprain</td>
<td>6.3</td>
<td>4.53</td>
<td>0.055±0.0018</td>
<td>0.039</td>
<td>0.21±0.0062</td>
</tr>
<tr>
<td>SIC 4953/4212 mechanics</td>
<td>Strain/sprain</td>
<td>8.1</td>
<td>1.59</td>
<td>0.096±0.0027</td>
<td>0.019</td>
<td>0.36±0.0093</td>
</tr>
<tr>
<td>SIC 4953/4212 equipment operators</td>
<td>Contusion</td>
<td>4.1</td>
<td>1.07</td>
<td>1.41±0.14</td>
<td>0.37</td>
<td>4.52±0.18</td>
</tr>
<tr>
<td></td>
<td>Fracture</td>
<td>2.9</td>
<td>0.76</td>
<td>0.014±0.0004</td>
<td>0.0037</td>
<td>0.059±0.0016</td>
</tr>
<tr>
<td></td>
<td>Laceration</td>
<td>2.5</td>
<td>0.65</td>
<td>0.012±0.00017</td>
<td>0.0031</td>
<td>0.032±0.0015</td>
</tr>
<tr>
<td></td>
<td>Strain/sprain</td>
<td>15.7</td>
<td>4.11</td>
<td>0.43±0.018</td>
<td>0.11</td>
<td>1.66±0.052</td>
</tr>
<tr>
<td>SIC 5093 workers</td>
<td>All injuries</td>
<td>71.3</td>
<td>1.80</td>
<td>2.40±0.14</td>
<td>0.061</td>
<td>8.92±0.32</td>
</tr>
<tr>
<td></td>
<td>Contusion</td>
<td>10.1</td>
<td>0.25</td>
<td>0.60±0.038</td>
<td>0.015</td>
<td>2.19±0.078</td>
</tr>
<tr>
<td></td>
<td>Fracture</td>
<td>8.7</td>
<td>0.22</td>
<td>0.26±0.017</td>
<td>0.0066</td>
<td>0.94±0.033</td>
</tr>
<tr>
<td></td>
<td>Laceration</td>
<td>8.1</td>
<td>0.20</td>
<td>0.14±0.0070</td>
<td>0.0035</td>
<td>0.54±0.017</td>
</tr>
<tr>
<td></td>
<td>Strain/sprain</td>
<td>22.5</td>
<td>0.57</td>
<td>0.67±0.031</td>
<td>0.017</td>
<td>2.53±0.086</td>
</tr>
</tbody>
</table>

*Million dollars

**Annual cost having a 20 year return period, in millions

2.5.5. Assessment of Total Numbers of Injuries

To assess actual numbers of injuries in Florida associated with the health and safety of MSW workers, reflecting not only WC costs but those borne by employers,
workers, and communities, information acquired from the literature search of Section 1 was integrated with the Florida Workers’ Compensation data and OSHA 200 data for one public and one private MSW collection operation in Florida. Because literature studies did not indicate injury severity, actual risks were assessed only in terms of numbers of injuries. The predictive Bayesian method employed was described in Section 2.1. Actual injury numbers were considered to be represented by the number of injuries reportable in OSHA 200 Logs and Florida SAF 200. As such, injuries for which only first aid was administered, and administered only once, were not considered. Workers in SICs 4953/4212 were considered.

Prior Information

Based on the epidemiological literature review alone, it was estimated with low confidence that annual numbers of musculoskeletal injuries per 100 MSW (SICs 4953/4212) workers were between 0.4 and 25, with an expected value of approximately 10. Dermal injury rates were estimated at between 0.13 (minimum) and 5 to 12 (maximum) per 100 workers per year, with an expected value of approximately 6. The average work force for SICs 4953/4212 from 1993 to 1996 was estimated at 5960 ± 1790, not including administrative workers, using data given in Section 2.3. Therefore, the average total musculoskeletal and dermal injury numbers were subjectively estimated as follows:

\[
MN_{subj} = 5960 \text{ workers} \times 10 \text{ injuries/100 workers} = 596 \text{ injuries/year} \quad (2.7)
\]
\[
DN_{subj} = 5960 \text{ workers} \times 6 \text{ injuries/100 workers} = 358 \text{ injuries/year} \quad (2.8)
\]

In Equations 2.7 and 2.8, \(MN_{subj}\) and \(DN_{subj}\) are the subjectively estimated mean total numbers of musculoskeletal and dermal injuries, respectively, per year in Florida. These estimates were used to specify parameters of the prior distributions for mean injury numbers in the predictive Bayesian analysis.

As described in section 2.1.4.2, both Poisson and normal distributions were used for the analysis, for comparison. For the Poisson distribution, subjectively estimated injury numbers were set equal to the Poisson parameter \(\lambda\), assuming \(\lambda\) had a gamma (\(\alpha_n, \beta_n\)) distribution. For the normal distribution, the estimated injury numbers were used as expected values of the normal parameter \(m\), and standard deviations of the means’ distributions were specified equal to \(m\). The prior distributions for the inverse variance parameters, \(1/\sigma^2\), of the normal distributions were assumed gamma distributed with parameters \(\alpha\) and \(\beta\). The parameter \(\alpha\) represented confidence in prior information, and was set equal to unity, indicating low confidence. The parameter \(\beta\) was then determined such that the mean of the standard deviation of the normal distributions were not greater than three times those of the Poisson distributions. The data and parameters used to predict musculoskeletal and dermal injury distributions are summarized in Table 2.17.

Data

113
Musculoskeletal and dermal injuries were found to be the principle injuries reported to Workers' Compensation, accounting for almost 90% of the cases of greater than seven calendar lost work days (LWD). Table 2.14 lists the total and annual numbers of musculoskeletal and dermal WC cases among Florida MSW workers (SICs 4953/4212).

Table 2.14: Numbers of Musculoskeletal and Dermal WC cases (>7 LWD) for MSW Workers (SICs 4953/4212) in Florida

<table>
<thead>
<tr>
<th>Injury</th>
<th>Total in 5 years (1993-1997)</th>
<th>Annual injury number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Musculoskeletal</td>
<td>1083</td>
<td>216.6</td>
</tr>
<tr>
<td>Dermal</td>
<td>429</td>
<td>85.8</td>
</tr>
</tbody>
</table>

Because OSHA 200 and Florida SAF 200 reports include all injuries requiring more than first aid, such data was used to estimate actual injury numbers. Facility data is generally considered highly confidential. However, OSHA 200 data for 1996-1997 from one large private MSW collection operation, and a five summary of SAF 200 data from one large public collection agency in Florida, were obtained. Therefore, ratios of the numbers of Workers' Compensation claims to the numbers of OSHA/SAF 200 cases for the two facilities, as shown in Table 2.15, were used to estimate total injury rates for the State.

Table 2.15: Comparison of Injuries Reported to Workers Compensation (>7 LWD) and OSHA/SAF Log-200

<table>
<thead>
<tr>
<th>Year</th>
<th>log-200 injuries</th>
<th>Workers' Comp Injuries</th>
<th>log-200/Workers Comp</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>83</td>
<td>6</td>
<td>7.22%</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>61</td>
<td>7</td>
<td>11.5%</td>
<td>9.35%</td>
</tr>
<tr>
<td>Public</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>229</td>
<td>98</td>
<td>42.8%</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>249</td>
<td>78</td>
<td>31.3%</td>
<td>37.1%</td>
</tr>
</tbody>
</table>

The combination of WC and OSHA/SAF 200 records for 1996 and 1997 were considered to represent two data points on total annual injuries. Due to the significant difference in the rate of injuries becoming Worker's Compensation claims between the public and private sectors, the estimate of total injuries in Florida was done by: (1) identifying the dermal and musculoskeletal injury numbers within private and public sectors from the Workers' Compensation database; (2) assuming the sampled private and public facility were representative; (3) calculating the total dermal and musculoskeletal injury numbers using the sample rates of public and private sectors, respectively, and (4) adding public and private sectors' injury numbers to obtain total dermal and musculoskeletal injury number. The estimated dermal and musculoskeletal injury numbers for 1996 and 1997 are shown in Table 2.16. The mean and variance of these injury numbers were used to represent the data in the Bayesian analysis.
Table 2.16: Estimated Total Dermal and Musculoskeletal Injury numbers

<table>
<thead>
<tr>
<th>Year</th>
<th>Dermal</th>
<th>Musculoskeletal</th>
<th>Dermal + Musculoskeletal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996</td>
<td>961</td>
<td>3170</td>
<td>4131</td>
</tr>
<tr>
<td>1997</td>
<td>497</td>
<td>1667</td>
<td>2164</td>
</tr>
<tr>
<td>Average</td>
<td>729</td>
<td>2418.5</td>
<td>3147.5</td>
</tr>
<tr>
<td>Variance</td>
<td>53824</td>
<td>564752</td>
<td>967272.25</td>
</tr>
</tbody>
</table>

Table 2.17: Specified Parameters of the Predictive Bayesian Distributions

<table>
<thead>
<tr>
<th></th>
<th>Musculoskeletal</th>
<th>Dermal</th>
<th>Musculoskeletal + Dermal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poisson:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>(\bar{x})</td>
<td>2420</td>
<td>729</td>
<td>3420</td>
</tr>
<tr>
<td>(\alpha_p)</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>(\beta_p)</td>
<td>0.0017</td>
<td>0.0028</td>
<td>0.00105</td>
</tr>
<tr>
<td>(\alpha_p/\beta_p)</td>
<td>596</td>
<td>358</td>
<td>954</td>
</tr>
<tr>
<td>Normal:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>(\bar{x})</td>
<td>2420</td>
<td>729</td>
<td>3420</td>
</tr>
<tr>
<td>(s_x^2)</td>
<td>564752</td>
<td>53824</td>
<td>967272</td>
</tr>
<tr>
<td>(m)</td>
<td>596</td>
<td>358</td>
<td>954</td>
</tr>
<tr>
<td>(s_m^2)</td>
<td>355216</td>
<td>128164</td>
<td>910116</td>
</tr>
<tr>
<td>(\alpha)</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>(\beta)</td>
<td>5625</td>
<td>3600</td>
<td>9025</td>
</tr>
<tr>
<td>(\alpha/\beta)</td>
<td>0.00018</td>
<td>0.00028</td>
<td>0.00011</td>
</tr>
</tbody>
</table>

**Predictive Bayesian Assessment**

Based on the above data and prior information, predictive Bayesian distributions of the numbers of musculoskeletal and dermal injuries occurring per year to MSW workers in Florida were obtained using Equations 2.1 and 2.2. Results are shown in Figures 2.25 through 2.27. As discussed in Section 2.1, incident numbers are generally distributed Poisson, assuming that the incidents are infrequent enough that no two can occur simultaneously. However, injuries to Florida collectors over the course of a year are many, and may be considered to occur simultaneously. Results shown in the figures bear out this suspicion, as probability distributions for incident numbers based on the Poisson assumption are unrealistically narrow. Results labeled “normal PDF” are considered to accurately reflect variability and uncertainty in annual injury numbers in Florida.
Figure 2.25. Probability distributions for the actual annual average number of dermal injuries to Florida MSW (SICs 4953/4212) workers. While the Poisson results are shown for comparison, they are not considered valid for the high injury rates analyzed. Results labeled “Normal PDF” are considered to indicate actual risks, including those arising from information limitations and those inherent to MSW collection.
Figure 2.26. Probability distributions for the actual annual average number of musculoskeletal injuries to Florida MSW (SICs 4953/4212) workers. While the Poisson results are shown for comparison, they are not considered valid for the high injury rates analyzed. Results labeled “Normal PDF” are considered to indicate actual risks, including those arising from information limitations and those inherent to MSW collection.
Figure 2.27. Probability distributions for the actual annual average total number of dermal and musculoskeletal injuries to Florida MSW (SICs 4953/4212) workers.
All probabilities calculated reflect variability in the numbers of injuries occurring annually, as well as uncertainty due to the lack of information on injuries not compensated through Workers’ Compensation. The expected number of musculoskeletal injuries to MSW workers in Florida in 1996 and 1997 was assessed at 2420 annually, or 40 musculoskeletal injuries per 100 workers per year. The expected number of dermal injuries to MSW workers in Florida was assessed at 729 annually, or 12 per 100 workers per year. Total mean musculoskeletal and dermal injuries were assessed at 3400 annually, or 57 injuries per 100 workers per year. Although some workers may be injured more than once during a year, this finding presumably means that almost half of MSW workers can expect to sustain an injury not treatable with first aid in an average year in Florida. Each year there is a 5% probability that there will be more than 66 musculoskeletal injuries, more than 21 dermal injuries, and/or more than 90 total musculoskeletal and dermal injuries, per 100 MSW workers in Florida during the year. The means and 5% exceedance probabilities are listed in Table 2.18.

Table 2.18: Mean and 5% Exceedance

<table>
<thead>
<tr>
<th></th>
<th>Dermal Mean</th>
<th>Dermal 5% exceedance</th>
<th>Musculoskeletal Mean</th>
<th>Musculoskeletal 5% exceedance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poisson</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>728.5</td>
<td>1242</td>
<td>2417</td>
<td>2516</td>
</tr>
<tr>
<td>Normal</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>729</td>
<td>1242</td>
<td>2418.5</td>
<td>3951</td>
</tr>
</tbody>
</table>

On the basis of the literature search, three principal categories of health risk to MSW workers were identified: respiratory, dermal, and musculoskeletal injuries and diseases (Poulsen, 1995a). The respiratory category included many chronic conditions such as coughing and wheezing that can generally be described as illnesses. Because chronic illness and disease do not appear in reported data to any significant extent, respiratory conditions were not quantifiable even by Bayesian techniques. Dermal and musculoskeletal were more typically reported. Therefore, these categories were assessed. Because no indication of the severity of such injuries was found in literature studies, risks were assessed only in terms of the numbers of such injuries on an annual basis.

It should be noted that the data obtained for this study were not collected for this study, but for purposes of legal and medical compensation. In particular, workers were categorized in the data according to the SIC code best representing the employer’s principal business activity. Individual workers may or may not be engaged in this particular activity. Moreover, SIC codes may be assigned separately to each company owned by a larger corporation, or may be assigned consistently for such a corporation at a national or regional level. Therefore, results are reported in this document according to SIC code rather than by the implied business activity of the worker. For example, a worker at a recycling facility operated by an employer engaged primarily (at either the corporate or company level) in refuse disposal and reporting to OSHA as such would be referenced by SIC 4953 (Refuse Systems).
No estimates of actual incidence rates are available at the national level for comparison. However, such numbers of injuries are extremely high, indicating a high level of chronic morbidity. If more were known about the actual risks, for example if data were collected on actual incidence rates, the assessed risks would be expected to be somewhat lower. However, assessed risks could, with less likelihood, be even higher.

Only musculoskeletal and dermal injuries were estimated here. Occupational illnesses, such as respiratory ailments and skin conditions, could not be estimated. Because of data limitations, no effort was made to estimate the total loss caused by musculoskeletal and dermal injuries. In addition to Workers’ Compensation cost, many indirect losses are sustained. Employers may incur additional hiring and training costs, disruption of work processes, and reduced coworker productivity under perceived risk. Workers and their families may experience reduced income, depletion of savings, expenditures for counseling, caregiving, and retraining, costs for home modifications and equipment related to disability, and loss of education for family members. The community may also incur expenses, such as for increased use of social services. Non-economic losses may include changes in family and community roles, and loss of self-esteem of disabled workers.

2.5.6. Occupational Disease Risks in MSW Workers

Although occupational disease in MSW workers was not reported in the data obtained, such occupational health effects are considered to be significantly underreported based on literature surveys of worker-reported symptoms. Poulsen, et al. (1995) report a relative risk of 1.5 for occupational disease in Danish workers in the waste collection industry compared with the total work force. In particular, gastrointestinal disease was 2.0 times more prevalent, infectious disease was 6.0 times more prevalent, and allergic respiratory disease was 2.6 times more prevalent. The same study found a relative risk for occupational accidents of 5.6 for such workers, in agreement with results of this study for Florida workers. The Danish Registration of Occupational Accidents and Diseases shows 0.83 cases of occupational diseases per 100 workers reported per year. A survey by Hansen and coworkers (1997) indicated high rates of disease among MSW workers relative to the general workforce. In the study, respiratory symptoms among 1515 male Danish waste collectors were studied. Prevalence rates were found to be 27.8% for cough, 14.6% for phlegm, 23.2% for wheeze, 12.7% for wheeze and breathlessness, 11.5% for itching nose, 8.7% for asthma, 7.8% for chronic bronchitis, and 3.9% for chest tightness. In comparison with the control group of park workers, significantly increased prevalence proportional ratios (PPR) were found for cough (PPR=1.3), itching nose (1.9), and wheeze (1.4), and chronic bronchitis (2.3). Gastrointestinal problems have also been found prevalent among waste collectors. Ivens and coworkers (1997) found that 210 out of 1337 waste collectors reported having diarrhea several times per month or more. They found that high exposure to fungal spores, as may be found in MSW, corresponded with a high incidence of diarrhea. Higher prevalence of respiratory disorders and atopy were also reported among recycling and composting workers (Sigsgaard et al, 1994). Several studies have found a correspondence between respiratory and gastrointestinal disease in
MSW workers with exposure to dust or microorganisms, especially Gram-negative bacteria (Lundholm et al., 1980) and fungal spores (Ivens 1997; Sigsgaard, 1994).

Given their exposure to bacteria, fungi, volatile organics, and other airborne contaminants, it is reasonable to suspect high rates of occupational disease in refuse workers. Some of the microorganisms emitted from residential and commercial MSW may be infectious. Table 2.19 lists microorganism counts compiled from primary literature sources by Pahren (1987) in various solid wastes. Overall, results indicate similar numbers of organisms in MSW, medical waste, and sewage sludge.

Table 2.19. Microorganism counts in solid waste (microorganism/gram of waste)

<table>
<thead>
<tr>
<th></th>
<th>Sewage sludge</th>
<th>Medical waste</th>
<th>MSW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total coliforms</td>
<td>2.8×10⁹</td>
<td>9.0×10⁸</td>
<td>7.7×10⁸</td>
</tr>
<tr>
<td>Fecal coliforms</td>
<td>2.4×10⁸</td>
<td>9.0×10⁸</td>
<td>4.7×10⁸</td>
</tr>
<tr>
<td>Fecal streptococci</td>
<td>3.3×10⁷</td>
<td>8.6×10⁸</td>
<td>2.5×10⁹</td>
</tr>
<tr>
<td>Total plate count</td>
<td>1.7×10⁸</td>
<td>3.8×10⁸</td>
<td>4.3×10⁹</td>
</tr>
</tbody>
</table>

Because of the correspondence found by the Investigators between Florida data on injury rates, and data reported in Denmark, it is considered that occupational disease rates in Florida MSW workers may be elevated as has been found there. However, insufficient information is currently available to conduct an assessment, even by modern methods of information-limited risk assessment. Further study is needed.

2.6. CONCLUSIONS AND RECOMMENDATIONS

The risk assessment conducted to date, based on Florida Workers Compensation data and the comprehensive literature review conducted during the first year of the project, indicates that MSW workers suffer high rates of musculoskeletal and dermal injuries, and may experience a high rate of respiratory illness and disease. Results were the first known to the authors to reveal the very high occupational health and safety risks to MSW collectors in the U.S.

General conclusions regarding mortality and injury rates include:

a) The mortality rate for Florida MSW collectors was estimated at 90 fatalities per 100,000 workers, from 1993 to 1997. Nationally, only two occupations have higher estimated fatality rates. Collector deaths are often vehicle-related;

b) The expected number of musculoskeletal and dermal injuries to collectors was assessed at 3400 annually, or 57 injuries per 100 (±30) collectors per year, accounting for variability and uncertainty using advanced predictive Bayesian techniques. A 5% believed probability of more than 90 musculoskeletal or dermal injuries occurring per 100 (±30) MSW collectors per year was assessed. No such estimates of actual injury numbers are available for other occupations for comparison. However, these numbers are an order of magnitude higher than the
numbers of WC cases of greater than seven calendar lost work days, and indicate a very high level of chronic morbidity in Florida MSW collectors; and

c) Concerns regarding liability within the solid waste industry were found to be a major obstacle to the flow of information regarding accident prevention.

General conclusions regarding rates and costs of Workers’ Compensation cases of greater than seven calendar lost work days (>7 LWD) include:

a) From 1993 to 1997, the annual rate of Workers’ Compensation cases (>7 LWD) per 100 workers in Florida increased significantly, while the rate for the general Florida workforce has fallen;

b) Workers’ Compensation (>7 LWD) costs for MSW workers in Florida averaged $12.6 million per year, constant 1998 dollars, and had a 5% probability of exceeding $47 million in any year; and

c) True costs of occupational injury and disease in MSW workers entails many costs not paid by Workers Compensation, borne by employers, workers and their families, and by communities, including lost salary if fewer than seven calendar days of work are missed, costs of mortality in excess of approximately $100,000, indirect costs, and non-economic costs;

Conclusions regarding WC cases (>7 LWD) under SIC 4953/4212 included:

a) Drivers/helpers were injured most frequently per capita of all MSW occupational groups, suffering an average of 9.8 ± 3 Workers’ Compensation cases (>7 LWD) per 100 workers annually, 7.4 times higher than the rate for the general workforce in Florida;

b) Strains and sprains to the lower back, particularly by lifting, were the most frequently reported injury for all occupational groups;

c) Other frequent injuries among drivers and helpers included lacerations, particularly of fingers and often by glass, fractures, particularly in the foot, and contusions, particularly to the knee; and

d) Relative to the general workforce, vehicular injuries were proportionally higher among SIC 4953/4212 workers as a group.

Conclusions regarding WC cases (>7 LWD) under SIC 5093 (recycling industry) included:

a) Strains and sprains to the lower back, particularly by lifting, were the most frequently reported injuries;

b) Other frequent injuries to recycling industry workers included contusions and fractures, both often by being struck by a falling or flying object, and lacerations, all in varied body locations; and

c) Relative to the general workforce, SIC 4953/4212 workers reported higher proportions of burns, injuries resulting from being caught in or between objects or
equipment, injuries resulting from being cut, punctured, or scraped, and injuries resulting from being struck by objects and equipment.

Initial findings regarding reasons for occupational injury and disease in MSW workers include:

a) High rates of musculoskeletal and dermal cases in MSW workers appear related to (i) heavy and continuous lifting by drivers and helpers on collection routes, causing back strains and sprains, (ii) moving equipment parts, causing contusions and fractures, (iii) the presence of sharp material in MSW causing lacerations of fingers and other body parts, (iv) exposure to infectious aerosol contaminants in MSW causing occupational illnesses and infectious disease, and (v) the potential for vehicular injuries to collectors collecting both sides of the street around large collection vehicles and passing motorists, both having limited visibility; and

b) Although occupational disease was not reported significantly in data obtained for this study, a study of reported illness in Danish workers indicated a 50% higher prevalence of occupational disease in MSW workers relative to the general Danish workforce. In particular, gastrointestinal disease was 2.0 times more prevalent, infectious disease was 6.0 times more prevalent, and allergic respiratory disease was 2.6 times more prevalent in reported data for MSW workers. Reported Danish MSW worker injury rates corresponded well with results of the assessment of Florida data, indicating that Florida workers may experience similarly high occupational illness rates. Data reported elsewhere indicates that MSW may have an infectivity similar to medical waste and sewage sludge.

Several recommendations were made on the basis of the statistical and risk analyses presented in this chapter. Results were the basis for county-level analysis of WC data presented in Chapter 3. Results also provided partial basis for development of questionnaires used to survey collectors and supervisors, as described in Chapter 3. The Predictive Bayesian methods presented allowed rigorous use of professional judgment, to support decisions reflecting the full range of possible confidence levels in subjective information. It is recommended that a similar approach be used to assess economic losses associated with collector injuries, mortality, and illness, as a compliment to the results presented to motivate injury prevention efforts. Also, further study of the reasons for high rates of fractures to the foot in collectors appears warranted, as such injuries are relatively frequent and serious. It is recommended that occupational illness in MSW workers be studied. Further, the public should be made aware of the dangers of waste collecting, particularly regarding proper passing of collection vehicles by motorists, and proper waste disposal. Finally, it is recommended that legislation to motivate open disclosure of information on health, safety, and environmental risks of conducting business be enacted.

2.7. REFERENCES


3. DEVELOPMENT OF HEALTH AND SAFETY RECOMMENDATIONS FOR MUNICIPAL SOLID WASTE COLLECTORS

James D. Englehardt
Lora E. Fleming
Judy A. Bean
Huren An
Nicolette John
Jeff Rogers

Although the quantitative risk assessment results of the type presented in Chapter 2 for Florida are not currently available for other national or international populations, risks relative to the general workforce are considered quite high. To develop recommendations for reducing injuries and deaths, as a basis of an educational outreach program, three additional studies were conducted. First, a county-level analysis of Workers’ Compensation data was conducted to identify factors causing apparently high claim rates in Miami-Dade County. Second, a survey was conducted of MSW collectors, safety officers, and supervisory personnel to solicit their ideas concerning approaches to reducing injuries and death. Finally, a categorical logistic analysis of all Workers’ Compensation was conducted to identify various high-risk populations. An objective of the three tasks was identify influential factors related to high injury rates, including:

1. Worker literacy and native language, and associated difficulty of communicating risks to workers,
2. Use of temporary workers for waste collection, and level of training provided by temporary agencies,
3. Enforcement of safety regulations and procedures by agencies and employers,
4. Total volume of waste collected,
5. Building density
6. Population density,
7. Public vs. private operation,
8. Vehicle age,
9. Street width,
10. Mechanization
11. Race/ethnic differences and associated environmental justice issues,
12. Training,
13. Experience,
14. Age, and
15. Gender

In addition to the tasks described in the chapter, several public and private waste collection agencies, and a trade organization, were contacted to collect written materials developed as part of existing safety programs. However, no such information was released by any agency, perhaps due to fear of associated liability.
3.1. METHODS

Methods used for the county-level WC data analysis, survey of workers and supervisors, and logistic analysis, are described in this section.

3.1.1. County-Level Analysis of Workers' Compensation Data

The nature, specific causes, and contributory factors, of injuries in Miami-Dade and Broward Counties were compared to those reported for and the State at large, through further study of the WC data. Data used in this analysis were the same as described in Section 2.1.2 (as described in Chapter 2, these data represent claims for which greater than seven calendar days of work were lost). Claims reported for Miami-Dade and Broward Counties were sorted, and private and public facilities were identified manually by organization name. In addition, entries for which data on injury type, body location, cause and occupational codes were miscoded as “other” or “miscellaneous”, were re-coded as to specific category manually, using descriptions of the incidents given in the data set. Injuries were then characterized in terms of:

1. Accident type,
2. Zip code
3. Injury nature,
4. Public vs. private operations,
5. Body location,
6. Cause,
7. Job title,
8. Year,
9. Season, and
10. Day of week.

Characteristics of major injuries (e.g., cause, body location) for Miami-Dade and Broward Counties were compared graphically with those for the state of Florida. Broward County was selected as control because of geographic similarity and accessibility to researchers. Data characteristics and irregularities were investigated. Potential reporting biases were sought, due to such factors as the relative incentive to report an injury in public operations versus private.

Attempts were made to find an accurate denominator on which to base injury rates, to improve upon the use of total tons of waste collected by county (as presented in Chapter 2). The Florida Department of Labor and Employment Security, Bureau of Labor Market and Performance Information, and the American Federation of State, County, and Municipal Employees, Council 79, Local 3292, Solid Waste, AFL-CIO, Miami, FL, were contacted. However, no reliable information on the total number of workers in Miami-Dade and Broward Counties was located. Hence, an injury rate per worker was not possible to calculate. Data on total MSW tonnage collected in Miami-Dade and Broward Counties and the State of Florida were obtained from the Florida
Department of Environmental Protection (FDEP) Bureau of Solid and Hazardous Waste. However, total waste tonnage by county could not be broken down according to private and public sectors, due to limitations in the data sources used by FDEP. Total amounts for the period 1993-1997 are shown in Table 3.1.

Table 3.1. The Average Waste Collected Per Year in State of Florida, Miami-Dade, and Broward Counties

<table>
<thead>
<tr>
<th>State/County</th>
<th>Waste Collected Per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Florida</td>
<td>23.4 million tons</td>
</tr>
<tr>
<td>Miami-Dade</td>
<td>3.5 million tons</td>
</tr>
<tr>
<td>Broward</td>
<td>2.2 million tons</td>
</tr>
</tbody>
</table>

The SPSS® version 9 statistical software package was used to analyze Workers’ Compensation data for the years 1993-1997. Microsoft Excel® 2000 was used to generate charts showing the distribution of the reported cases by the designed characteristics. Comparisons of total injury frequency among regions and among injury types among regions were done in terms of injury frequency per million tons of waste collected. Other comparisons were made in terms of the percentage of the total number of cases. Neither the actual tonnage, nor the number of workers per agency type (public or private), year, month, day, occupation or zip code, could be estimated.

One-Way Analysis of Variance was used to compare the means of the number of claims for the five years (1993-1997) of data used. For each analysis, the null hypothesis tested was that all the population means were equal. The results provided a $p$-value which indicated whether or not to reject the null hypothesis at the chosen 95% significance level. The $p$-values are presented along with the results for each analysis in the following section.

3.1.2. Survey of Collectors and Supervisors

To gather data about the safety practices, injuries, and the working environment, two brief survey forms were designed to be administered to solid waste collectors, safety officers, and supervisory personnel. Survey forms were developed by the Investigators with input from both the study Technical Advisory Group and representatives of the solid waste injury. No personal identifying information was collected. The results of the survey were entered into a database and analyzed by Microsoft Excel. Permission to interview solid waste workers was obtained from the participating public and private solid waste companies located in Miami-Dade County, Florida. This study was approved by the University of Miami Human Subjects Committee.

The survey was administered anonymously to 251 solid waste collectors, and 4 supervisory personnel in public and private companies located in Miami-Dade County, Florida. The survey was administered by trained engineering students from the University of Miami in both English and Spanish. The participants were chosen randomly by the students at the work sites. The survey for the collectors consisted of 17 questions.
Thirteen of the questions were multiple choice with the option of choosing “other” and providing an original response. The last four questions consisted of open-ended questions to help develop ideas for changes and improvements in industry work practices. The survey for the safety personnel consisted of 39 questions including 14 for company profiles and 25 for health and safety issues. The questionnaires were designed based on the result of the analysis results of Workers' Compensation data, literature, and consultation of TAG members and other experts. We tried to design direct, easy-understand surveys.

Every effort was made to get true answers from the collectors. The survey was kept extremely anonymous, by removing all questions that could possibly lead to identification of the collectors. Blank survey forms were not released. The collectors were not made aware of the study prior to its administration. An explanatory letter signed by the P.I. was read and given to the collectors before survey started. Each collector was told that the information would be collected anonymously, without identifying worker or workplace, that participation was voluntary, and that there would be no negative consequences related to employment if the worker decided not to participate the survey. The purpose of the survey was also briefed to the collectors to be surveyed.

3.1.3. Categorical Logistic Analysis

Workers' Compensation data described in Chapter 2 were analyzed using logistic regression analysis to determine the variables with the highest risk of occurrence. Logistic regression is generally used to model the probability (risk) that an individual will acquire an illness or injury during some specified time period during which he/she is exposed to a condition (risk factor) known to be or suspected of being associated with that illness or injury (Rimm et al., 1980). The objective of the logistic regression analysis presented here was to determine the variables most closely associated with particular injury types, when compared with a selected reference group. Predictive Variable Groups selected for analysis included:

a. Body Location,
b. Age,
c. Occupation, and
d. Cause of injury.

Injury types studied included:

1. Diseases,
2. Sprains and Strains,
3. Minor Injuries, and

These injury types were the Outcome Variables in the logistic regression model used.
For each analysis, a hypothesis was made and tested for significance. Based on the hypotheses, appropriate reference groups were chosen, and a comparison between the reference group and the other variables in its group were made, using the calculated Odds Ratio. The Odds Ratio is a ratio of the odds of exposure among the cases to that of the control or reference group (Hennekens and Buring, 1987).

WC data were provided by the Florida Department of Labor and Employment Security, Division of Workers’ Compensation, as described in detail in Chapter 2. The data used in this analysis included WC claims reported under standard industrial codes (SICs) 4953 and 4212 (collectors only). SIC 4953 represented employees of firms engaged primarily in operations of refuse systems, and may have included small numbers of hazardous waste workers and recycling workers. SIC 4212 data was sorted to include only workers reported as refuse Collectors for local trucking without storage. The database included only claims for which more than seven calendar days of work were lost. Data were collected for the years 1993 through 1997. Data fields included injury type, injured body location, cause of injury, disability type, worker’s occupation, age, gender, accident date, employer name and zip code. The WC data provided, included several entries for which the data on injury type, body location, cause and occupational codes were miscoded as “other” or “miscellaneous”, when they should have been coded into one of the named categories. Using the text description of the incident provided in the data set, these entries were recoded accordingly.

For the logistic regression modeling it was necessary to condense the large number of injury types, body locations, ages, occupations and causes of injuries found in the WC database into a small number of individual groups. The variable groups selected are outlined in Table 3.2.
Table 3.2. Variable Groups for Logistic Analysis

<table>
<thead>
<tr>
<th>Type of Injury (Outcome Variables)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Diseases: Occupational Disease, Infection, MI, Hernia, Heat</td>
</tr>
<tr>
<td>2. Sprain/Strain: Sprains and Strains</td>
</tr>
<tr>
<td>3. Minor Injuries: Fracture, Dislocation, Laceration, Puncture, Contusion, Crush</td>
</tr>
<tr>
<td>4. Major Injuries: Amputation, Other Leading Injuries, Multiple Injuries, Hearing Loss, Vision Loss, Concussion, Burn, Electric Shock</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Body Location (Predictive Variable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Head &amp; Neck: Head, Neck</td>
</tr>
<tr>
<td>2. Back: Back, Trunk</td>
</tr>
<tr>
<td>3. Extremities: Upper and Lower Extremities</td>
</tr>
<tr>
<td>4. Multiple Body Parts</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Age (Predictive Variable, The range of ages of the workers was equally trisected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Young: Less 30 years</td>
</tr>
<tr>
<td>2. Middle: 30 – 40 years</td>
</tr>
<tr>
<td>3. Old: More than 41 years</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Occupation (Predictive Variable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Collectors: Driver, Collector, Labor/Temporary Worker</td>
</tr>
<tr>
<td>2. Administrators: Administrators</td>
</tr>
<tr>
<td>3. Skilled Workers: Mechanics, Equipment Operator, Welder</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cause of Injury (Predictive Variable)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lift: Sprain or Strain</td>
</tr>
<tr>
<td>2. External Causes: Motor Vehicle, Struck or Injured By, Rubbed or Abraded By, Caught in or between, Burn/Scald (heat/cold exposure)</td>
</tr>
<tr>
<td>3. Accidental: Cut, Puncture, Scrape, Striking Against/Stepping On, Fall or Slip Injury</td>
</tr>
</tbody>
</table>

The SPSS® version 9 statistical software package was used to generate the cross-tabulation graphs for the WC data. These graphs showed the sample size for each variable within each injury type. The SAS® version 6.12 statistical software package was then used to analyze Worker’s Compensation data for the years 1993-1997. Variables such as injury type, injured body location, worker age, worker occupation and cause of injury were used as the database for the SAS® statistical program. Microsoft Word® 2000 was used to generate the output tables showing the variables and their associated Odds Ratios and Confidence Intervals.

In the logistic regression model developed, the outcome variable (Y) was dichotomous. A successful event was given a value of 1, and a failure or non-successful event was given a value of 2. In this study, the four outcome variables were modeled individually. These outcome variables represented the different types of incidents recorded in the WC data set used. For these models, a successful event referred to an event in which the outcome variable was equal to the injury type being tested. Similarly, predictive variables (x_i) were dichotomous. A successful event was given a value of 1, and a non-successful event was given a value of 0. The predictive variables represented...
various body types, age groups, occupations and causes of injuries. Each of these four groups was modeled individually.

The expected value or mean of the outcome variable, \( Y \), is the probability that \( Y = 1 \). If \( p \) denotes the probability that the dependent variable, \( Y \), is equal to its expected value of 1, then the logistic regression model is given as:

\[
\ln \left( \frac{p}{1-p} \right) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_i x_i 
\]

(3.1)

where \( \alpha, \beta \) = sample regression coefficients, and \( x_i \) = predictive variable \ (Rimm et al., 1980)

The following is an example of a model used in this study:

\[
Y = \alpha + \beta_1 x_1 + \beta_2 x_2 
\]

(3.2)

Table 3.3 Logistic Model Example. Outcome Variable: Sprain and Strain (\( Y = 1 \))

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Y</th>
<th>Age</th>
<th>( x_1 )</th>
<th>( x_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disease</td>
<td>2</td>
<td>Young</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Sprain and Strain</td>
<td>1</td>
<td>Middle</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Minor Injuries</td>
<td>2</td>
<td>Old (Reference)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Major Injuries</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The output of the model displays the values of Sample Regression Coefficient, the Standard Error and the Odds Ratio. The Odds Ratio is a comparison of the value of the predictive variable being tested, to the chosen reference group. The 95% Upper and Lower Confidence intervals (CL) for the Odds Ratio were calculated using the regression coefficient and the standard error, in the following equation:

\[
CL = \exp \left[ \text{parameter estimate} \pm Z_{0.05} \times \text{(standard error)} \right] 
\]

\[
= \exp \left[ \text{parameter estimate} \pm (1.96) \times \text{(standard error)} \right]
\]

The 95% confidence interval represents the interval for which there is a 95% chance that the population Odds Ratio falls within.

3.1.4. Development of Health and Safety Recommendations

Recommendations presented in this chapter for reducing injury and death were developed in the course of several research meetings among investigators, and one final meeting for the purpose of collecting, refining, and integrating all ideas. Notes from meetings held with student surveyors immediately after each of the four surveys were reviewed for inclusion as appropriate. A draft of output from the final meeting underwent review and editing by all team members. Final recommendations were reviewed and refined by TAG members representing Broward County, the Florida Division of Safety, Miami-Dade County, Brown and Caldwell, Onyx/Montenay Power Corp., and the University of Miami.
3.2 WORKERS' COMPENSATION CLAIM'S CHARACTERISTICS OF DADE COUNTY, BROWARD COUNTY, AND STATE OF FLORIDA.

Results of the statistical analysis of Florida's Workers' Compensation (WC) data for MSW workers for the period 1993-1997, are presented in the following sections. This analysis builds on the statistical analysis presented in Chapter 2, with the addition of a comparison by geographic location. The geographic locations chosen for further study are Miami-Dade and Broward Counties. The distributions of key elements in these two counties were compared to each other and to the distribution for the State of Florida, as a whole.

Analysis of the Workers' Compensation (WC) claims for 1993-1997 in Miami-Dade, Broward, and the state of Florida, per million tons of MSW collected, is shown in Figure 3.1. As shown, Miami-Dade County had a significantly different (p=0.009) claims rate approximately twice that of both Broward County and the State of Florida, independent of the amount of waste collected. As mentioned in Chapter 2, this finding may be attributed to the practice by the predominantly public collection operations in Miami-Dade County of compensating all injuries requiring any medical attention through the Workers’ Compensation mechanism. Private agencies may compensate more injuries through other mechanisms. For example, non-union employers have greater flexibility in assigning workers to various positions, allowing greater use of restricted work activity days and thus reducing the number of injuries required to be reported as Workers' Compensation claims. The use of automated collection methods during 1996 and 1997, which could also affect relative injury rates among counties, was not studied. Analysis of the summary SAF 200 data provided by the public collection agency in Miami-Dade County, and information provided on worker populations for the relevant years and job categories, indicated that SAF 200 injury rates per man-day were consistent with those of the private agency in another county for which data was made available. Uncertainties in actual numbers of collectors, including permanent and temporary garbage and trash collectors and associated drivers, obscured this analysis, as for other parts of the overall study. Here, as in the overall study, no distinction was made between collectors of garbage, and trash. Locally, trash refers to cardboard, small appliances and other metal, rubber, tires, plastic and small furniture items placed at the curb and collected by means of clamshell equipment with manual assistance from collectors.
Figure 3.1 WC cases by geographic location, per million tons MSW collected.
3.2.1. Injury Type

Analysis of the relative frequencies of injuries of different types in Miami-Dade, Broward, and the State, are shown in Figure 3.2. The highest frequency of injury per million tons of waste collected was seen for sprains/strains (Code 49 & 52), followed by lacerations (Code 40), contusions (Code 10) and fractures (Code 28). An analysis of these injuries for Miami-Dade County revealed that Sprains and Strains (p<0.0001) were significantly higher than the other aforementioned major injury types. More interesting is that, although injury frequencies were higher in Miami-Dade County for all four major types, there were relatively even higher numbers of lacerations and contusions, in comparison with fractures and strains/sprains. This observation is consistent with the belief that minor injuries are more frequently reported to Workers’ Compensation by public agencies in Miami-Dade County than by agencies statewide.
Figure 3.2 Type of injury, per million tons MSW collected, by geographic region.
3.2.2. Agency Sector

In Figure 3.3, the percentages of cases attributed to public and to private agencies are shown. The name of the employer was used to divide the cases into the two classifications of companies. It was found that a significantly greater number of cases were reported for public versus private companies in Dade County (p=0.0005). The reverse trend was seen in Broward County (p=0.0084), where the majority of cases were reported for private firms. Relative percentages reflect the significantly higher percentage of publicly-operated collection operations in Miami-Dade County relative to Broward County.
Figure 3.3  Workers’ Compensation cases, by agency sector and geographic region.
3.2.3. Body Location

Body Locations of Injuries, by geographic region are shown in Figure 3.4. The Low Back Area (Code 42) showed the highest percentage of total injuries for all three geographic regions investigated. Other locations such as the Knee (Code 53), Fingers (Code 36), Upper Arm (Code 31) and Lower Leg (Code 54) also showed relatively high percentages of occurrence. An analysis of claims in Dade County revealed that the Low Back Area (p<0.0001) was significantly higher than the other high frequency body locations discussed. Results are based on manually recoded data, and are therefore somewhat more representative than those presented in Chapter 2. Differences among regions were not considered significant.
Figure 3.4 Body Locations of Injuries, by geographic region.
3.2.4. Cause of Injury

Cause of Injuries, by geographic region are shown in Figure 3.5. Strain from Lifting (56) was found to be the major cause attributed to the reported cases for all three geographic regions (p<0.0001). Other major causes of injury included Fall or Slip from Different Level (Code 25), Cut from Broken Glass (Code 15), Collision with Another Vehicle (Code 45), Struck by Motor Vehicle (Code 77) and Struck by Object being Lifted or Handled (Code 79).
Figure 3.5 Cause of Injuries, by geographic region.
3.2.5. Occupation

Injuries by Job Category and Geographic Region are shown in Figure 3.6. Driver/Helpers sustained approximately 83% of the total number of incidents in Miami-Dade County, 68% in Broward, and less than 73% in Florida. This high injury rate for the Driver/Helper group was partly due to their greater population. According to the previous year’s report, in Florida, approximately 40% of MSW workers are Drivers/Helpers. However, for all injury types, this occupational group is at a very high risk of injury compared to the other occupations (p<0.0001) and as such more emphasis should be placed on assessing the safety risks to these workers.
Figure 3.6. Injuries by job category and geographic region
3.2.6. Other Characteristics of Workers' Compensation Claims

(1) Yearly Trend

The data used in this study collectively summarized Workers’ Compensation claims for the period 1993 to 1997. Rates of claims per year were highest in 1996 for Miami-Dade and Broward Counties and the State (Appendix G.1).

(2) Season and Day

Figures G.2 and G.3 show the distribution of injuries by season and by day, respectively. There seemed to be no significant effect of seasonality. In all three study regions, the number of claims during the winter months (December, January, February) was the lowest.

The distribution of claims by day of the week (Appendix G.3) shows that there were considerably more claims on Monday and the least number of claims for the weekend, for Miami-Dade and Broward Counties, and the State. As discussed in Chapter 2, the highest load of waste is collected on Mondays and the least on Weekends, and this may explain the trend.

(3) Zip Codes

Analysis of cases by zip code for Miami-Dade and Broward Counties was initially performed in an attempt to pinpoint the locations of MSW sites in which high injury rates were occurring, so the site could be investigated for health and safety issues and causes. However, it was found that cases are often reported according to the zip code of risk management offices rather than collection vehicle bases. The distribution by zip codes for both counties can be found in Figures G.4 and G.5.

3.2.7. Some Characteristic of Most Frequently Reported Injuries

As reported in Chapter 2, and similarly to other industries, the most common injuries were found to be sprains and strains, lacerations, contusions, and fractures. Therefore, an analysis was conducted of body locations, causes, and agency sectors of such claims. As expected due to the distribution of public and private agencies, the majority of injuries of each type occurred in the public sector in Miami-Dade County, and vice versa for Broward. The exception was fractures in Miami-Dade County, which occurred more frequently in the private sector. This exception was not considered significant, as only 15 fracture cases were reported for the County. Rates per 100 workers could not be calculated, as discussed in Section 3.1.

(1) Sprain and Strain

Figure G.6 shows the percentage of total sprains and strains for Miami-Dade and Broward Counties, and the State of Florida. More than 40% of all sprains and strains
occurred in the Low Back Area for all three regions. The Knee was the location of about 10% of the sprains and strains in the State.

Figure G.7 shows that the major causes of sprains and strains were lifting, pushing or pulling, and fall or slips. The waste collector’s job involves repetitive motion, awkward working positions, forceful hand exertion, and frequent manual handling. Dim lighting in early morning hours, and rain, are inevitable. All such conditions potentially contribute to ergonomic problems. Studies are urgently needed to minimize this type of injury.

(2) Lacerations

As shown in Figure G.9, the greatest number of lacerations occurred in the Finger(s) (36) for all three regions. A significant number also occurred in the Lower Leg (54). These lacerations could be the result of improperly disposed waste and improper handling of waste by workers. The use of safety gloves is intended to reduce finger lacerations, and usually employers offer them. However, because the gloves quickly become soiled, employers often provide gloves that are part cloth, part leather, less protective than leather gloves. In addition, workers do not always wear the gloves, because of soiling, concern about rashes, and other reasons.

In Miami-Dade County, the main cause of lacerations was Cut from Broken Glass (15), as seen in Figure G.10. In Broward County and the State, the main cause was a Cut, Puncture or Scrape. Broward County also had a significant percentage of lacerations caused by being Caught in or Between. Proper disposal of sharps would reduce this injury.

(3) Contusion

Multiple Body Parts (90) was most frequently listed as the location of contusions for Miami-Dade County and the State. Figure G.12 shows that the Knee (53) was the most likely location in Broward, and was significant for Miami-Dade County and the State as well.

Figure G.13 shows that in Miami-Dade County, the main causes of contusions included Fall or Slip from a Different Level (25), Striking a Stationary Object (68) and Struck by a Falling or Flying Object (75). In Broward County, the most significant causes were Fall or Slip from a Different Level (25) and being Struck by a Falling or Flying Object. In the State the most prevalent cause was Striking a Stationary Object (68).

(4) Fracture

As indicated in Figure G.15, the most prevalent body locations for fractures in Miami-Dade County included Upper Arm (31), Lower Arm (33), and the Hand (35). In
Broward County the most frequent body location was the Finger(s). For the State of Florida, the overall most prevalent body location for fractures was the Foot.

In Miami-Dade and Broward Counties, the major cause of fractures was Being Caught in the Object Handled (12), as shown in Figure G.16. In Miami-Dade County, other significant causes included Being Caught in Machine or Machinery (10), Struck by Falling or Flying Object (75) and Struck by Motor Vehicle (75). In Broward County, there were several other significant causes. These included Fall, or Slip from Ladder or Scaffolding (26), Vehicle Upset (48), Striking Against or Stepping On (70) and Struck by Motor Vehicle (77).

3.2.8. Discussion

Several limitations of the preceding analysis of the Workers’ Compensation data provided by the State should be mentioned. The principal limitation was that the number of workers in the different geographical locations and in the private and public sectors could not be obtained. Obtaining valid worker population estimates for any given year was complicated by the complexity of the structure of responsibility for Miami-Dade County solid waste operations. According to Paul Moriello, Miami-Dade County Department of Solid Waste, current operations represent a combination of public, private, municipal, county, and subcontracted services. For example, the County collects in unincorporated areas, and many municipalities including Pinecrest, Sweetwater, Aventura, and Sunny Isles Beach. Private firms providing services to those and other municipalities include Waste Management, BFI, and Republic. Commercial waste collection is generally by private contract, with the County servicing approximately 2000 remaining commercial accounts. Miami and Hialeah operate collection fleets. Coral Gables operates a City fleet, while contracting residential pickup in some areas to Waste Management. The City of Miami operates public residential collection operations, and maintains franchise operations for commercial accounts. Miami Beach contracts residential pickup to a subsidiary of Montenay Power Corp. The Resource Recovery (incinerator) facility is owned by the County, and operated by Montenay Power Corp. Ash, garbage, and trash landfills are owned and operated by the County, along with three transfer facilities processing a few hundred thousand tons per year each. However, some County disposal is by private contract (e.g., with Medley Landfill, Waste Management, Inc.). In addition, 18 cities, and some private firms such as BFI, contract with Miami-Dade County for disposal.

Other limitations are related to the scope of the data and the possibility of reporting bias. The data used does not represent all incidents that have occurred in the time period, but rather, only those that are reported as Workers’ Compensation claims. As such, the data used in the analysis reflects reporting policies of the companies. Information on other factors, such as educational level and pay class, were not provided in the WC data. This information could be useful in explaining or predicting workers’ behavior and their response and understanding of safety training and procedures. Further, for analysis of individual injury types and agency sectors at the County level, numbers of
injuries over the five year period were not sufficient to obtain statistically significant comparisons.

Results indicated that Miami-Dade County had similar pattern of Workers’ Compensation claims as either Broward County or the state of Florida in major injury types, major causes of the injuries, body locations etc. It was found that Miami-Dade County reported significantly more injuries from public sectors. However, as mentioned, there were relatively even higher numbers of lacerations and contusions, in comparison with fractures and strains/sprains. This observation is consistent with the possibility, considered likely by the researchers, that minor injuries are more frequently reported to Workers’ Compensation by public agencies in Miami-Dade County than by agencies statewide.

3.2.9. Conclusions

Principal conclusions of the county-level analysis of WC data were as follows. First, results corroborated and “truthed” those presented in Chapter 2. Second, injury patterns in Miami-Dade County followed those found elsewhere in the State. No results were found indicating a higher rate of injury in Miami-Dade County. The main type of injury in all regions was sprain/strain. Other prevalent injuries included lacerations, contusions and fractures. These findings are consistent with major injury types in the general workforce. Ergonomics research is needed to reduce such injuries. The major body location of the injuries was the lower back area. Other areas included the knee, the upper extremities and the lower leg. These results suggest directions for improvements of personal protective equipment and other measures to protect these body parts. The main causes of injuries were strain from lifting, fall and slips, punctures, cuts and scrapes, and struck or being caught in objects and machinery. The observation that fractures often occur to the foot suggests that proper footwear is important.

3.3. HEALTH AND SAFETY SURVEY ANALYSIS

The survey forms shown in Appendix H were administered anonymously to 251 solid waste collectors, and 4 supervisory personnel in one public and one private agency, both located in Miami-Dade County, Florida. The capture rate (i.e., number of eligible participants who responded divided by the total number of eligible participants) and participation rate (i.e., number of eligible persons approached who participated divided by the total number of eligible persons approached) for each site are shown in Figure 1. There was an average capture rate of 92% and an average participation rate of 97.23%, as shown in Table 3.4. Note that the number of collectors approached is two more than the number available, for the first site visit. That is, 84 responses and 2 declinations were received, whereas the supervisor reported that a total of 84 collectors were present. The two apparently extra responses were attributed to either drivers or collectors participating more than once. Collectors conveyed the impression that they were aware of the risks they face, and were enthusiastic about participation in the survey. These surveys took place approximately one year following release of first year results to the media.
The collectors were classified as permanent, temporary, inexperienced (<2 years experience), and experienced (>2 years experience). In this study, 75.9% of the collectors were permanent employees, 24.1% were temporary employees, 82.0% were experienced, and 18% were inexperienced. Of the collectors, 242 were employed in the public sector, and 9 in the private sector.

Table 3.4. Participation and Capture Rates for the Collector Survey

<table>
<thead>
<tr>
<th></th>
<th>Site #1</th>
<th>Site #2</th>
<th>Site #3</th>
<th>Site #4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># respondent / # approached (%)</td>
<td># respondent / # approached (%)</td>
<td># respondent / # approached (%)</td>
<td># respondent / # approached (%)</td>
</tr>
<tr>
<td>Participation Rate</td>
<td>84 / 86 (97.7%)</td>
<td>60 / 65 (92.3%)</td>
<td>9 / 9 (100%)</td>
<td>92 / 93 (98.9%)</td>
</tr>
<tr>
<td>Capture Rate</td>
<td>84 / 82 (100%)</td>
<td>60 / 82 (73.2%)</td>
<td>9 / 9 (100%)</td>
<td>92 / 97 (94.8%)</td>
</tr>
</tbody>
</table>

3.3.1. Survey Results

Figure 3.7 shows the most frequent responses of the survey. Results are as follows:

- 97.1% of those surveyed reported that collectors usually follow safety procedures. Of the 2.9% collectors who indicated that collectors usually do not follow established safety procedures, the reasons given for not following safety procedures included: saving time (30.8%), discomfort (30.8%), not aware of risks (19.2%), and don’t care (19.2%);

- Saving time (44.9%) and discomfort (21.85%) were also two of the top responses to why collectors do not wear safety equipment;

- The notion that risk was an inherent part of the job was addressed in the survey: 15.9% of the workers surveyed believed that nothing could be done to prevent injuries and 53.8% stated that the nature of the work was a main reason for injuries and illnesses;

- Of the workers, 48.8% said there were no positive incentives for them to work safely;

- Collectors were reported what they thought were the main reasons for injuries and illnesses: Improper disposal of waste by residents (70%), Weather (43.8%), Lack of visibility around trucks (37.9%), and Carelessly passing motorists (55.8%);
The most frequently reported injuries by the collectors surveyed were: strain or sprain (44.7%), cut/wound (42.5%), serious bump or bruise (34.5%). Of note, only 25.2% reported no injury during the past 12 months;

The illnesses reported by the collectors within the last year included: rash or skin disease (46.1%), asthma, chronic coughing, breathing trouble, sinus congestion (29.4%), diarrhea, stomach trouble (22.5%), and allergies (22.1%). Of note, only 29.9% of the collectors reported no illnesses during the past year;

The collectors reported the following aspects of their job that were of greatest concern: Improper disposal by residents/ lack of knowledge about the compostition of the waste (45.5%), Carelessly passing motorist (40.3%), Riding on the back of the truck / getting hit by the truck (10.3%), and Lifting and back injuries (5.6%);

The collectors were asked to make recommendations to make their jobs safer and healthier. The most common recommendations were: Reducing the route size and workload (24.5%) and Educating citizens about proper disposal procedures (14.9%);

When specifically asked to suggested methods for injury prevention, the collectors recommended: Working cautiously and being careful (36.7%), Following procedures and safety guidelines (25.1%), and Taking their time finishing their collection route (10.1%); and

Finally, the collectors made the following specific suggestions to change the current solid waste collection system to increase the safety and health of the workers: Reduction of the route size/ workload (24.5%), Education of citizens (14.9%), Ensuring that proper uniforms and safety gear are distributed and worn by workers (13.0%), and Including more training, specialized training for lifting, and group training (9.6%).
### Figure 3.7. Top responses of collectors to health and safety survey questions

<table>
<thead>
<tr>
<th>Question 1</th>
<th>% answered</th>
<th>Question 2</th>
<th>% answered</th>
<th>Question 3</th>
<th>% answered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are you a permanent or temporary employee?</td>
<td>Permanent: 76.9</td>
<td>Do you have two or more years of experience as a waste collector?</td>
<td>Two or more: 92.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Temporary: 24.1</td>
<td>Less than two: 18.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Not answer: 0</td>
<td>No answer: 0.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question 4</td>
<td>% answered</td>
<td>Question 5</td>
<td>% answered</td>
<td>Question 6</td>
<td>% answered</td>
</tr>
<tr>
<td>(Do collectors usually follow established safety procedures?) If not, why not?</td>
<td>Out of 226 participants</td>
<td>What types of safety equipment are you required to wear?</td>
<td>Out of 245 participants</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>To save time: 39.8</td>
<td>Glasses: 94.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>To save money: 39.1</td>
<td>Boots: 94.3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Not aware of risks: 19.3</td>
<td>Back Support: 82.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Do not care: 19.2</td>
<td>Uniform: 74.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No answer: 66.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question 7</td>
<td>% answered</td>
<td>Question 8</td>
<td>% answered</td>
<td>Question 9</td>
<td>% answered</td>
</tr>
<tr>
<td>(How many workers usually wear the safety equipment during work?) If not, why not?</td>
<td>Out of 278 participants</td>
<td>Are there negative incentives for you to work safely?</td>
<td>Out of 269 participants</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>To save time: 44.3</td>
<td>Documentation and follow up: 44.5</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>To save money: 21.8</td>
<td>Forced disciplinary action: 37.8</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Do not care: 19.3</td>
<td>None: 12.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Not aware of risks: 11.6</td>
<td>Verbal warning: 4.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No answer: 66.2</td>
<td>No answer: 14.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question 10</td>
<td>% answered</td>
<td>Question 11</td>
<td>% answered</td>
<td>Question 12</td>
<td>% answered</td>
</tr>
<tr>
<td>What do you think are the main reasons for injuries and fatalities among collectors?</td>
<td>Out of 226 participants</td>
<td>Which of the following injuries have you experienced over the past 12 months?</td>
<td>Out of 226 participants</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Improper disposal of waste by residents: 70.6</td>
<td>Same or strain: 44.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Carelessness passing motorists: 56.8</td>
<td>Cut wound: 42.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nature of the work: 53.8</td>
<td>Serious bruise or bump: 34.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Weather: 43.8</td>
<td>None: 25.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lack of visibility around trucks: 37.5</td>
<td>Fracture: 12.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No answer: 20.0</td>
<td>No answer: 7.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question 13 (note, there was no question 12)</td>
<td>% answered</td>
<td>Question 14</td>
<td>% answered</td>
<td>Question 15</td>
<td>% answered</td>
</tr>
<tr>
<td>Which of the following illnesses have you experienced over the last 12 months?</td>
<td>Out of 231 participants</td>
<td>For how many workers do you think language is a significant barrier to following safety procedures?</td>
<td>Out of 226 participants</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rash or other skin disease: 48.1</td>
<td>None: 61.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Asthma, chronic coughing, breathing trouble, sinus congestion: 40.4</td>
<td>A few workers: 19.6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Diabetes, stomach trouble: 22.5</td>
<td>Some workers: 15.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Allergies: 22.1</td>
<td>Most workers: 8.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No answer: 19.7</td>
<td>No answer: 8.2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question 16</td>
<td>% answered</td>
<td>Question 17</td>
<td>% answered</td>
<td>Question 18</td>
<td>% answered</td>
</tr>
<tr>
<td>What do you think is the most dangerous part of your work? What worries you the most?</td>
<td>Out of 223 participants</td>
<td>What do you think collectors could do to prevent work injuries?</td>
<td>Out of 237 participants</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Handling waste / residue improper disposal / not knowing what is in waste: 45.5</td>
<td>Work cautiously / carefully: 36.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Carelessness passing motorists / hitting hit: 40.3</td>
<td>Follow procedures / safety guidelines: 25.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Riding on back of truck / falling off truck / hit by truck: 10.3</td>
<td>Nothing: 15.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lifting back injuries: 9.6</td>
<td>Take their time: 10.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No answer: 4.9</td>
<td>No answer: 15.5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question 19</td>
<td>% answered</td>
<td>Question 20</td>
<td>% answered</td>
<td></td>
<td></td>
</tr>
<tr>
<td>If you were in charge, what would you do to make collectors' jobs safer and healthier?</td>
<td>Out of 220 participants</td>
<td>real work / restroom / smoking / breaks / training / group meetings to discuss safety /</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>reduce truck size / reduced workload: 24.5</td>
<td>reduce employees / union safety</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>reduce pay / adjust work / break / training / more training / group meetings to discuss safety: 9.6</td>
<td>No answer: 15.1</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Figure 3.7.** Top responses of collectors to health and safety survey questions
A comparison of the frequency of each response was performed examining the 4 subpopulations of permanent/temporary/experienced/inexperienced workers, as shown in Figure 3.8:

- Temporary and inexperienced collectors responded at a higher frequency (10.5 % and 10.8 %) than the permanent and experienced employees (8.6% and 9.4%) in suggesting more training or different kinds of training if they were in charge;

- Permanent and experienced workers responded at a greater frequency than did temporary and inexperienced workers when asked about the injuries they had experienced in the past 12 months; and

- The response of permanent collectors was significantly higher (48.9 %) than temporary (29.1%) and inexperienced (31.0%) workers with regards to the improper disposal by residence and/or hazardous waste in the waste collected as the most dangerous part of their job.

3.3.2. Discussion of Survey Results

The generality of the results obtained from this survey of solid waste workers was affected by the level of cooperation of the solid waste industry. Only one public (of perhaps 40) and one private agency permitted the investigators to survey their employees; this may have affected the representativeness of the sample taken. Results may not be applicable to the rest of the State, for example, due to potentially greater prevalence of private collection operations. Also, this study was a cross sectional survey, gathering prevalence data at one point in time, and therefore solely hypothesis generating. Additionally, there is the Healthy Worker Effect bias (Fox 1976, Checkoway 1989, Monson 1990) inherent in occupational studies. That is, especially in cross sectional studies, the prevalence of disease and injury are inevitably underestimated in working populations. In order to work, especially at physically demanding jobs such as solid waste collection, the worker must be relatively healthy; if he or she has acquired a work related a severe injury or disease, then the worker leaves the workforce, leading to an underestimate of the prevalence of disease and injury in that workforce. Only long term epidemiologic studies ("cohort studies") that follow up workers over time, including those who leave the workforce due to disease or injury, would be able to evaluate the true incidence of disease and injury among solid waster workers.

In an attempt to receive unbiased answers from the collectors, the data were obtained anonymously. The results of injury and disease incidence rates for the prior year were obtained from the self-reported survey. There was no objective validation of these self-reported data. Therefore, these incidence rates could be subjected to either under or over-reporting. However, these rates are similar to those reported in other similar studies, including those with objective data collection, from the Danish solid waste worker studies.
This study showed that permanent and experienced collectors reported higher rates of injury and disease. Since time at work is a surrogate for time of occupational exposure, this result was to be expected. However, since temporary and inexperienced workers may not have worked for a complete year, comparing their responses concerning their reported injuries or illnesses during the past year to those of more experienced workers may not have been a completely appropriate comparison.

Temporary and inexperienced workers reported a greater need for more training than the more experienced and permanent workers. This could be due to the fact that the permanent and experienced workers feel that they do not need more training since they already know everything about their job. In addition, the inexperienced and temporary workers may have felt that the recent training was inadequate.
### Question 10
What do you think are the main reasons for injuries and fatalities among collectors?

<table>
<thead>
<tr>
<th>Response</th>
<th>Total responses</th>
<th>Permanent</th>
<th>Temporary</th>
<th>Inexperienced</th>
<th>Experienced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improper disposal of waste by residents</td>
<td>79.0</td>
<td>73.6</td>
<td>59.6</td>
<td>11.0</td>
<td>56.7</td>
</tr>
<tr>
<td>Carelessness passing motorists</td>
<td>55.8</td>
<td>59.2</td>
<td>44.8</td>
<td>9.0</td>
<td>46.7</td>
</tr>
<tr>
<td>Nature of the work</td>
<td>43.6</td>
<td>56.6</td>
<td>64.8</td>
<td>6.6</td>
<td>44.1</td>
</tr>
<tr>
<td>Weather</td>
<td>43.8</td>
<td>46.7</td>
<td>34.8</td>
<td>6.8</td>
<td>35.9</td>
</tr>
<tr>
<td>Lack of visibility around trucks</td>
<td>37.9</td>
<td>39.5</td>
<td>32.8</td>
<td>8.8</td>
<td>30.5</td>
</tr>
<tr>
<td>No answer</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Question 11
Which of the following injuries have you experienced over the past 12 months?

<table>
<thead>
<tr>
<th>Response</th>
<th>Total responses</th>
<th>Permanent</th>
<th>Temporary</th>
<th>Inexperienced</th>
<th>Experienced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strain or sprain</td>
<td>44.7</td>
<td>43.3</td>
<td>32.7</td>
<td>20.3</td>
<td>48.1</td>
</tr>
<tr>
<td>Cut wound</td>
<td>42.6</td>
<td>43.7</td>
<td>38.5</td>
<td>23.7</td>
<td>46.0</td>
</tr>
<tr>
<td>Fracture</td>
<td>35.6</td>
<td>37.4</td>
<td>22.9</td>
<td>25.7</td>
<td>38.0</td>
</tr>
<tr>
<td>Loose fit denim</td>
<td>26.2</td>
<td>21.8</td>
<td>16.5</td>
<td>44.7</td>
<td>21.2</td>
</tr>
<tr>
<td>No answer</td>
<td>7.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Question 13 (note, there was no question 12)
Which of the following illnesses have you experienced over the last 12 months?

<table>
<thead>
<tr>
<th>Response</th>
<th>Total responses</th>
<th>Permanent</th>
<th>Temporary</th>
<th>Inexperienced</th>
<th>Experienced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rash or other skin disease</td>
<td>46.1</td>
<td>49.0</td>
<td>30.0</td>
<td>40.5</td>
<td>32.2</td>
</tr>
<tr>
<td>None</td>
<td>29.0</td>
<td>25.2</td>
<td>34.0</td>
<td>48.2</td>
<td>18.4</td>
</tr>
<tr>
<td>Asthma, chronic coughing, breathing trouble</td>
<td>39.4</td>
<td>36.1</td>
<td>8.0</td>
<td>15.2</td>
<td>22.0</td>
</tr>
<tr>
<td>Corneal, stomach trouble</td>
<td>22.5</td>
<td>22.6</td>
<td>22.0</td>
<td>19.0</td>
<td>17.1</td>
</tr>
<tr>
<td>Allergies</td>
<td>22.1</td>
<td>24.5</td>
<td>16.0</td>
<td>19.8</td>
<td>16.7</td>
</tr>
<tr>
<td>No answer</td>
<td>16.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Question 16
What do you think is the most dangerous part of your work? What worries you the most?

<table>
<thead>
<tr>
<th>Response</th>
<th>Total responses</th>
<th>Permanent</th>
<th>Temporary</th>
<th>Inexperienced</th>
<th>Experienced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazardous waste / residue improper disposal</td>
<td>45.6</td>
<td>40.0</td>
<td>20.1</td>
<td>31.0</td>
<td>36.7</td>
</tr>
<tr>
<td>Speechlessness in reading, writing</td>
<td>40.3</td>
<td>40.4</td>
<td>40.0</td>
<td>35.7</td>
<td>32.2</td>
</tr>
<tr>
<td>Reading back of truck falling off truck hit by truck</td>
<td>10.3</td>
<td>7.3</td>
<td>20.0</td>
<td>19.0</td>
<td>6.5</td>
</tr>
<tr>
<td>Lifting / back injuries</td>
<td>5.6</td>
<td>6.7</td>
<td>1.8</td>
<td>2.4</td>
<td>4.9</td>
</tr>
<tr>
<td>No answer</td>
<td>4.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Question 19
If you were in charge, what would you do to make collectors' jobs safer and healthier?

<table>
<thead>
<tr>
<th>Response</th>
<th>Total responses</th>
<th>Permanent</th>
<th>Temporary</th>
<th>Inexperienced</th>
<th>Experienced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce route size / reduce workload</td>
<td>24.6</td>
<td>24.7</td>
<td>15.8</td>
<td>21.6</td>
<td>24.0</td>
</tr>
<tr>
<td>Rest and rest break</td>
<td>14.9</td>
<td>17.3</td>
<td>5.3</td>
<td>13.5</td>
<td>15.2</td>
</tr>
<tr>
<td>Properly wear uniforms / safety equipment / follow procedures</td>
<td>13.0</td>
<td>11.1</td>
<td>15.8</td>
<td>24.8</td>
<td>7.0</td>
</tr>
<tr>
<td>Lifting training / more training / group meeting to discuss safety</td>
<td>9.6</td>
<td>8.5</td>
<td>10.5</td>
<td>10.6</td>
<td>9.4</td>
</tr>
<tr>
<td>No answer</td>
<td>15.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3.8. Comparison between permanent and temporary, inexperienced and experienced collectors.
3.3.3. Surveys of Safety Officers and Supervisors

One safety officer and one collections supervisor were interviewed using the survey form for supervisors shown in Appendix H. Due to the small numbers of supervisors and the confidential nature of the surveys, results are presented only in terms of the conclusions drawn. First, collectors were reported to collect 1100-1200 houses, representing 7-18 tons a day. Residential routes usually employed three-man crews, including one driver. Union regulations sometimes prevent switching between driver and helper duties, as the senior workers typically hold driver positions and required driver's licenses. Safety meetings were reported to be held (by supervisors and workers), generally on-site before leaving the base. Frequency of meetings was reported variously from weekly to monthly, and involve discussion of current problems observed. Although agencies apparently have established safety procedures, supervisors and workers alike reported different requirements regarding what safety equipment was required and what safety equipment was available to workers at the same agency. Therefore, it was concluded that procedures should be written and widely circulated and reviewed. In contrast with responses by workers, supervisors reported that monetary rewards are provided as incentives for good safety records. Apparently awareness of such rewards was low among workers. It was observed that route supervisors often deferred answers to some questions to the appropriate safety officer, indicating that more accountability on the part of route supervisors was needed. However, safety officers and supervisors reported the same opinions regarding major injuries (strain/sprain, laceration, contusion, and fracture). Supervisors were similarly aware that skin disease was the most frequent illness. They considered weather, including cold, hot (related to fatigue), and slippery conditions, to be major causes of injuries.

3.3.4. Conclusions from the Survey

Solid waste collection continues to be an occupation that involves substantial risk to the safety and health of the workers. The solid waste industry is not easily accessible to independent research assessments. Nevertheless, as shown in various studies (Ivens et al., 1997a, 1998), improvements to the current system of waste collection are necessary to reduce the risk to workers’ health and safety. The workers of the solid waste industry who experience these threats to their health and safety are one source of important information to make these improvements. Conclusions of the survey were:

1. As expected based on Workers’ Compensation regulations, total numbers of injuries are much higher than numbers of WC claims. Survey results were consistent with the risk assessment results presented in Chapter 2, indicating a high level of chronic morbidity in collectors;

2. The survey results were consistent with the Workers’ Compensation data in terms of patterns of injuries, both indicating strain/sprain, contusion, laceration, and fracture as major injuries, and with the survey indicating higher proportions of lacerations and contusions (potentially less likely to lead to lost work days than back strains and fractures);
3. Working conditions were the first concern of collectors, who attributed injuries and illnesses to improper disposal of waste, inclement weather, and carelessly passing motorists; and

4. Occupational illness may be high among MSW collectors, considering results of Sigsgaard et al. (1997), Ivens et al. (1997), and Hansen et al. (1997), potential exposure to infection, and the rate of illness reported in the survey. Caution should be used in interpreting the results of the survey in this regard, however, as the survey was not designed as the basis for statistical analysis, and further research in this area is recommended.

Based on this survey, several general recommendations were developed. First, residential MSW collection methods should be evaluated with a focus on exposure of workers to ergonomic, health, and safety risks. Second, positive incentives to work safely should be established and promoted. Reflective safety vests should be redesigned, and the effect of gloves on the occurrence of rashes should be investigated. Communication between drivers, helpers, and supervisors should be increased, using team training techniques and through increased route visits and accountability on the part of supervisors. Finally, public education regarding safe passing of garbage trucks by automobiles, and proper disposal of wastes, is recommended.

3.4. CATEGORICAL LOGISTIC REGRESSION ANALYSIS

To identify high-risk groups and significant causes for particular injury types, hypotheses were generated and revised for testing using logistic regression analysis, as described in the following section.

3.4.1 Hypotheses and Reference Groups

Hypotheses were made for every variable within each group of injuries. These hypotheses were generated using physiological knowledge of the types of injuries. Appropriate reference groups were then chosen in order to show whether or not there was an increased risk of occurrence of the other variables within that group. In conducting the analysis of diseases, only the age and occupation variables were tested since there was no biological plausibility for analyzing the body location and cause of diseases, based on the classifications used in the data set.

Hypotheses

Table 3.5 shows the hypotheses generated for each injury type (outcome variable) and for each predictive variable tested. Each cell contains the body location, age group, occupation or cause, which is believed to place the worker at the highest risk of having a disease/injury.
Table 3.5. Hypotheses Generated.

<table>
<thead>
<tr>
<th>Diseases</th>
<th>Body</th>
<th>Age</th>
<th>Occupation</th>
<th>Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprains/Strains</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body</td>
<td>Old</td>
<td></td>
<td>Collectors</td>
<td></td>
</tr>
<tr>
<td>Back</td>
<td>Young</td>
<td></td>
<td>Collectors</td>
<td>Lifting</td>
</tr>
<tr>
<td>Minor Injuries</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body</td>
<td>Young</td>
<td></td>
<td>Collectors</td>
<td>Accidental causes</td>
</tr>
<tr>
<td>Extremities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major Injuries</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body</td>
<td>Young</td>
<td></td>
<td>Collectors</td>
<td>External causes</td>
</tr>
<tr>
<td>Multiple Body Parts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Reference Groups

In the initial analyses, the body location, age group, occupation and cause believed to have the lowest risk of occurrence based on the disease/injury type, was used as the reference group in the logistic regression model. These groups are outlined in Table 3.6.

Table 3.6. Reference Groups for Initial Analysis

<table>
<thead>
<tr>
<th>Diseases</th>
<th>Body</th>
<th>Age</th>
<th>Occupation</th>
<th>Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sprains/Strains</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body</td>
<td>Young</td>
<td></td>
<td>Administrators</td>
<td></td>
</tr>
<tr>
<td>Minor Injuries</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body</td>
<td>Middle</td>
<td></td>
<td>Administrators</td>
<td>Accidental</td>
</tr>
<tr>
<td>Extremities</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major Injuries</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body</td>
<td>Middle</td>
<td></td>
<td>Administrators</td>
<td>Lifting</td>
</tr>
<tr>
<td>Back</td>
<td>Middle</td>
<td></td>
<td>Administrators</td>
<td>Lifting</td>
</tr>
</tbody>
</table>

157
Subsequently, the reference groups were revised for reasons of simplicity. The initial results produced some odds ratios with values less than unity. This indicated that a particular body location, age, occupation or cause had a protective effect. Since it was believed that these variables did not truly have this protective attribute, we chose to assign the reference group to those variables that had the least risk of causing diseases/injuries. This reference groups are given in Table 3.7.

Table 3.7. Reference Groups for Final Analysis.

<table>
<thead>
<tr>
<th>Diseases</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Body</td>
<td>Age</td>
</tr>
<tr>
<td>Middle</td>
<td>Collectors</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sprains/Strains</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Body</td>
<td>Age</td>
</tr>
<tr>
<td>Multiple Body Parts</td>
<td>Old</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Major Injuries</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Body</td>
<td>Age</td>
</tr>
<tr>
<td>Back</td>
<td>Middle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Minor Injuries</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Body</td>
<td>Age</td>
</tr>
<tr>
<td>Back</td>
<td>Middle</td>
</tr>
</tbody>
</table>

3.4.2. Results

The Florida WC database used in this study consisted of 1711 WC claims for the years 1993-1997 in the State of Florida. Each claim consisted of information on the type of injury, the body location affected, the age and occupation of the affected worker, and the cause of the injury.

The following cross-tabulation tables displays a count of each claim by disease/injury type, classified by the individual body locations, age groups, occupations and causes. The total number of claims identified in these tables and used in the statistical analysis totaled 1709, since 2 observations were deleted due to missing values for the response or explanatory variables.

The total count for each outcome variable was:
1. Diseases = 38
2. Sprains and Strains = 944
3. Minor Injuries = 519
4. Major Injuries = 208
Cross-tabulation Tables

a. Injury Type x Body Location:
   - 944 Sprains/Strains, 519 Minor Injuries and 208 Major Injuries were included in the analysis by Body Location.
   - A total of 102 Head & Neck, 520 Back, 861 Extremities, 188 Multiple Body Parts claims were included in the analysis by Body Location.

   Table 3.8. Body Location x Injury Type Crosstabulation Count

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Body Location</th>
<th>Sprain/Strain</th>
<th>Minor</th>
<th>Major</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head, Neck</td>
<td>33</td>
<td>34</td>
<td>35</td>
<td>102</td>
<td></td>
</tr>
<tr>
<td>Back</td>
<td>458</td>
<td>34</td>
<td>28</td>
<td>520</td>
<td></td>
</tr>
<tr>
<td>Extremities</td>
<td>402</td>
<td>401</td>
<td>58</td>
<td>861</td>
<td></td>
</tr>
<tr>
<td>Multiple</td>
<td>51</td>
<td>50</td>
<td>87</td>
<td>188</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>944</td>
<td>519</td>
<td>208</td>
<td>1671</td>
<td></td>
</tr>
</tbody>
</table>

b. Injury Type x Age:
   - 38 Disease claims, 944 Sprains/Strains, 519 Minor Injuries and 208 Major Injuries were included in the analysis by Age.
   - A total of 496 Young, 674 Middle-aged and 539 Old workers’ claims were included in the analysis by Age.

   Table 3.9. Age * Injury Type Crosstabulation Count

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Age</th>
<th>Disease</th>
<th>Sprain/Strain</th>
<th>Minor</th>
<th>Major</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disease</td>
<td>Young</td>
<td>12</td>
<td>273</td>
<td>152</td>
<td>59</td>
<td>496</td>
</tr>
<tr>
<td>Sprain/Strain</td>
<td>Middle</td>
<td>11</td>
<td>391</td>
<td>197</td>
<td>75</td>
<td>674</td>
</tr>
<tr>
<td>Minor</td>
<td>Old</td>
<td>15</td>
<td>280</td>
<td>170</td>
<td>74</td>
<td>539</td>
</tr>
<tr>
<td>Major</td>
<td>Total</td>
<td>38</td>
<td>944</td>
<td>519</td>
<td>208</td>
<td>1709</td>
</tr>
</tbody>
</table>

c. Injury Type x Occupation
   - 33 Disease claims, 920 Sprains/Strains, 504 Minor Injuries and 201 Major Injuries were included in the analysis by Occupation.
   - There were 5 missing Occupation codes for Diseases, 24 for Sprains/Strains, 15 for Minor Injuries, and 7 for Major Injuries.
   - A total of 1323 Collectors, 43 Administrators and 292 Skilled workers’ claims were included in the analysis by Occupation.
Table 3.10. Occupation * Injury Type Crosstabulation Count

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Disease</th>
<th>Sprain/Strain</th>
<th>Minor</th>
<th>Major</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collector</td>
<td>21</td>
<td>745</td>
<td>393</td>
<td>164</td>
<td>1323</td>
</tr>
<tr>
<td>Administrator</td>
<td>2</td>
<td>29</td>
<td>6</td>
<td>6</td>
<td>43</td>
</tr>
<tr>
<td>Skilled</td>
<td>10</td>
<td>146</td>
<td>105</td>
<td>31</td>
<td>292</td>
</tr>
<tr>
<td>Total</td>
<td>33</td>
<td>920</td>
<td>504</td>
<td>201</td>
<td>1658</td>
</tr>
<tr>
<td>Missing Values</td>
<td>5</td>
<td>24</td>
<td>15</td>
<td>7</td>
<td>51</td>
</tr>
</tbody>
</table>

d. Injury Type x Cause of Injury

- 933 Sprains/Strains, 515 Minor Injuries and 179 Major Injuries were included in the analysis by Cause of Injury.
- There were 11 missing entries for Cause of Sprains/Strains, 4 for Minor Injuries, and 29 for Major Injuries.
- A total of 661 incidents were caused by Lifting, 468 were caused by External causes and 533 were attributed to Accidental causes.

Table 3.11. Cause * Injury Type Crosstabulation Count

<table>
<thead>
<tr>
<th>Cause</th>
<th>Sprain/Strain</th>
<th>Minor</th>
<th>Major</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lift</td>
<td>604</td>
<td>19</td>
<td>13</td>
<td>636</td>
</tr>
<tr>
<td>External</td>
<td>101</td>
<td>243</td>
<td>115</td>
<td>459</td>
</tr>
<tr>
<td>Accidental</td>
<td>228</td>
<td>253</td>
<td>51</td>
<td>532</td>
</tr>
<tr>
<td>Total</td>
<td>933</td>
<td>515</td>
<td>179</td>
<td>1627</td>
</tr>
<tr>
<td>Missing Values</td>
<td>11</td>
<td>4</td>
<td>29</td>
<td>44</td>
</tr>
</tbody>
</table>

3.4.3. Logistical Analysis

The following is the output of the logistic regression model for the four chosen outcome variables. Each predictive variable is modeled individually and the corresponding sample size (n), Parameter Estimate (regression coefficient), Standard Error, Odds Ratio and 95% Confidence Intervals for the Odds Ratio are given.

The reference groups displayed here refer to the second reference group selection described previously. These reference groups refer to those predictive variables that place the worker at least risk for a disease/injury.
### Table 3.12. Logistic Analysis of Disease

<table>
<thead>
<tr>
<th>Age</th>
<th>n</th>
<th>Parameter Estimate</th>
<th>Standard Error</th>
<th>Odds Ratio</th>
<th>LCL</th>
<th>UCL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young</td>
<td>12</td>
<td>0.4017</td>
<td>0.4217</td>
<td>1.494</td>
<td>0.654</td>
<td>3.415</td>
</tr>
<tr>
<td>Middle</td>
<td>11</td>
<td>REFERENCE GROUP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Old</td>
<td>15</td>
<td>0.5454</td>
<td>0.4012</td>
<td>1.725</td>
<td>0.786</td>
<td>3.788</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Occupation</th>
<th>n</th>
<th>Parameter Estimate</th>
<th>Standard Error</th>
<th>Odds Ratio</th>
<th>LCL</th>
<th>UCL</th>
</tr>
</thead>
<tbody>
<tr>
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### Table 3.13. Logistic Analysis of Sprain

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<table>
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Table 3.14. Logistic Analysis of Minor Injuries

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<tbody>
<tr>
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<td>Extremities</td>
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<table>
<thead>
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<th>Odds Ratio</th>
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<tr>
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<tr>
<td>Skilled</td>
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<table>
<thead>
<tr>
<th>Cause</th>
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<td>26.911</td>
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Table 3.15. Logistic Analysis of Major Injuries

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</tr>
</thead>
<tbody>
<tr>
<td>Head &amp; Neck</td>
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<td>16.662</td>
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<td>Extremities</td>
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<td>1.332</td>
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<tr>
<td>Multiple Body Parts</td>
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<td>2.7128</td>
<td>0.2418</td>
<td>15.071</td>
<td>9.383</td>
<td>24.209</td>
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<table>
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<tr>
<td>Young</td>
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<td>0.902</td>
<td>1.791</td>
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</table>

<table>
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<th>Occupation</th>
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<th>Odds Ratio</th>
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<th>Cause</th>
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<td>7.525</td>
</tr>
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<td>Accidental</td>
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<td>0.5175</td>
<td>0.2168</td>
<td>1.678</td>
<td>1.097</td>
<td>2.566</td>
</tr>
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</table>

3.4.4. Discussion

The purpose of the logistic regression analysis was to determine the attributes (predictive variables) that were at the highest risk of occurrence in the WC claims dataset used. Several hypotheses were generated and tested. The Odds Ratios were calculated and used to compare the risk of occurrence of the variables to specified reference groups.

A review of the results must encompass several key factors. Firstly, the WC data set used did not represent the totality of incidents in the Florida MSW industry. WC claims were filed by workers who were affected by a job-related injury or illness. However, these incidents referred only to those that required medical attention and/or resulted in lost workdays.

Another factors to be considered, was the sample size for each outcome and predictive variable pair. Diseases had the lowest number of claims (38 claims), while
Sprains and Strains had the highest number of claims (944 claims). The size of the sample studied could have affected the degree to which chance affected the results of the study (Hennekens and Buring, 1987).

It is important to consider that each claim may or may not have represented different individuals. The data set used did not provide information that would have allowed the identification of each claimant. Hence, it was possible that one worker may have had more than one claim in the data set and as such, each data value represented an individual claim and not an individual worker.

There was also the possibility of misclassification especially for variable values such as multiple body parts and other leading injuries. The WC filing system differed from employer to employer and hence variability in classification may have existed in the data set.

The differences in filing of WC claims may have also affected the diligence with which claims were filed by workers. It was possible that the workers who were more aware of how the system worked, were more likely to file for workers’ compensation. This would have resulted in an under-reporting of incidents by those workers who were less knowledgeable of the system.

The results of the models for the four outcome variables are discussed below. The sample size and hypothesis for each model is given, along with a comparison between the findings and the hypotheses.

**Diseases**

The sample size for this outcome variable was very low (38 claims). It has been said that WC data were highly underreported for diseases. As mentioned previously, this small sample size may have affected the degree to which chance affected the outcome of the models for diseases.

In conducting the analyses, only the age and occupation variables were tested since there was no biological plausibility for analyzing the body location and causes of diseases based on the classifications of the variables used in the data set.

It was hypothesized that Older Collectors would be the group at the highest risk for diseases. The age hypothesis failed to be rejected but the occupation hypothesis was rejected in the analysis.

Time on the job is a useful surrogate for exposure and is highly correlated with the onset and development of diseases. However, time on the job was not available in the data set for analysis, so the age of the worker was used to measure this effect.

The results showed that the Middle-aged group was at least risk and it was used as the reference group in the final model. It was hypothesized that Older workers would
have been at the greatest risk due to the correlation between disease and time on the job. However, both the Old age group (OR=1.725, 95%CI=0.786-3.788) and the Young group (1.494, 0.654-3.415) had slightly elevated risks.

The small sample size in this model, and the only slight elevation in the Odds Ratios, could have also been due to the fact that younger workers may not have had enough time to develop a disease on the job, and Older workers may have left the job when they developed a disease.

For the occupation model, it was hypothesized that the Collectors would have been at highest risk because, of the three occupational groups, they were considered to be the most exposed group to injury/illness. However, this hypothesis was rejected since the Odds Ratio for the Administrators (2.529, 0.581-11.015) was more than twice that of the Collectors, which were used as the reference group in the model. Skilled workers also had and elevated risk of 1.839 (0.877-3.855). One explanation of this outcome could be the potential for reporting bias, as discussed earlier. Another possibility is that some of the Administrators who filed these claims were previously Collectors who, due to the latency of some occupational diseases, did not develop the illness while they were working as a Collector.

**Sprains and Strains**

Sprains and Strains had the highest frequency of all the injury types recorded in the WC data used. There were 944 Sprain and Strain WC claims in Florida from 1993-1997.

It was hypothesized that Young Collectors would be at the greatest risk for Sprains and Strains, to the Back area, caused by Lifting. Younger workers would be less experienced and less aware of the hazards at their workplace, than Older workers and hence may be more susceptible to experience a Strain/Sprain (Englehardt et al., 1999). Sprains/Strains of the back is one of the most common and significant musculoskeletal problems in the United States according to Grazier et al. (1984).

As hypothesized, the Back was at the highest risk for Sprains (14.429, 9.750-21.355), using Multiple Body Parts as the reference group. The other body locations, Head & Neck (1.322, 0.784-2.230) and Extremities (2.435, 1.721-3.443), were both elevated.

The results for age were not fully in accordance with the hypothesis that the Younger worker would be at highest risk. Instead, it was found that neither the Middle-age group (1.278, 1.018-1.605) nor the Young age group (1.132, 0.887-1.446) was highly elevated compared to the reference group (Old age group).

Collectors’ risk was slightly elevated (1.312, 1.034-1.664), but they were not the highest risk group as expected. Administrators were twice as likely (2.108, 1.076-4.128) as the Skilled Workers reference group to be at risk of having a Sprain/Strain.
The results for both the age and occupation models were not in full accordance with the hypotheses. These may be explained by the fact that correlation has been found between time and back injuries. The correlation is such that younger workers may not have enough time to develop sprains on the job, whereas older workers may leave the job when they develop sprains. This same argument holds for Administrators who may have previously been Collectors and who, either because they were unaware of the claims system, or because the condition did not develop while they were a Collector, did not claim this injury as a Collector but as an Administrator instead.

As predicted, Lifting had the highest risk (38.128, 27.058-53.732) of causing a Sprain/Strain. External Cause was used as the reference group, and Accidental causes (2.690, 2.052-3.526) were twice as likely as this group of causing a Sprain/Strain.

**Minor Injuries**

Minor injuries included fractures, dislocations, lacerations, punctures, crushes and contusions. There were a total of 519 claims for Minor injuries in the WC data used. This accounted for the second highest number of claims, after Sprains and Strains.

It was hypothesized that Young Collectors would be at highest risk of suffering a Minor injury to the upper and lower Extremities. These Minor injuries were believed to be most likely caused by Accidental causes such as cutting, puncturing, scraping, falling, slipping, or striking.

As predicted the Extremities (13.040, 8.989-18.916) were at the highest risk for Minor injuries. Both Head & Neck (7.435, 4.343-12.728) and Multiple Body Parts (5.239, 3.263-8.410) were at elevated risks for Minor injuries, compared to the Back, which was the comparison group in this model.

Although it was hypothesized that the Younger age group would be at greatest risk, mainly because of their lack of job experience, neither the Young age group (1.070, 0.831-1.378) nor the Old age group (1.116,0.872-1.427) was highly elevated compared to the reference group (Middle-aged group). This indicated that age might not have been a major factor in the risk of experiencing a Minor injury.

It was hypothesized that the Collectors would be the group at highest risk for a Minor injury. However, the results showed that Skilled workers (1.952, 1.136-3.353) were almost twice as likely as the Administrators (reference group) of having a Minor injury, whereas, the Collectors (1.469, 0.892-2.421) were only at a slightly higher risk.

As predicted, Accidental causes (26.911, 17.179-42.154) had a highly elevated risk of producing a Minor injury. However, in contradiction to the hypothesis, Accidental causes did not pose the highest risk in the results. Instead, it was found that
External Causes produced the highest risk (32.165, 20.441-50.615), as compared to Lifting (reference group).

**Major Injuries**

Major injuries included amputations, multiple injuries, hearing and vision loss, concussion, burns, and electric shock. There were 208 claims of Major injuries in the Florida MSW Workers’ Compensation used.

It was hypothesized that Young Collectors would experience Major injuries to Multiple body parts, caused by External causes, such as heat/cold exposure, motor vehicles, being struck or caught in or between equipment and machinery.

As expected Multiple Body Parts (15.071, 9.383-24.209) were at the highest risk for Major injuries compared to the Back (reference group). The Head & Neck region also showed an elevated risk (9.540, 5.462-16.662), whereas the Extremities were only slightly elevated (1.332, 0.837-2.119).

Although it was hypothesized that the Younger workers would be at greatest risk, the results for Major injuries were similar to that for Minor injuries. It was found that there was not a large difference between the risk for the Young age group (1.078, 0.750-1.550), the Old age group (1.271, 0.902-1.791) and the Middle-age group (reference group).

The hypothesis for occupation was that Collectors would be the most at risk of experiencing a Major injury. However the results showed that both the Collectors (1.136, 0.781-1.652) and Administrators (1.302, 0.516-3.286) both showed only small elevations of risk compared to Skilled Workers (reference group).

As hypothesized, External Causes (5.166, 3.547-7.525) had the highest risk for Major injuries. Accidental Causes (1.678, 1.097-2.566) had a slightly elevated risk compared to Lifting (reference group).
3.4.5. Conclusion and Recommendations

The results of the logistic regression analysis presented showed that age might not have been a significant factor for risk of having a disease or illness. The Odds Ratios for age for the four chosen outcome variables were only marginally greater than one. One explanation for this is that although younger workers would be considered at greatest risk due to their lack of job experience, time on the job, represented by age, can be considered a useful surrogate for exposure. Hence, younger workers may not have had enough time on the job to experience a disease or injury. On the other hand, older workers would perhaps leave the job if they were to have an injury or develop a disease, and hence may not appear at great risk for incurring an injury or disease.

Sprains and Strains to the Back area proved to be highly significant, as has been shown in occupational literature. These sprains/strains were also found to be caused by Lifting, which if improperly performed, has been proven to be a major factor in causing back injuries.

Surprisingly, it was found that the Collectors were not the occupational group at greatest risk for Diseases or Injuries. Instead, Administrators were at greatest risk for all but the Minor Injuries, for which the Skilled workers were at greatest risk. It is possible that reporting bias played an integral part in these results, such that the Administrators would be more aware of the filing procedures for WC claims than the Collectors would be. Another possible explanation is that the Collectors became Administrators, and due both to the latency of the symptoms of some diseases and injuries, and their increased knowledge of the filing process as an Administrator, only then did they file a WC claim for their illness or injury.

It is strongly recommended that this study be conducted using more complete data. The data used should include information on time on the job, employment history, pre-employment (baseline) medical data, periodic medical surveillance data and daily habits (such as smoking, alcohol and drug consumption). OSHA 200 logs, medical records and surveys of the workers themselves may prove to be useful sources of such information.

3.5. RECOMMENDATIONS FOR IMPROVING MSW COLLECTOR SAFETY

The tasks described in this chapter, along with those of Chapters 1 and 2, resulted in the recommendations for reducing injuries and deaths among MSW collection workers reported in this section. While changes in the vehicle-based collection method presently employed (e.g., pneumatic conveyance) may eventually reduce occupational risks, the recommendations below were developed regarding the present system.

3.5.1. Collection Vehicle Design

Item to consider regarding engineering design improvements for collection vehicles, to supplement those published by NIOSH (1997), include:
1. Side loading vehicle design, to reduce the incidence of workers pinned against trucks by passing motorists and being backed over by the collection vehicle,
2. Devices to increase communication between driver and the collectors, such as (a) microphones and speakers on the outside of trucks and inside cabs, and (b) cellular phones/radios for frequent communication between the supervisor/base and the driver,
3. Shields over the compaction area, to reduce exposure of workers to objects, aerosols, and liquids,
4. Better ventilation of cabs to minimize the accumulation of malodorous airborne garbage emissions inside cabs,
5. Flashing lights and signs on the upper sides and backs of trucks to warn oncoming motorists (similar to those used o school buses), and
6. Increased automation of collection systems.

3.5.2. Workers and Administration

Recommendations regarding work procedures and administration include:

1. Collectors should briefly test the weight of each container before lifting, to prepare for the load,
2. Route supervisors, in addition to safety officers, should be accountable for injuries on their respective routes,
3. Route supervisors should visit routes frequently and discuss proper/improper technique with workers on the spot,
4. Written safety procedures should be widely distributed, reviewed, and enforced,
5. Incentives for safety compliance should be maintained and advertised,
6. Workers should be instructed not to pick up containers weighing over 50 lbs. or containing hazardous materials, but to leave an informative tag on the container for the resident,
7. Payment by the hour rather than by the route should be considered, and
8. Scheduled medical surveillance of workers should be implemented.

3.5.3. Training

Principal recommendations regarding collector training included:

1. Training in teamwork and communication techniques within crews should be conducted,
2. Continuous training in proper lifting and carrying techniques, constituents of MSW, potential hazards of exposure to aerosol contaminants, and techniques for inclement weather, should be implemented, and
3. MSW management agencies should assume responsibility for training of temporary workers, and ensure training equivalent to that provided for permanent workers,
3.5.4. Personal Protective Equipment

Recommendations regarding safety equipment included:

1. Reflective safety vests should be redesigned, or eliminated through redesign of uniforms, to prevent catching on trucks, and
2. Boots adapted to local weather conditions should be issued.

3.5.5. Public Education

Mailings or inclusions with waste collection bills should be distributed to residents regarding:

1. Procedures for passing collection vehicles, including special caution in inclement weather and low-visibility situations,
2. Allowable waste constituents, maximum disposal and container weight, and
3. Hazards of waste collection.

3.6. REFERENCES


4. EDUCATIONAL OUTREACH PROGRAM

James D. Englehardt
Lora Fleming
Huren An
Jeff Rogers
Nicolette John

Results of the study presented in Chapters 1 through 3 were used to develop and implement an educational outreach program. The program included development and distribution of an educational pamphlet to approximately 200 public and private MSW collection agencies in Florida; distribution of the pamphlet and final report via the project website and the Florida Center for Solid and Hazardous Waste Management (FCSHWM); presentation of results to the Advisory Board of the FCSHWM; development of a University of Miami press release; two conference presentations; and four refereed journal publications.

4.1. METHOD

Development of the educational outreach phase consisted of four tasks: development of a mailing list, development of an educational brochure, dissemination of reports and brochure, and professional and public media outreach. First, a database of public and private MSW collection agencies in Florida was developed, to serve as a mailing list. To do this, a search was conducted for residential MSW collection companies, public and private, in Miami-Dade, Broward, and Palm Beach Counties. Current addresses were acquired by several methods, including electronic search of the American Business Disk database (InfoUsa, Inc, 1999) by standard industry code (SIC), review of listings developed by the Florida Department of Environmental Protection, and search of local companies including those given by company name in the WC database. All companies were then contacted to update and verify addressees. Then, addresses of directors of solid waste collection operations for every county in Florida, most of whom are listed in Solid Waste Management in Florida (Florida Department of Environmental Protection, 1998).

The second task was the design and printing of an educational pamphlet, including key findings of the study and safety recommendations outlined in Chapter 3. The brochure, shown in Appendix J, is 8 pages in length, and 8.5 x 5.5 inches in size, presented in an accessible format. The material is targeted in particular towards solid waste collection supervisors and administration, and safety personnel. Material on risks found for the State as a whole was used to motivate recommendations. Special emphasis was on relevant information not typically available to facility-based professionals, and new recommendations developed as a result of this study. The recommendations developed in this study and included in the pamphlet are not intended to be comprehensive, but to supplement existing literature and knowledge (NIOSH, 1997). A disclaimer to this effect...
is included in the pamphlet.

The third task was dissemination by the investigators of findings and materials, including the Final Report and the educational pamphlet. First, the educational brochure was mailed to approximately 200 agencies on the mailing list, the Florida Division of Safety, OSHA, Florida Association of Counties, Florida League of Cities, and the Florida Center for Solid and Hazardous Waste Management. In addition, results were posted to the project website continually over the course of the project, including Progress Reports, key findings, the Final Report for downloading, the Fact Sheet, and the educational pamphlet. Finally, the Final Report and results of the two year project were presented to the Advisory Board of the Florida Center for Solid and Hazardous Waste Management, representing solid waste industry, government, and academic sectors in Florida, on 25 February 2000.

The final educational task was media outreach and publication, including press releases, two conference presentations, and at least four peer-reviewed publications. Results presented in Chapter 2 were released to media and interested parties who contacted the Principal Investigator at the end of Year 1 (Jones, 1999; Drudi, 1999; Hope, 1999; Maldonado, 1999; Rodriguez, 1999; Rogers, 1999; Biderman, 1999; Miller, 1999; AFL-CIO, 1999; McBride, 1999; Radio 610, 1999; Bauerlein, 1999; Moffet, 1999; WAMI Television, 1999; Gonzalez, 1999; Sun Sentinel, 1999). A second University of Miami press release was developed after all comments were received from the TAG and participating MSW collection agencies, and the Final Report was finalized. Risk assessment results of Chapter 2 were presented at the Annual Meeting of the Society for Risk Analysis, December 2000, Atlanta, GA, and submitted for review to Risk Analysis: an International Journal (Society for Risk Analysis). The analysis of WC data given in Chapter 2 was presented at the American Society of Civil Engineers-Canadian Society of Civil Engineers Conference on Environmental Engineering, Norfolk, VA, July 25-28 (An et al., 1999a; Englehardt et al., 1999), and was published in the journal Waste Management & Research (An et al., 1999b). A draft paper describing the summary results of the survey presented in Chapter 3 was prepared for review by participating agencies and submission to the Journal of Solid Waste Technology and Management. The literature review of Chapter 1 was submitted for review to the American Journal of Industrial Medicine.

4.2. REFERENCES


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5. LITERATURE REVIEW OF EXPOSURES AND HEALTH EFFECTS OF SOLID WASTE IN COMMUNITIES

Lora E. Fleming
Nicolette John

5.1. INTRODUCTION

This Report summarizes the scientific literature available on the exposures and health effects in communities surrounding Municipal Solid Waste (MSW) disposal sites. These disposal sites consist primarily of landfills, although other activities such as incineration, composting and recycling can be associated with solid waste disposal.

The discussion is divided into several key areas. The first will be a brief outline of studies pertaining to the Hazardous Waste Industry. Within this topic, exposure and human health studies will be reviewed for both the workers and for the communities surrounding known hazardous waste facilities. The second, and the key area of interest in this Report, is an outline of studies performed within the MSW industry. These include studies on both occupational and community exposures and health effects.

Hazardous waste studies are reviewed in this Report on solid waste because there is an overlap of exposures from these two types of waste. As discussed below, studies have suggested that hazardous waste can find its way into MSW sites by several means. Hence, exposure information collected in hazardous waste site studies may give some indication of what should be expected and evaluated in the MSW industry, albeit at lower levels of exposure. Another reason for reviewing the hazardous waste industry in this Report is that the bulk of the published literature relates to hazardous waste sites, particularly for the hazardous waste worker, rather than for MSW sites. This trend may be a result of the prevailing perception that hazardous waste sites pose a greater risk than solid waste sites to both workers and communities.

Studies on exposure and health effects in the workplace have been included in the reviews of both hazardous and solid wastes for the following reasons. There have been substantially more studies performed with regards to the workplace than in the community, particularly in the solid waste field. Furthermore, with some caveats discussed below, the health effects observed in workers may be applicable to community studies. It is easier to investigate a dose response relationship in the workplace because there tends to be higher occupational doses than in the community. In addition, it may easier to quantify actual exposure in the workplace than in the community. It is also very difficult to perform epidemiological studies on the effects of low-level exposures in the community. These studies require that researchers follow a fairly large population for long periods of time to measure their exposures and to see if there is any incidence of disease. Finally, comparatively, occupational populations are often more stable, more uniform, and easier to delineate than community populations.
Nevertheless, when extrapolating from worker data to community exposures and health effects, there are several factors to consider. There may be differences in the doses, the routes of exposure and in the generalizability of the study population.

- Community exposures tend to be much lower than in the workplace. At the same time, these exposures are not limited to a 40 hours workweek, but may occur over the entire lifespan of a person;
- Occupational routes of exposures are predominantly through inhalation and skin, while community exposure routes potentially include ingestion through both water and the foodchain, as well as the potential for inhalation and skin exposure;
- Communities have heterogeneous populations comprised of elderly, young, healthy and sick people, whereas the workforce generally is comprised of young, healthy individuals. In addition, levels of pollutants relatively tolerated by adults may cause serious adverse effects in fetuses and in growing children.

Epidemiological studies are the primary sources of information on the possible human health effects associated with waste sites. These studies have attempted to determine associations between exposure to waste and its byproducts with particular human health effects. This determination is made by comparing unexposed and exposed populations for disease risk or by comparing diseased and well populations for exposure risk. Nevertheless, very few epidemiologic studies have been performed to assess the possible associated exposures and human health effects, especially chronic effects, of waste disposal. Cancer, and other chronic diseases, require a latency period between the time of exposure and the onset of the disease. This latency period simply does not exist for the majority of known waste sites.

In the future, it is expected that the literature concerning the exposures and potential human health effects for communities living near solid waste facilities will increase. In the meantime, this Report is a review of the existing directly and indirectly relevant published scientific literature relevant to this issue.

5.2. HAZARDOUS WASTE WORKER EXPOSURE AND HEALTH EFFECTS

In 1995, the EPA estimated that over 214 million tons of hazardous waste regulated by the Resource Conservation and Recovery Act of 1976 (RCRA) were generated in the United States (www.niehs.nih.gov). Hazardous waste workers are involved in many types of skilled labor including construction, transport, heavy equipment operation, plumbing, electrical work, chemistry, etc. (Ruttenberg 1996).

The US Hazardous Waste Operations and Emergency Response Standard (HAZWOPER) applies to five distinct groups of hazardous waste employers and their employees (OSHA 29CFR - 1910.120). This includes any employees who are exposed or potentially exposed to hazardous substances – including hazardous waste – and who are engaged in one of the following operations: clean-up, corrective actions, direct treatment, storage and disposal, and emergency response. A major concern in the hazardous waste industry is the potential for adverse health effects resulting from the
exposure of workers to hazardous waste (Favata and Gochfeld 1989). The main routes of exposure for workers are inhalation and direct skin contact. Other theoretically possible but rare routes include injection (through puncture wounds), absorption through the mucous membranes, and ingestion (with poor hygiene).

Health effects include both chronic and acute effects. These can be temporary and reversible, permanent, or fatal. In addition to acute effects, exposure to hazardous substances can cause chronic health effects including impairment of organ function and cancer as a result of exposure to toxic, carcinogenic, or infectious materials found at the site (NIOSH 1985). Health effects may be a result of a mixture of hazards (chemical, physical and biological) at hazardous waste sites. These hazards are a function of the work being done and the chemicals found at the site. Some of these hazards include:

- chemical exposure
- fire & explosion
- oxygen deficiency
- ionizing radiation
- biologic hazards
- safety hazards
- electrical hazards
- heat stress
- cold exposure
- noise

Some of these hazards (e.g. chemical exposure, fire and explosion, heat stress) also exist in other occupational settings that involve the use of hazardous material. However, peculiar to hazardous waste workers is the enormous amount and range of chemicals combined with exposure uncertainty; these conditions can create additional risks for these workers.

Chemical exposure is the primary health and safety concern at waste sites. These chemicals can exist in the solid, liquid or gaseous form. They can contaminate the body at the point of contact and/or systemically (causing a toxic effect at parts of the body away from the point of contact). (NIOSH 1985). The effect of the exposure will depend on the chemical: its concentration, route of entry, the duration of exposure, and personal risk factors. Some of the common chemicals found at hazardous waste sites include aromatic hydrocarbons, asbestos, dioxins, halogenated aliphatic hydrocarbons, heavy metals, herbicides, organochlorine insecticides, organophosphate and carbamate insecticides, and polychlorinated biphenyls (PCBs) (NIOSH 1985). These substances are associated with neurologic, hematologic, respiratory, dermal, cardiovascular and gastrointestinal effects, nephrotoxicity, and cancer (Levy and Wegman 1988; NIOSH 1985; Goldfrank 1998; Klassen 1996).

The following is a table outlining the most common toxicants found at hazardous waste sites, their potential health effects and the medical monitoring techniques used for each. As will be discussed below, although the quantities may differ, these exposures can also be shared by solid waste workers and communities.
<table>
<thead>
<tr>
<th>Substances or Chemical Group</th>
<th>Compounds</th>
<th>Uses</th>
<th>Target Organs</th>
<th>Potential Health Effects</th>
<th>Medical Monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aromatic Hydrocarbons</td>
<td>Benzene, Ethyl benzene, Toluene, Xylenes</td>
<td>Commercial solvents and intermediates for synthesis in the chemical and pharmaceutical industries</td>
<td>Blood, Bone marrow, CNS, Eyes, Respiratory system, Skin, Liver, Kidney</td>
<td>All causes, CNS depression, decreased alertness, headache, sleepiness, loss of consciousness, Deflating dermatitis. Benzene suppresses bone marrow function, causing blood changes. Chronic exposure can cause leukemia. Note: Because other aromatic hydrocarbons may be contaminated with benzene during distillation, benzene-related health effects should be considered when exposure to any of these agents is suspected.</td>
<td>Occupational: general medical history emphasizing prior exposure to these or other toxic agents. Medical examination with focus on liver, kidney, nervous system, and skin. Laboratory testing: CBC, Platelet count, Measurement of kidney and liver function.</td>
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<td>Asbestos (or asbestiform particles)</td>
<td>A variety of industrial uses, including: Building, Construction, Cement work, Insulation, Fireproofing, Pipes and ducts for water, air, and chemicals, Automobile brake pads and linings</td>
<td>Lungs, Gastrointestinal system</td>
<td>Chronic effects of Lung cancer, Mesothelioma, Asbestososis, Gastrointestinal malignancies. Asbestos exposure coupled with cigarette smoking has been shown to have a synergetic effect in the development of lung cancer.</td>
<td>History and physical examination should focus on the lungs and gastrointestinal system. Laboratory tests should include a stool test for occult blood evaluation as a check for possible hidden gastrointestinal malignancy. A high quality chest X-ray and pulmonary function test may help to identify long-term changes associated with asbestos disease, however, early identification of low-dose exposure is unlikely.</td>
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<tr>
<td>HAZARDOUS SUBSTANCE OR CHEMICAL GROUP</td>
<td>COMPOUNDS</td>
<td>USES</td>
<td>TARGET ORGANS</td>
<td>POTENTIAL HEALTH EFFECTS</td>
<td>MEDICAL MONITORING</td>
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<td>Halogenated Aliphatic Hydrocarbons</td>
<td>Carbon</td>
<td>Commercial solvents and intermediates in organic synthesis.</td>
<td>CNS, Kidney, Liver, Skin</td>
<td>All causes; CNS depression; decreased alertness, headaches, sleepiness, loss of consciousness; Kidney changes; decreased urine flow, swelling (especially around the eyes), anemia; Liver changes; fatigue, malaise, dark urine, liver enlargement, jaundice. Vinyl chloride is a known carcinogen; several others in this group are potential carcinogens.</td>
<td>Occupational/general medical history; emphasizing prior exposure to these or other toxic agents; Medical examination with focus on liver, kidney, nervous system, and skin; Laboratory testing for liver and kidney function, carbon-monoxide-hemoglobin where relevant.</td>
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<td>Chloroform</td>
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<td>Ethyl bromide</td>
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<td>Methyl chloride</td>
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<td>Chloroform</td>
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<td>Methylene chloride</td>
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<td>Tetrafluoroethylene</td>
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<td>Tetrachloroethylene</td>
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<td>Trichloroethylene</td>
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<td></td>
<td>Vinyl chloride</td>
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<tr>
<td>Heavy Metals</td>
<td>Arsenic</td>
<td>Wide variety of industrial and commercial users.</td>
<td>Multiple organs and systems including; Blood, Cardiopulmonary, Gastrointestinal, Respiratory, Kidney, Liver, Lung, CNS, Skin.</td>
<td>All are toxic to the kidneys. Each heavy metal has its own characteristic symptom cluster. For example, lead causes decreased mental ability, weakness, (especially hands), headache, abdominal cramps, diarrhea, and anemia. Lead can also affect the bloodforming mechanism, kidneys, and the peripheral nervous system. Long-term effects also vary. Lead toxicity can cause permanent kidney and brain damage; cadmium can cause kidney or lung disease. Chromium, beryllium, arsenic, and cadmium have been implicated as human carcinogens.</td>
<td>History-taking and physical exam; search for symptom clusters associated with specific metal exposures, e.g., for lead looks for neurological deficit, anemia, and gastrointestinal symptoms. Laboratory testing: Measurement of metallic content in blood, urine, and tissues (e.g., blood lead levels, urine screen for arsenic, mercury, chromium, and cadmium). CBC (complete blood count). Measurement of kidney function, and liver function where relevant. Chest X-ray or pulmonary function testing where relevant.</td>
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<td>Beryllium</td>
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<td>Cadmium</td>
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<td>Chromium</td>
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<td>Lead</td>
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<td>Mercury</td>
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<td>HAZARDOUS SUBSTANCE OR CHEMICAL GROUP</td>
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<tr>
<td>Herbicides</td>
<td>Chlorophenoxy compounds: 2,4-dichlorophenoxyacetic acid (2,4-D), 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) Dioxin (tetrachlorodibenzo-p-dioxin, TCDD), which occurs at a trace contaminant in these compounds, poses the most serious health risk.</td>
<td>Vegetation control</td>
<td>Kidney Liver CNS* Skin</td>
<td>Chlorophenoxy compounds can cause chloracne, weakness or numbness of the arms and legs, and may result in long-term nerve damage. Dioxin causes chloracne and may aggravate pre-existing liver and kidney diseases.</td>
<td>History and physical exam should focus on the skin and nervous system. Laboratory tests include: Measurement of liver and kidney function, where relevant. Urinalysis.</td>
</tr>
<tr>
<td>Organochlorine Insecticides</td>
<td>Chlorinated ethanes: DDT Cyclodieneres: Aldrin Chlordane Dieldrin Endrin Chloroxyhydroxanes: Lindane</td>
<td>Pest control</td>
<td>Kidney Liver CNS*</td>
<td>All cause acute symptoms of apprehension, irritability, dizziness, disturbed equilibrium, tremor, and convulsions. Cyclodieneres may cause convulsions without any other initial symptoms. Chloroxyhydroxanes can cause anemia. Cyclodiens and chloroxyhydroxanes cause liver toxicity and can cause permanent kidney damage.</td>
<td>History and physical exam should focus on the nervous system. Laboratory tests include: Measurement of kidney and liver function. CBC for exposure to chloroxyhydroxanes.</td>
</tr>
</tbody>
</table>
The RCRA classifies hazardous waste as waste that is ignitable, corrosive, or reactive. Hence, explosion and fires on the sites is another major concern for workers. These can be caused by the ignition of explosive or flammable chemicals; ignition of materials due to oxygen enrichment; chemical reactions that produce explosion, fire or heat; and sudden release of materials under pressure. The hazards posed here include exposure to intense heat and open flame, smoke inhalation, flying objects and release of toxic chemicals into the environment (NIOSH 1985). In addition, there are significant dangers of traumatic injury with exposure to the equipment used in hazardous waste sites.

Noise pollution is yet another health and safety concern at hazardous waste sites. These sites use heavy machinery and equipment, hence there is the potential for a very noisy working environment. This in and of itself is a chronic health concern for
individuals, and may require the use of additional protective equipment. In addition, workers may be distracted by the noise, and communication may be interfered with, adding to the hazards that already exist on the site.

In light of these occupational safety and health hazards, the Occupational Safety and Health Administration (OSHA) requires that these workers undergo a pre-employment medical check (to establish a baseline health assessment) and medical surveillance at least annually and at the end of employment (OSHA 1993). OSHA also regulates the engineering controls, work practices, personal protective equipment, and exposure monitoring used at the sites. In combination, these systems are required to reduce exposures to below established exposure levels for the hazardous substances involved (OSHA 1993).

5.2.1. Incineration

Although incineration of solid wastes is extremely ancient, the controlled incineration of hazardous waste is a relatively new disposal technique. Workers can be exposed to the products of hazardous waste incineration through the contamination of the air by dusts and volatiles, and less commonly through the contamination of the water and soil through improper disposal of the fly ash.

There have been a few studies specifically performed to look at the health risks to hazardous waste incinerator workers. The effects found have been highly variable by facility. These studies were also performed in older facilities, which may not have had the same level of environmental control, or personal protection as is required today. Hence, those findings may not be applicable to workers in the modern facilities (Englehardt et al. 1999).

Air pollution is considered relevant to the study of the human health effects associated with hazardous waste incineration. This is because inhalation of polluted air could be a major route of exposure (Fleming and Bean 1999). Other routes of exposure to air-borne incinerator emissions, include the lungs; eye; skin; through the food chain; through drinking water; in utero and through mother’s milk (Fleming and Bean 1999).

Studies of air pollution arising from hazardous waste incinerators have shown that these pollutants include heavy metals, dioxins, the volatile organic compounds (VOCs) and polychlorinated biphenyls (PCBs). (Fleming and Bean 1999). These substances are included in the list of 189 chemicals identified in Section 112 b(1) of the 1990 Clean Air Act, that are considered to be potentially dangerous to human health (Klassen 1996; Goldfrank 1998).

Epidemiological studies have suggested that air pollution, especially at high concentrations, causes and/or exacerbates the morbidity and mortality of the following lung conditions: asthma, chronic respiratory diseases, and possibly even Lung Cancer. (Fleming and Bean 1999, Goldfrank 1998). The elderly, children, the infirm and sensitive groups (such as asthmatics and persons with immune deficiencies) seem to be
particularly affected by air pollution (Fleming and Bean 1999). Human health effects may also be affected by other factors, such as occupational exposures and personal risk factors (smoking habits, diet, etc.).

The difficulty in using toxicological and epidemiological knowledge of air pollution and the major emission substances to assess the effects of hazardous waste incineration on the worker is due to the low-level exposure to multiple pollutants. It is difficult to classify and quantify mixed exposures. It is also possible that synergism and/or antagonism of pollutants within the human may occur. Hence a mixed exposure may cause more or less health effects than exposure to a single pollutant. In addition, the mixture emitted from the sites is subject to great variability.

5.3. HAZARDOUS WASTE COMMUNITY EXPOSURE AND HEALTH EFFECTS

5.3.1. Relevance to Solid Waste Community Exposure and Health Effects

There is very limited scientific literature available on the human health effects in communities surrounding Municipal Solid Waste (MSW) disposal facilities (i.e. landfills and incinerators, as well as composting and recycling facilities). However, there has been more investigation into the possible exposure and effects in communities surrounding hazardous waste disposal sites. These communities can be exposed to both hazardous and solid waste through inappropriate disposal practices, through contamination of the air by both volatiles and dusts, and through contamination of the soil, water and food chain from improperly contained leachate.

In 1974, the EPA estimated that 90% of all hazardous wastes were improperly disposed of in open pits, surface impoundments, vacant land, farmlands, and water bodies (EPA 1974). The promulgation of Resource Conservation and Recovery Act of 1976(RCRA) was in response to this problem. RCRA regulates the management of solid waste, hazardous waste, and underground storage tanks holding petroleum products or certain chemicals. The primary goal of this Act is to protect human health and the environment from the potential hazards of waste disposal, to conserve energy and natural resources, to reduce the amount of waste generated, and to ensure that wastes are managed in an environmentally sound manner.

RCRA classifies waste that is ignitable, corrosive, or reactive as hazardous. Hazardous wastes also include waste containing certain amounts of toxic chemicals. In addition to these, the EPA has developed a list of over 500 specific hazardous wastes. Hazardous wastes can be in a solid, semi-solid or a liquid form.

Although the type of material dumped in MSW sites is regulated by law, some MSW sites may contain quantities of industrial waste (Schrab 1993, Goldberg 1995; U.S. EPA 1997a) either through illegal dumping and/or the dumping of household hazardous wastes (e.g. pesticides). Studies have shown that hazardous waste can enter MSW landfills by the dumping of household waste containing quantities of hazardous chemicals such as chlorinated and non-chlorinated hydrocarbons, solvents, pesticide, and
MSW sites may contain products that were manufactured using toxic materials. Lagakos et al. (1986) found that when these products are buried, they can cause similar hazards to the environment as the toxic by-products and residues dumped in hazardous waste landfills. The authors found that they both produced chemically similar leachates that can have an adverse effect on the surrounding environment (Hofler 1986).

5.3.2. Incineration

As mentioned above, the incineration of solid wastes is extremely ancient, the controlled incineration of hazardous waste is a relatively new disposal technique. Communities can be exposed to the products of hazardous waste incineration through the contamination of the air by dusts and volatiles, and through the contamination of the water and soil through the improper disposal of the fly ash.

A 10-year follow up study was performed by Kurttio et al. (1998), of mercury exposure in inhabitants living in proximity to a hazardous waste incinerator. A baseline survey of the surrounding population and the environment was conducted in 1984 before the incinerator began operation. From 1984-1994 there was an ongoing environmental monitoring program and a plant emission program. Mercury exposure was the focus of this study because mercury was present in the stack emissions and environmental monitoring found mercury concentrations near the plant.

The results of this study showed an increase in hair mercury concentration as the distance from the plant decreased. These increases in exposure were minimal and, on the basis of current medical and toxicological knowledge, the levels found did not pose a health risk to the subjects. The increase in hair mercury concentrations found in workers and in the high-exposure group were consistent with the results of annual environmental monitoring around the same plant.

A comprehensive review of other studies performed to investigate the human health effects associated with hazardous waste incineration can be found in the Report on the “General Human Health Impacts Associated with Hazardous Waste Incineration” (Fleming and Bean 1999).

5.3.3. Land Disposal

Exposure

Fifty percent of the potable water in the United States is obtained from groundwater. Groundwater is thought to be the primary source of human exposure to chemical pollutants (Maugh 1982). According to a 1984 EPA statement, approximately 74% of the hazardous wastes sites in the U.S. are associated with groundwater.
contamination, primarily involving contamination by heavy metals and organic solvents (U.S. EPA 1984).

Another source of exposure to communities from these sites is their gaseous emissions. In one study by Deloraine et al. (1995) in France, the toxic landfill was located within a residential area. The site was closed in 1988 because of intense local community concern about the malodorous conditions caused by emissions of volatile organic compounds (VOCs) from the site. Air studies performed at the closure and a few months after closure of the site identified approximately 300 volatile organic compounds VOCs. In response to these results and community concerns, an additional study was performed to evaluate the possibility for residual health impacts following the closure of the site (Zmirou 1994)

Since there have been instances cited that have confirmed the existence of offsite exposure to landfill emission, it is necessary to evaluate studies that have been performed on the potential human health effects associated with the land disposal of hazardous waste. Studies have looked at proximity to these sites in relation to outcomes such as short-term health effects, cancer, reproductive effects, and effects on children. These studies have been extensively reviewed (Englehardt et al. 1999); more recent relevant studies are discussed below.

**Short Term Health Effects**

Zmirou et al (1994) assessed the short-term health impacts of a hazardous waste landfill in Montchanin, France. The time period studied reflected 18 months before and 18 months after the site was closed. The consumption of medications categorized as psychiatric and ENT-pulmonary drugs did not increase in Montchanin as much as in the whole of France for the same period of time after the site was closed. Also, no relationship between individual exposure and drug consumption could be found.

As an infamous example of community exposure to hazardous waste, the Love Canal site was located in Niagara Falls, New York. During the 1940s, it received organic solvents, chlorinated hydrocarbons, acids and other hazardous wastes. As of 1980, the United States Department of Health, Education, and Welfare (DHEW), had identified 258 chemicals in the waste buried at the site. In 1953, the landfill was closed and covered, and the land was sold and developed. By 1977, neighborhood creeks, storm sewers, soil, sump pumps, and indoor air of homes were found to be contaminated with chemicals (Leonard 1977). In 1978, the New York State Department of Health evacuated families living closest to the canal, because of an excess of miscarriages found for residents of the area. By 1980, the Federal government assisted in the evacuation of the remaining 800 or more families.

Paigen et al. (1987) looked at whether living near the Love Canal site had an adverse impact on the growth (height and weight) of children. The results of the study indicated that exposed Love Canal children were smaller in mean stature for age percentile than matched control children. An analysis of the distribution of stature-for-
age z-scores was consistent with earlier studies on the effects of lead, radiation and PCBs on growth. These studies showed that males were more susceptible than females. In this particular study, researchers found that males (both white and black), and to a lesser extent, black females were affected, but white females were not affected. Exposure to Love Canal chemicals can be considered the most likely explanation for the reduced growth of exposed children (75% of childhood) since neither the noted confounders, nor a dose effect, had been found to have a significant effect. However, it is important to note that the results of this study do not prove a causal association between chemical exposure and reduced growth.

Vianna and Polan (1984) used data on the incidence of low birth weight among infants born near the Love Canal from 1940 through 1978, to test the hypothesis that there was an excessive incidence of low birth weight infants who were conceived and born in the area of exposure. The findings in this study suggested that a real excess of low birth weight occurred in the high exposure drainage areas only during the active dumping period.

Berry and Bove (1997) studied the possible association of birth weight reduction with residence near a hazardous waste landfill in New Jersey. The analysis revealed that a substantially lower average birth weight and a higher proportion of low birth weights were found in the area categorized as the highest exposure area. During the period of heaviest dumping (and hence considered the period of greatest potential exposure), the average birth weight dropped 189 grams.

Geschwind et al. (1992) evaluated the possible relation between birth defects and potential exposures to toxic waste sites. Five hundred and ninety sites in New York counties were studied. The results of the study suggested a 12% increased risk for birth defects in children born to mothers living in proximity to a hazardous waste site (OR = 1.12, 95% CI = 1.06–1.18). The results also showed a dose-response relation of malformations associated with waste site characteristics.

Croen et al. (1997) examined 2 California population based case control studies for the possible association of maternal residential proximity to toxic waste sites with the risk for neural tube defects (NTDs), conotruncal heart defects and oral cleft defects. Overall, the results did not show an increased risk in a census tract containing a waste site, however they showed a slightly increased risk for NTDs and conotruncal heart defects for maternal residence within ¼ mile of an NPL site.

**Chronic Health Effects**

Budnick et al. (1984) looked at the incidence of cancer near the Drake Superfund site in Clinton County, Pennsylvania. This site received carcinogenic chemicals such as naphthylamine, benzidine, and benzene. During the 1970’s, there was a significant increase in the number of bladder cancer deaths among the white male population of Clinton County. There was also a significant increase in the number of other cancer deaths in the general population of Clinton and in three of the surrounding counties. The
findings suggest a higher incidence of bladder cancer in white males. This increase could be due to the occupational exposure to established carcinogenic substances since it is believed that more males were occupationally exposed than females.

Griffith et al. (1989) studied cancer mortality in U.S. counties with hazardous waste sites and potable groundwater pollution. Analysis of the contaminants revealed 198 known chemical compounds. Of the 13 selected cancer sites, 4 cancers (bladder, stomach, large intestine, and rectum) showed statistical association with proximity to hazardous waste sites. These cancer sites were associated with chemical exposures in previous studies (Najem 1985; Budnick 1984). The main limitation in this particular study was the inability to explicitly link exposure and outcome due to the lack of actual personal exposure.

**Psychological Health Effects**

In many community studies around hazardous waste sites, there is often an elevated level of anxiety due to the perception of any adverse health effects being related to emissions from hazardous waste sites. This anxiety also influences economic concerns, such as decreased property value (Fleming and Bean 1999).

Delorine et al. (1995) and Zmirou et al. (1994) in their assessment of short-term health effects of a toxic landfill in Montchanin, France, noted that living near a hazardous waste site can elicit psychological responses. These residents believed that hazardous waste sites could threaten their health and that public health assessments and thorough clean up of the sites were necessary (Zmirou 1994). Residents near this site were reported to suffer from insomnia, anxiety and depression that were likely to be related to the proximity of the site and to the fear of associated adverse health effects (Deloraine 1995).

Shusterman (1992) reported on interviews conducted by the California Department of Health Services near three hazardous waste sites. The results indicated a positive relationship between the geographic area exposed to odorous emissions and the prevalence rates of several self-reported symptoms such as headache, nausea, eye and throat irritation, and sleep disturbances. Residents who lived in proximity to the site were divided into two groups according to their reported anxiety to living near the site and by their perception of the ambient air odor. A comparison between the two groups revealed that both variables exerted individual and synergistic effects on the frequency of symptom reporting.

**Study Limitations**

There are several limiting factors in performing studies such as these in communities. Firstly, the size of the populations residing around these disposal sites was usually small (Levine and Chitwood 1985; Zmirou 1994; Fleming and Bean 1999). This small population size may have resulted in an analysis with low statistical power and inconsistent results (Shy 1985). Secondly, disposal sites have a wide variety of
chemicals, and the health effects associated with complex mixtures have not been well documented. There may also be incomplete characterization of chemicals at the site (Paigen 1985, Zmirou 1994). In addition, in community studies, the exposure would most likely be low dose chronic exposures. Hence, the results of these studies would rely on the extrapolation of dose-response relationships to low doses (Zmirou 1994).

Another important limitation in these studies is the absence of actual individual exposure data. Exposure in these studies was determined indirectly, instead of by using biological monitoring methods. This may lead to misclassification of truly exposed and non-exposed subjects, and hence may alter the true risk (Geschwind 1992; Berry and Bove 1997; Croen 1997). Confounders in studies on cancer (e.g. smoking) and in studies on reproductive effects (e.g. sex of child) are usually taken into account in the analysis of the data. However, the effects of these confounders themselves may still not be clear, especially in heterogenous community populations (Geschwind 1992). In addition, some risk factors (such as maternal health for birth defect studies) may not have been available in the data source (Berry and Bove 1997).

Cancer, and the other chronic diseases mentioned, require long latency periods between the onset of exposure and the onset of the disease. This can be a limiting factor in these studies since this latency period has not yet elapsed in the study communities. Furthermore, community populations can be very mobile, hampering complete follow up of exposed persons. Hence, the absence of an association in the study at the time the study was conducted may not mean that an association does not exist (Goyer 1983).

Psychological effects may affect the reported prevalence of health effects, especially with commonly used subjective self-reported data such as headache, vertigo, insomnia, skin rash and upper airway irritation (Zmirou 1994). This subjectivity may also result in bias, both recall bias and interviewer bias, and may affect whether an association is drawn between the exposure(s) and the health effect(s). Recall bias may arise because persons with a particular symptom and/or exposure are likely to remember that experience differently from persons who have not exposed or ill. Interviewer bias may arise if the investigator elicits or interprets the information collected without being blinded to the disease and/or exposure (Hennekens and Buring 1987).

5.4. MSW WORKER EXPOSURE AND HEALTH EFFECTS

5.4.1 Introduction to Municipal Solid Waste Industry

The United States Environmental Protection Agency (EPA) defines solid waste as *Any garbage, or refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility, and other discarded material, including solid, liquid, semi-solid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities.*

Thus, MSW includes durable goods (e.g. appliances), non-durable goods (e.g. newspapers), containers and packaging, food wastes, yard trimmings, and miscellaneous
inorganic wastes, resulting from residential, commercial, institutional and industrial activity (U.S. EPA 1997a).

According to the EPA, in 1996, approximately 209 million tons of Municipal Solid Waste (MSW) was generated in the U.S. by residents, businesses, and institutions. This equates to approximately 4.3 lbs of waste per person per day. The figures below show the components of MSW (before recycling), and their respective percentages and tonnage collected (U.S. EPA 1997a).

![1996 Total Waste Generation - 209.7 Mil. Tons (before recycling)](chart)

Source: www.epa.gov/epaoswer/non-hw/muncpl/facts.htm

The management of MSW involves source reduction initiatives, recycling and composting activities, and disposal by landfilling or incineration. About 27% of the waste generated is recovered and recycled or composted. Another 17% is burned at combustion facilities and the rest (about 55%) is disposed of in landfills. (U.S. EPA 1997a).

There are several factors that affect how waste is managed within in a community. These factors include:

1. availability of suitable landfill space
2. population density
3. commercial and industrial activity
4. proximity of markets for recovered material
5. climatic and groundwater variations
(U.S. EPA 1997a)

In addition, the siting of waste disposal sites has raised a key social and legal issue. This issue relates to whether these sites are located in communities that are of a specific demographic nature. Over the past decade, there has been growing concern that minority and low-income populations may bear a disproportionate amount of adverse health
environmental effects. These communities are usually already affected by a high disease burden and have little or no political voice.

Robert Bullard in his 1994 article, “Overcoming Racism in Environmental Decisionmaking,” demonstrated that there is a positive correlation between the distribution of air pollution, the location of municipal landfills, incinerators and abandoned toxic waste sites, with low socioeconomic and minority communities (Bullard 1994). He noted that these industries would likely be situated in locations that offer the least political resistance, that is, the poor, overburdened communities (Bullard 1994).

The growing concern about the siting of disposal sites in disadvantaged communities led to the issuance of the Executive Order 12898 in 1994, which focused Federal agency attention on these issues (U.S. EPA 1997b). The U.S. EPA has developed the "Environmental Justice Strategy” which focuses on the Agency’s efforts in preventing minority and low-income communities from being subject to disproportionately high adverse environmental effects from activities such as landfills, toxic dumps, oil refineries, and highway construction (U.S. EPA 1999b).

The Environmental Justice initiative of the U.S. EPA has incorporated specific activities into the operation of the agency. These activities include:

- conducting environmental risk studies in communities where there are environmental justice concerns;
- using Geographic Information Systems (GIS) to identify communities with environmental justice concerns;
- enhancing and promoting outreach, communications, and partnerships for communities likely to have environmental justice concerns;
- developing ways in which to increase public involvement in siting and permitting.


To date, much of the work in the Environmental Justice Movement has focused on poor and minority communities around hazardous waste communities, however future research will need to evaluate the exposures and health effects of solid waste facilities on these communities.

5.4.2. Municipal Solid Waste Worker Exposure and Health Effects

There have been relatively few epidemiological studies performed in the published literature to assess the exposure and resulting health risk to solid waste workers. Mortality due to job related accidents are required by law to be reported to the Occupational Safety and Health Administration (OSHA). Workers’ compensation claims are a major source of disease and injury data (Englehardt et al. 1999). However, information on mortality from chronic diseases associated with occupational exposure is not as readily available. Thus, the potential level of actual acute and chronic morbidity in this industry may be under-reported.
The occupational exposures and health effects experienced by MSW workers have been extensively reviewed by Englehardt et al. (1999). The following table gives a brief summary of these possible exposures and health hazards related to solid waste industry workers. Similar to their hazardous waste colleagues, MSW workers are exposed to physical and chemical/biological hazards from their work. The physical hazards are associated with the waste itself (i.e. Heavy loads, sharp objects, inappropriately disposed of hazardous wastes) and the machinery; these physical hazards cause significant ergonomic health effects (particularly back injury), trauma (lacerations, amputations and burns), and even death.

Again similar to hazardous waste, the chemical/biological hazards are predominantly associated with the solid waste itself (i.e. Biological aerosols, inappropriately disposed of hazardous wastes, heavy metals, and VOCs). These exposures have been associated with acute and chronic health effects of multiple organ systems, including dermatological (skin rashes), respiratory (asthma), cardiovascular (myocardial infarctions), gastrointestinal (gastroenteritis), and neurologic (noise induced hearing loss).
### Summary of Reported Exposures and Health Effects of MSW Workers

<table>
<thead>
<tr>
<th>Reported Exposures</th>
<th>Reported Health Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy lifting</td>
<td>Disorders of the neck, shoulder and back, tendon diseases, extreme pain, lumbar disc prolapse, increased pulmonary ventilation</td>
</tr>
<tr>
<td>Machinery</td>
<td>Crushed body parts, broken bones, amputations, musculoskeletal aches, twisted muscles, sprains, permanent disability, noise-induced hearing loss</td>
</tr>
<tr>
<td>Traffic</td>
<td>Pedestrian accidents, broken bones, bruising, death</td>
</tr>
<tr>
<td>Chemicals improperly disposed of</td>
<td>Burns, fires, explosions, eye and skin irritation</td>
</tr>
<tr>
<td>Sharp and broken objects</td>
<td>Lacerations, punctures, abrasions</td>
</tr>
<tr>
<td>Unknown exposure</td>
<td>Coronary heart disease, myocardial infarction, angina, insufficiency</td>
</tr>
<tr>
<td>Explosions &amp; Fires</td>
<td>Burns, trauma</td>
</tr>
<tr>
<td>Diesel Exhaust</td>
<td>Eye irritation, asthma, decreased lung function, upper respiratory tract irritation, lung cancer</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>No documented health effects; potential cardiovascular, neurologic, asphyxiation</td>
</tr>
<tr>
<td>Polycyclic Aromatic Hydrocarbons</td>
<td>Skin irritation, potentially carcinogenic</td>
</tr>
<tr>
<td>Dust</td>
<td>Eye irritation, asthma, organic dust toxic syndrome (ODTS), non-allergic pulmonary disorders, impaired lung function</td>
</tr>
<tr>
<td>Microorganisms</td>
<td>Dry cough, exercise induced dyspnea, asthma, chronic bronchitis, ODTS, chest tightness, fever, chills, flu symptoms</td>
</tr>
<tr>
<td>Endotoxin</td>
<td>Fever, chest tightness, airway irritation, headache, joint and muscle pain, nausea, fatigue, non-allergic pulmonary disorders, impaired lung function, acute gastrointestinal symptoms</td>
</tr>
<tr>
<td>Gram-negative bacteria</td>
<td>Inflammation of airways, diarrhea, nausea</td>
</tr>
<tr>
<td>Fungal spores</td>
<td>Allergic alveolitis, asthma</td>
</tr>
<tr>
<td>Aerosols from waste</td>
<td>Eye and nose irritation, nausea, vomiting</td>
</tr>
</tbody>
</table>

(A summared from tables from Englehardt et al. 1999)

A review of the available literature on the occupational exposures and health risks of the solid waste worker illustrated many shortcomings in research design, which in turn further limits the knowledge of the waste industry and associated definitive health outcomes (Englehardt et al. 1999). Many of the reviewed studies had fundamental design flaws, including: a lack of control population, lack of exposure data (such as inadequate knowledge about the timing and order of the contamination and environmental exposure), scientific uncertainty about the impact of low-dose exposures, and the often inconclusive nature of findings, the latter probably due to small sample size and low power. Although, rarely mentioned as a problem, the underestimation of injury and disease probably exist due to under-reporting, especially for disease. Further research needs to be performed into the apparently substantial burden of morbidity and mortality among solid waste workers. Nevertheless, the existing results in the occupational setting are relevant for predicting possible exposures and health effects for communities surrounding solid waste facilities (Englehardt et al. 1999).

### 5.5. SOLID WASTE COMMUNITY EXPOSURE AND HEALTH EFFECTS
In general, in extrapolating from MSW workers to community exposures and their possible health effects from solid waste, the chemical and biological exposures are usually more relevant than the physical exposures. Nevertheless, non-occupational pedestrian accidents can occur from the waste collecting machinery as well as noise pollution, and improperly disposed of solid waste can lead to lacerations and other trauma for community people as well as MSW workers. Of note, in the developing world where the disposal of solid waste is relatively unregulated, physical, chemical and biological exposures and health effects have been documented in both workers and community people (Cointreau-Levine 1998).

5.5.1 Exposure

Landfill

Approximately 55% of the municipal solid waste in the United States is disposed of in landfills (U.S. EPA 1997a). In 1997, there were approximately 2,400 MSW landfills in the U.S., with the greatest number in the Southeast and Western regions of the country (U.S. EPA 1997a).

The main exposure sources for communities from MSW landfills are leachates and biogas. Leachate is formed when precipitation infiltrates wastes in the landfill and dissolves the contaminants (ATSDR and IDPH 1997). Biogas is created during the anaerobic decomposition of organic compounds. It is composed of a mixture of methane and carbon dioxide, and it may contain varying quantities of volatile organic compounds (VOCs) and sulfur-based substances (Goldberg 1995a).

Both biogas and leachate from MSW landfills contain many chemicals, for which their associated health and other hazards have not yet been established. In the U.S., about 1,000 new chemicals are being developed each year and of the more than 65,000 in use today, only about 200 are regulated and analyzed for, in MSW leachate (Lee and Jones Lee 1994).

It is important to consider that the older landfills, private landfills and landfills whose locations are unrecorded (unknown), are likely to pose more of a threat to communities than the currently “properly” operated ones.

Leachate

Although modern day landfills are designed to collect leachate and prevent its infiltration into groundwater, studies have shown that leachate may contaminate groundwater due to faulty design and/or construction of plastic landfill liners and due to the migration of VOCs through synthetic flexible membrane and compacted clay liners even at dilute concentrations (Schrab 1993; Laine and Miklas 1989; NUS Corp 1988; Haxo and Lahey 1988; Johnson 1989).
The sources of contaminants in landfill leachate include MSW and its degradation products, illegally disposed hazardous waste, and legally disposed small quantity generator hazardous waste (Schrab 1993). For instance, the Agency for Toxic Substances and Disease Registry (ATSDR and IDPH 1997) investigated two Illinois MSW landfills, Yeoman Creek and Edwards Fields, suspected of receiving unknown amounts of PCBs (ATSDR and IDPH 1997).

**Biogas**

Biogas is created during the anaerobic decomposition of organic compounds. It is composed of a mixture of methane and carbon dioxide, and it may contain varying quantities of volatile organic compounds (VOCs) and sulfur-based substances (Goldberg 1995a). Biogas from landfills are the largest source of methane emissions in the U.S. (U.S. EPA 1999a). Methane is a colorless and odorless gas, but it is highly explosive and it is considered to be a “greenhouse” gas (Jones and Lee-Jones 1994).

Landfill gas can migrate both vertically and laterally through soil. Thus, there is the potential for off-site migration. The degree of exposure to biogas compounds depends on the pattern of dispersal, the ability of compounds to enter homes (especially via lateral migration in the soil) and personal activity patterns (Schrab 1993). The off-site migration of biogas present several hazards to the surrounding community. These hazards include the potential for explosions and adverse human health associated with the gases present.

Today landfills are required by law to set up gas collection systems at the site. The gas collected is then flared off. This flaring may be another source of public health concern. It is possible for toxic dioxins to be formed during the burning of the landfill gas. However, collection systems can be designed so as to minimize the conditions that lead to dioxin formation (Lee and Jones-Lee 1994).

Other gases are also contained in biogas and some have odors. These odors can be emitted miles from the MSW site and provide a tracer for the non-odorous gases that are also emitted. Since biogas can contain several hazardous chemicals, the detection of landfill odors away from the site, may signal the need for off-site ambient air monitoring to avoid any possible public health hazards due to the emissions (Lee and Jones-Lee 1994). Malodorous conditions can bring about many adverse health reactions. Shusterman (1992) reported that symptoms such as headache, nausea, throat irritation and sleep disturbances, can be associated with noxious environmental odors. Odors can also exacerbate pre-existing medical conditions such as bronchial asthma. Odors are also known to increase sensitivity to nausea during pregnancy (Shusterman 1992).

In reference to air emissions from landfills, Lee and Jones-Lee (1994) reported that although landfills are required to install collection systems to minimize the off-site transportation of explosive methane, there are no regulations in place today to control the off-site migration of highly malodorous gases from the landfill.
**Regulations**

When discussing possible exposures to communities in proximity to solid waste sites, it is important to consider the standards promulgated with respect to solid waste disposal facilities. These standards could give insight to possible areas for exposure and health studies, especially in situations where the standards were not upheld.

The EPA issued the “Solid Waste Disposal Facility Criteria: 40 CFR Part 258” on October 9th, 1991, under the authority of both the RCRA and Section 405 of the Clean Water Act. This criteria was created to provide a minimum national criteria for all solid waste landfills that are not regulated under Subtitle C of RCRA, and that:

- Receive MSW or
- Co-dispose sewage sludge with MSW
- Accept non hazardous municipal waste combustion ash

(U.S. EPA 1993)

Some major issues raised in these criteria have a direct impact on the level of exposure to communities living in proximity to landfill facilities. These issues include the location of the landfill; the choice of cover material used; air emission control and public access to the landfill facilities (U.S. EPA 1993).

**Incineration**

There has been a call for research into finding alternative ways of disposing of solid waste, other than by landfiling. As such, incineration of solid waste is becoming more prevalent (Bresnitz 1992). Studies have found that, as with hazardous waste incineration, potential toxic substances present in the by-products of solid waste incineration (air-borne emissions and solid residues of ash and slag) include:

- heavy metals (lead, cadmium, mercury, arsenic
- total respirable particulates
- dioxins
- furans
- polycyclic aromatic hydrocarbons
- solvents such as benzene

(Mozzon 1987; Lisk 1988; Kellam 1989; Denison and Silbergeld 1989; Mumma 1990). The EPA siting requirements for new incinerator facilities include an analysis of the impact of the newly proposed facilities on the ambient air quality, visibility, soils, and vegetation. The results of these analyses must be made available for public comment.

With regards to the emissions from incinerators, the EPA (1997a) stipulates the following:
• if the ash tests hazardous (using the RCRA Toxic Characteristics Leaching Procedure) it must be managed as a hazardous waste. If it does not test hazardous, then it may be disposed in a municipal waste (non-hazardous landfill);
• there must be continuous emission monitoring for sulfur dioxide, nitrogen oxides and carbon monoxide;
• there must be annual stack testing for particulates, lead, cadmium, mercury, dioxins/furans, hydrochloric acid and fugitive ash.

**Composting**

Composting of wastes reduces the amount of waste requiring disposal in landfills and incinerators. This method relies on a controlled biological decay process that involves many species of microorganisms and invertebrate animals.

Composting systems must be carefully constructed and maintained to reduce any potential adverse effects to those exposed to these sites. Properly constructed and maintained sites reduce access to pests such as rodents, raccoons and flies, which are human disease vectors. These sites also restrict the materials being composted. Materials such as fish and meat scraps, dairy products and animal feces, should not be composted since they can harbor human pathogens that can survive the composting process. Another source of potential adverse human health effect may result from the production of methane gas and other malodorous compounds (such as sulfur dioxide), if anaerobic composting is the technique employed (U.S. EPA 1997a).

**Studies on Exposure**

There have been very few studies on the possible exposure and health risks to community populations residing near to MSW sites. The studies on exposure performed thus far have looked at the composition of the gaseous effluents, and the acute and genetic toxicity of leachate (Hofler 1986; ATSDR and IDPH 1997). A few additional studies have been performed the possible health hazards associated with these exposures. These studies looked at the incidence of cancer, of low birth weight and of pre-term births in populations in close proximity to MSW landfills. These studies are outlined below:

Schrab *et al.* (1993) assessed the environmental hazards to groundwater and the genetic and acute toxicities of four MSW landfill leachates. The four sites chosen were representative of landfills at various stages of completion with various waste streams (MSW with and without hazardous waste, and residential). The leachate and groundwater samples were also analyzed for organic constituents and its chemical attributes were used to calculate the estimated cumulative cancer risk for each sample. The *Salmonella* microsome (Ames test) mutagenicity bioassay, the *Bacillus subtilis* DNA repair bioassay, and the diploid *Aspergillus nidulans* chromosome damage bioassay were used to assess the genetic toxicities of the landfill leachate and groundwater samples. Gas chromatography and gas chromatography/mass spectrometry were used to identify
organic constituents. The estimated cumulative cancer risk for each sample was calculated using the method developed by Crouch et al. (1983).

The results showed that leachate from the MSW site receiving primarily residential waste, could be more genetically toxic, and at least as acutely toxic, as the leachate from the sample taken from the co-disposal site. Chronically toxic volatile, semi-volatile or non-volatile organic compounds were found in all 5 samples. MSW leachate and the groundwater samples contained several of these compounds in excess of the promulgated USEPA regulatory standard for potable water. The leachate from the MSW sites had an estimated cumulative cancer risk on the same order of magnitude as leachates from co-disposal and hazardous waste sites.

Höfler et al. (1986) performed a study to assess the environmental impact and commercial usability of the biogas formed by the anaerobic decomposition of waste deposited in a large landfill near Wannsee in West Berlin. The landfill contained about 11 million cubic meters of waste, most of it composed of household garbage, but with a substantial amount of unknown origin. In this study, chemical analysis was performed to determine the identity of other compounds found in the biogas. These were found to comprise of many halogenated compounds, especially chlorinated compounds. The most prominent chlorinated compound was tetrachloroethylene, followed by trichloroethylene.

The Agency for Toxic Substances and Disease Registry (ATSDR) and the Illinois Department of Public Health (IDPH) looked at the possible exposure of communities in the vicinity of two sites in Waukegan, Lake County, Illinois (1997). These two sites were the Yeoman Creek and the Edwards Field Landfill; both landfills were not currently in operation and were covered. The Edwards Field Landfill received municipal wastes and is suspected of having received polychlorinated biphenyls (PCBs). The Yeoman Creek Landfill received landscape and demolition wastes, domestic garbage, sludge, and had also reportedly received an unknown amount of PCBs. The only known or suspected health hazard created by these sites was the possible leakage of leachate from the Yeoman Creek into Lake Michigan. However, due to the volume of Lake Michigan and the low level of possible contamination of Yeoman Creek, any contamination due to leachate would have a negligible effect on the potable water obtained from Lake Michigan. From the exposure data collected at the sites, they determined that the sites posed no apparent public health hazard, although no exposure or health studies were performed in the surrounding communities. No adverse health outcomes had been reported by the surrounding communities at the time of this study, although no formal surveillance system was established.

5.5.2 Municipal Solid Waste Health Effects

Few studies have been performed to look at the health effects associated with living in proximity to MSW landfills and incinerators. These studies are difficult to perform, in part, due to the inherent limitations of epidemiological community studies. As discussed above, these flaws include small study populations, reporting bias, short
latency time, and the lack of individual exposure information. Studies on the association between proximity to MSW landfills and incidence of reproductive effects and cancer are outlined below.

**Acute and Subacute Health Effects**

The following study is included in this Review as an example of how easily communities can be affected by what is seemingly considered “safe” solid waste. Tosi et al. (1994) investigated a strange epidemic paralysis in Saval, Italy. The outbreak affected 41 people during the period of October 1942 and June 1943. Members of a farm owner’s family and the resident laborers were affected by a form of paralysis. One of the members of the family became ill 20 days after returning to the farm. Only one person who was never on the farm became ill, however this woman ate a vegetable grown on the farm. Some of the animals on the farm were similarly affected. The symptoms presented mirrored the description of the tri-ortho-cresyl phosphate (TOCP) poisoning in 1963 (Scheid 1963). The farm received rags, waste paper, glass and metals for sorting (as part of its recycling activities). It is suspected that tins and drums with residual military engine oil, containing TOCP, were brought to the farm leading to contamination of the soil with subsequent contamination of the crops and the human poisonings.

Goldberg et al. (1995b) conducted a case-control study of infants born to women living near the Miron Quarry landfill in Montreal, Canada. Miron Quarry has been in operation since 1968 and served as a repository for domestic, commercial, and industrial wastes. The main environmental concerns were the amount of toxic chemicals on the site, and the production of vapors and biogas. Although leachates were also produced, their potential to contaminate groundwater was not a primary health concern because Montreal obtains its potable water from other sources. The major health concern lay in the release of biogas into the ambient air and soil. Other health considerations included exposure to noise, diesel fumes, and dust.

Some of the substances in the biogas produced at MSW sites were believed to interfere with the development of the embryo and fetus, possibly causing infertility, intrauterine death, spontaneous abortions, low birth weight, and congenital anomalies. These effects are highly dependent on the timing and levels of the exposure. This study demonstrated an increased risk for "small for gestational age" and low birth weight among children of women residing near the Miron Quarry MSW landfill. However, no definitive conclusion could be drawn with regards to a possible association of biogas exposure to these findings: the individual actual exposure data and information on confounders (such as maternal smoking habits or length of residence in potential exposure area) were unknown.

**Chronic Health Effects**

The New York State Department of Health (DOH) conducted a case-control study to evaluate the cancer incidence among people living near 38 New York landfills. The purpose of the study was to ascertain whether people living near to these landfills had an
increased risk of cancer compared to people living elsewhere due to exposure to the hazardous volatile organic compounds (VOCs), which may be released from wastes in a landfill (ATSDR 1989).

The 38 landfills selected for the study provided strong evidence that the landfill contents were creating methane gas. The potential exposure areas were defined as the area around the landfill boundary where people may have been exposed to landfill chemicals through soil gas moving into homes. The study looked at all the cases of leukemia, non-Hodgkin’s lymphoma, liver, lung, kidney, bladder, and brain cancer diagnosed from 1980 to 1989 for people who lived in the zip codes containing the selected landfills, at the time of diagnosis. The study then focused on whether people with cancer were more likely than people without cancer to live in the potential exposure areas.

There was no statistically significant elevation of cancer risk for liver, lung, kidney, brain, and non-Hodgkin’s lymphoma. For those within the potentially exposed areas, the study found a statistically significant elevation of risk for bladder cancer (OR = 5.52; 95% CI = 1.67–18.2) and leukemia in females (OR = 5.13; 95% CI = 1.45-18.1). In males, there were non-significant elevations of risk for bladder cancer (OR = 1.30; 95% CI = 0.42–3.97) and leukemia (OR = 2.16; 95% CI = 0.65–7.14).

Goldberg et al. (1995a) performed a second study of persons living near the Miron Quarry Solid Waste Landfill in Montreal, Canada to evaluate the cancer incidence. The residents who lived near the site voiced concerns about possible health effects associated with residing near the landfill. This concern, coupled with the fact that a number of the VOCs found in the biogas were recognized or suspected human carcinogens, prompted the city of Montreal to conduct a cancer-risk assessment study of the site.

The analysis of the data collected in this study suggested that there may be increased risks for cancers of the stomach, liver, lung, prostate, and cervix uteri among those residing near the Miron Quarry MSW landfill site. In women, two sites of cancer showed significant positive associations: stomach cancer (RR = 1.2; 95% CI = 0.9–1.5) and cancer of the cervix uteri (RR = 1.2; 95% CI = 1.0–1.5). Among men, four sites of cancer were significantly higher than expected: cancer of the stomach (RR = 1.3; 95% CI = 1.0–1.5); the liver and intrahepatic bile ducts (RR = 1.3; 95% CI = 0.9–1.8); the trachea, bronchus, and lung (RR = 1.1; 95% CI = 1.0–1.2); and the prostate (RR = 1.2; 95% CI = 1.0–1.4). Nevertheless, the authors concluded that because of the unavailability of actual exposure sampling data and the absence of information on possible confounders (such as length of residence), they were unable to definitively say whether the excess risks found represented true associations with exposure to biogas.

5.6 SUMMARY OF KNOWN CONCLUSIONS

There is very little scientific literature available on the exposures and health effects in communities surrounding Municipal Solid Waste (MSW) disposal sites. In the
case of landfills, the main exposure source would be biogas and leachate. In solid waste incineration, exposures could result from exposure to air-borne emissions and solid residues (ash and slag). For composting facilities, there is the potential for exposures to disease vectors, pathogens, methane gas and malodorous gases.

In reviewing the health impact of MSW waste sites, it is important to review studies performed on hazardous waste sites because of the overlap between these two industries due to illegal dumping and misclassification of wastes. The physical and biological exposures of hazardous and MSW waste sites appear to be very similar. Although quantitatively less, even the chemical exposures can be similar; several studies have found that the resultant emissions from MSW sites may have similar chemical properties as that from hazardous waste sites.

Hazardous waste present a mixture of potential hazards, which include chemical, physical and biological hazards. The short-term human health effects that have been investigated in relation to residential proximity to hazardous waste sites, include reproductive effects and developmental effects in children. Studies have suggested that there may be an association between these outcomes and exposures to the emissions from toxic disposal sites. Long-term effects, such as cancer, have also been looked at, and some positive correlation has been found. Another important human health effect is the psychological impact that proximity to these sites have on communities. These include elevated levels of anxiety, insomnia, depression, headaches and nausea.

Municipal solid waste disposal sites also present a mixture of physical, chemical and biological hazards. Physical hazards manifest themselves in injuries such as strains, sprains, lacerations, amputations, contusions, and even, death; these physical exposures are primarily seen among solid waste workers, rather than surrounding communities. However, chemical and biological hazards are associated with the inappropriate disposal of the waste itself and with emissions from the sites. These hazards have been found to be associated with both acute and chronic human health effects in solid waste workers. These health effects include dermatological; respiratory; cardiovascular; gastrointestinal and neurologic effects.

Modern landfills have been designed to collect leachate and biogas, and incineration plants designed to utilize high temperatures, and scrubbers and other pollution control devices; these are main sources of chemical exposure to the surrounding community. Nevertheless, studies have shown that leachate may contaminate groundwater due to faulty design and/or construction; there is still the possibility of migration of VOCs through the synthetic and compacted clay liners used; and air pollution is possible even with extensive control devices.

Epidemiology has been the major source of information on the health effects associated with living near MSW sites. These studies are limited because of several factors including the small study populations, recall bias, lack of actual exposure data, and lack of necessary latency periods for chronic exposures and diseases. Studies have shown that there is a possibility that living in proximity to these sites may increase the
risk of cancer and reproductive effects. However due to the flaws in these studies, the estimation of these risks are still questionable and warrant further investigation.

5.7. RECOMMENDATIONS

The primary recommendation is that primary prevention of exposure, and thus of health effects, is the best policy for both solid waste workers and communities surrounding solid waste facilities. Therefore, every effort should be made to minimize and monitor possible exposures from the solid waste and its by-products.

Most of the studies reviewed in this Report have had one major common flaw: the absence of actual exposure data. Therefore, one of the primary recommendations for future studies would be to implement the use of exposure monitoring. The establishment of both exposure and health effect surveillance programs would be an important step. In general, since the workers usually experience higher exposures than surrounding communities, and are easier to identify and follow, acute and chronic studies of solid waste workers exposure and health effects are recommended in the real world of limited resources. In addition to humans, other more sensitive biological indicators such as plant and animal species could be used in both exposure and effect surveillance.

Since it has been noted that there is incomplete characterization of chemicals present at disposal sites, it is important for health officials to follow up on reports of any health and environmental hazards surrounding MSW disposal sites since it is not fully known what effects can and cannot be associated with exposure to disposal site emissions. In particular, the literature suggests that both the MSW industry and health officials should also focus their attention on possible adverse psychological effects that may be prevalent in those communities as a result of their proximity to the site. These psychological effects may exacerbate certain physiological conditions, and may exaggerate the true association between the site emissions and the potential for effects on the public health.

The results indicated in this Report should be used as an impetus to carry out more detailed studies into the possible health effects of low-level biogas and chemical exposures in both solid waste workers and communities. Studies using more acute health indicators such as reproductive and respiratory effects to investigate a causal association between biogas and leachate exposure and adverse health outcomes should be conducted. These outcomes do not require a latency period such as is the case of chronic disease such as cancer. Nevertheless, additional studies are needed to take into account the long latency period of some of the possible chronic health effects.

One recommendation in the siting of these sites should be the mandatory inclusion of a sufficient buffer area around the site. This buffer zone would help to dilute any effects that the emissions may have in the surrounding community. It would also be useful to set up environmental monitoring devices in areas beyond the perimeter of the site as an early warning device.
Medical surveillance should also be implemented in communities around these sites, to survey any acute health effects that may arise. These acute effects could include reproductive and respiratory effects. The former can be easily obtained from birth certificate and State registries, and the latter, from prescription and hospital records.

It is highly recommended that future studies look more closely into the environmental justice concerns associated with the location of these disposal sites. Communities that can benefit from the Environmental Justice focus include those with low socioeconomic status and those that have a high disease burden. It would be useful to set up surveillance systems in these communities since they may provide an adequate population sample for valid epidemiological studies to be conducted.

Finally, it is imperative that the reports on existing studies on exposures and health effects in communities surrounding landfills be published and made available for review. There are several highly publicized landfills situated in communities, such as the Freshkills landfill in Staten Island, for which reports are unavailable for review.

5.8. REFERENCES


Fleming LE, Bean JA, Stabile IK, Teaf TM. The Role of Epidemiology in Evaluating the Potential Human Health Consequences of Hazardous Waste Incineration. in:


National Institute of Environmental Health Sciences (NIEHS) Website 2000 www.niehs.nih.gov
National Institute for Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA), United States Coast Guard (USCG) and United States Environmental Protection Agency (EPA). Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities. October 1985.


## Appendix A: Summary of Important References

<table>
<thead>
<tr>
<th>Citation</th>
<th># of Subjects</th>
<th>Description of Subjects</th>
<th>Time Period</th>
<th>Statistics</th>
<th>Health Effects</th>
<th>Selected Magnitude</th>
<th>Other Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poulsen et al., 1995a</td>
<td>N/A</td>
<td>Waste Collectors</td>
<td>N/A</td>
<td>Contains incidence rates, RR, prevalence, and concentrations</td>
<td>Injury, musculoskeletal, mucous membrane, pulmonary, respiratory, cardiovascular</td>
<td>Incidence 94.6/1000/yr (RR 5.6 (5.4-5.9) injuries; Incidence 0.84/1000/yr (RR 1.6 (1.2-2.0) skin; Incidence 3.5/1000/yr (RR 1.9 (1.6-2.2) musculoskeletal; Incidence 0.58/1000/yr (RR 2.6 (1.8-3.9) allergic respiratory; Incidence 0.36/1000/yr (RR 6.0 (3.6-10.0) infectious diseases</td>
<td>Compared to total Danish Workforce; A very thorough review article; one of the articles in a series of Danish reviews of the industry</td>
</tr>
<tr>
<td>Campbell, 1993</td>
<td>N/A</td>
<td>Waste Collectors (USA)</td>
<td>N/A</td>
<td>None</td>
<td>Injury and accidents</td>
<td>A good article for work practice related to collectors; no citations</td>
<td></td>
</tr>
<tr>
<td>Hansen et al, 1997</td>
<td>1938 males</td>
<td>Waste Collectors (Denmark)</td>
<td>1 year</td>
<td>Prevalence</td>
<td>Respiratory symptoms</td>
<td>Prevalence 1.3 (1.0-1.7)cough, 1.4 wheeze (1.0-1.8), 2.3 (1.3-4.3) chronic bronchitis</td>
<td>Compared to Park Workers; collected micro-organisms with positive dose response for reported chronic bronchitis</td>
</tr>
<tr>
<td>Verbeek et al., 1993</td>
<td>92 males</td>
<td>Refuse Collectors (Amsterdam Netherlands)</td>
<td>2 years</td>
<td>Prevalence</td>
<td>None</td>
<td>Incidence 15/1000 person years disabling injuries</td>
<td>Examined health intervention based on earlier Dutch study; study failed, design issues</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Citation</th>
<th># of Subjects</th>
<th>Description of Subjects</th>
<th>Time Period</th>
<th>Statistics</th>
<th>Health Effects</th>
<th>Selected Magnitude</th>
<th>Other Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1997</td>
<td>81 males</td>
<td>Collectors (Brazil)</td>
<td></td>
<td>Incidence</td>
<td>Injury</td>
<td>injuries/81 workers/yr; working man-hours; 30% wounds; 65%</td>
<td>National Institute of Social Security and reports with possible reporting bias</td>
</tr>
<tr>
<td></td>
<td>15 males</td>
<td>Waste (Japan)</td>
<td>5 days</td>
<td>air and in urine</td>
<td>PAH exposure</td>
<td></td>
<td>exposure and the degree of exposure collectors; smoking major small study group</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>observational study; no control group; only provided good background</td>
</tr>
<tr>
<td>Gellin, 1985</td>
<td></td>
<td>Waste Collectors Francisco, CA</td>
<td></td>
<td>Prevalence</td>
<td>Dermal — punctures, lacerations and calluses</td>
<td></td>
<td>examined injury and related issues in waste group; only one company</td>
</tr>
<tr>
<td></td>
<td>667 (662 males and 5 females)</td>
<td>Employees of a Waste Company (Denmark)</td>
<td></td>
<td>ORs and prevalence</td>
<td></td>
<td>Prev 15% back, 12% knee, 12% hand injuries</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>12 (10 males females)</td>
<td>Workers at Handling Plant</td>
<td>Study design was</td>
<td>Concentrations of bacteria, numbers</td>
<td>Mucous membrane, respiratory, pulmonary</td>
<td></td>
<td>study design; shows health effects but</td>
</tr>
<tr>
<td>Citation</td>
<td># of Subjects</td>
<td>Description of Subjects</td>
<td>Time Period</td>
<td>Statistics</td>
<td>Health Effects</td>
<td>Selected Magnitude</td>
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<tr>
<td>Ivens et al., 1997</td>
<td>2,858 males</td>
<td>Waste Collectors and Municipal Workers (Denmark)</td>
<td>N/A</td>
<td>Prevalence Proportional Ratio (PPR)</td>
<td>Gastrointestinal</td>
<td>PPR 1.51 nausea for loaders</td>
<td>Control group; Thorough evaluation of GI symptoms and how they are work related</td>
</tr>
<tr>
<td>Malmros et al., 1992</td>
<td>9 males</td>
<td>Waste Sorters (Denmark)</td>
<td>2 years</td>
<td>Case series, concentrations of bacteria</td>
<td>Asthma</td>
<td>individual results</td>
<td>Case series of occupational disease; plant modifications decreased airborne bacterial but not fungi</td>
</tr>
<tr>
<td>Swanson et al., 1992</td>
<td>3,792 males (94 Garbage Collectors)</td>
<td>Lung Cancer Cases (Detroit, Michigan)</td>
<td>1 phone interview</td>
<td>ORs</td>
<td>N/A</td>
<td>OR 2.6 (0.2-27.7) white men OR 12.5 (1.0-156.1) black men</td>
<td>Compared to colon cancer; Examined the relationship of job to cancer</td>
</tr>
<tr>
<td>Rendleman and Feldstein, 1997</td>
<td>106 people</td>
<td>Urban Recycling Workers (NYC, NY)</td>
<td>5 months</td>
<td>Prevalence</td>
<td>Dermal, respiratory, gastrointestinal</td>
<td>Prev 32% injuries; 46% lacerations</td>
<td>Examined homeless recyclers and related health effects</td>
</tr>
<tr>
<td>Sigsgaard et al., 1994a</td>
<td>72 males</td>
<td>Garbage-Handling and Recycling Workers (Denmark)</td>
<td>1 exam per employee</td>
<td>Concentrations, ORs</td>
<td>Respiratory, mucous membrane, gastrointestinal</td>
<td>Prev 27% eye problems; 14% upper respiratory tract Sx; 23% skin OR 5.43 (2.01-14.64) chest tightness; OR 17.19 (1.86-158.52) organic dust toxic syndrome</td>
<td>Compared to water workers; Good study design, detected health outcomes related to concentrations</td>
</tr>
<tr>
<td>Sigsgaard et al., 1994b</td>
<td>99</td>
<td>Recycling Workers (Denmark)</td>
<td>Sampling and Interview</td>
<td>Concentrations and prevalence</td>
<td>Examined correlation of lung function and dust</td>
<td></td>
<td>Total dust and endotoxins; no outside control group</td>
</tr>
<tr>
<td>Lundholm and</td>
<td>11 males 2</td>
<td>Compost</td>
<td>1 month</td>
<td>Concentrations of</td>
<td>Gastrointestinal and</td>
<td>Prev 30% GI and Neuro</td>
<td>Made an association</td>
</tr>
<tr>
<td>Citation</td>
<td># of Subjects</td>
<td>Description of Subjects</td>
<td>Time Period</td>
<td>Statistics</td>
<td>Health Effects</td>
<td>Selected Magnitude</td>
<td>Other Comments</td>
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<tr>
<td>Malkin et al., 1992</td>
<td>56 males</td>
<td>Incinerator Workers (NYC, NY)</td>
<td>1 month</td>
<td>Pb levels in blood, $\frac{1}{2}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bresnitz et al., 1992</td>
<td>86 males</td>
<td>Workers at a Incinerator Plant (Philadelphia PA)</td>
<td>5 days</td>
<td>Concentrations, Prevelance, ORs</td>
<td>Hypertension, urine abnormalities, pulmonary, respiratory</td>
<td>Prev 24% hypertension with proteinuria</td>
<td>Few health effects and lower levels of exposure; design issues</td>
</tr>
<tr>
<td>Gelberg, 1997</td>
<td>238 males</td>
<td>Employees at a Landfill Site (NYC, NY)</td>
<td>1 interview</td>
<td>Prevalence, Chi-square, ORs, prevalence</td>
<td>Dermal, neurologic, respiratory, pulmonary, mucous membrane, gastrointestinal, musculoskeletal</td>
<td>Prev 24.8% skin problems OR 2.07 (1.11-3.83) skin OR 2.14 (1.35-3.38) respiratory</td>
<td>Compares on and off site workers; Very good study; one site</td>
</tr>
<tr>
<td>Cimino, 1975</td>
<td>11,500</td>
<td>Sanitation workers (NYC, NY)</td>
<td>N/A</td>
<td>Prevalence, loose Relative Risks</td>
<td>Injury, pulmonary, respiratory, neurologic, dermal, cardiovascular</td>
<td>Prev 12% COPD among firemen; 5x increased prevalence injury; RR 2 for heart disease; Projections of costs to the city</td>
<td>Compare to injury statistics of other occupations; Although outdated, good background on procedure and working habits</td>
</tr>
<tr>
<td>Poulsen et al., 1995b</td>
<td>N/A</td>
<td>Recycling, Compost, Landfill and Incinerator Workers</td>
<td>N/A</td>
<td>ORs, RRs, concentrations</td>
<td>Dermal, mucous membrane, respiratory, pulmonary, cardiovascular, neurologic, musculoskeletal</td>
<td></td>
<td>Very good overview of all systems; one of a series of Danish review articles</td>
</tr>
<tr>
<td>Rylander, 1980</td>
<td>Females</td>
<td>Workers (Gothenburg, Sweden)</td>
<td>bacteria</td>
<td>neurological symptoms</td>
<td></td>
<td>symptoms</td>
<td>between health effect and exposure; one site, no control group</td>
</tr>
<tr>
<td>Citation</td>
<td># of Subjects</td>
<td>Description of Subjects</td>
<td>Time Period</td>
<td>Statistics</td>
<td>Health Effects</td>
<td>Selected Magnitude</td>
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<tr>
<td>Scarlett et al., 1990</td>
<td>104 males</td>
<td>Incinerator Workers from 7 Sites (USA)</td>
<td>3 months</td>
<td>Prevalence, ORs, urinary concentrations</td>
<td>Urinary mutagens</td>
<td>OR 9.7 (1.2-76.7) urinary mutagens</td>
<td>More abnormalities in incinerator workers than the control groups due to exposure to toxins</td>
</tr>
<tr>
<td>Rapiti et al., 1997</td>
<td>532 males</td>
<td>Incinerator Workers (Rome, Italy)</td>
<td>27 year retropective cohort</td>
<td>Standardized Mortality Ratios, prevalence</td>
<td>Gastric cancer, but a reduction on all-cause mortality</td>
<td>SMR 2.79 (0.94-6.35) gastric cancer</td>
<td>Design issues</td>
</tr>
<tr>
<td>Schecter et al., 1995</td>
<td>21 males</td>
<td>Waste Incinerator Workers (3 Cohorts) (Germany)</td>
<td>2 years</td>
<td>Dioxin concentrations in blood</td>
<td>Blood PCDDS and PCDFs</td>
<td>Unexposed worker control group; Exposure to incinerator slag and ash may increase blood levels of PCDDs and PCDFs</td>
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<tr>
<td>Angerer et al., 1992</td>
<td>53 (3 women and 50 men)</td>
<td>Municipal Waste Incinerator Workers (Germany)</td>
<td>Each worker was examined</td>
<td>Blood concentrations, linear correlations</td>
<td>Urinary and plasma pyrolysis products of organic substances</td>
<td>Higher concentrations in incinerator workers than controls, probably due to exposure</td>
<td></td>
</tr>
<tr>
<td>Ma et al., 1992</td>
<td>37 males</td>
<td>Incinerator Workers From 4 Plants (USA)</td>
<td>3 months</td>
<td>Chi-square, Kappa, urine, concentrations, prevalence</td>
<td>Urinary mutagens</td>
<td>Prev 21% mutagens in urine</td>
<td>Compared to water treatment plant workers; Poor repeatability; healthy worker effect +/- variable exposures</td>
</tr>
<tr>
<td>Gustavsson, 1989</td>
<td>176 males</td>
<td>Workers at Municipal Incinerator Plant (Stockholm, Sweden)</td>
<td>65 year retrospective</td>
<td>Mortality rates from death Certificates, SMR</td>
<td>Cancers, neurologic, pulmonary, respiratory, gastrointestinal, death</td>
<td>SMR 3.55 (1.62-6.75) lung cancer</td>
<td>Compared to local and national rates; Good information on disease; single site</td>
</tr>
<tr>
<td>Citation</td>
<td># of Subjects</td>
<td>Description of Subjects</td>
<td>Time Period</td>
<td>Statistics</td>
<td>Health Effects</td>
<td>Selected Magnitude</td>
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<td>Contreau-Levine, 1998</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Prevalence, RR, ORs</td>
<td>A review of health effects and exposures</td>
<td></td>
<td>A thorough review of entire industry with emphasis on international developing nations</td>
</tr>
<tr>
<td>Mozzon et al., 1987</td>
<td>N/A</td>
<td>1 Incinerator, 1 Transfer Station and 3 Landfills (Canada)</td>
<td>6 months</td>
<td>Concentrations and prevalence</td>
<td>None</td>
<td></td>
<td>Examined three types of facilities and the high risk of exposure to workers</td>
</tr>
<tr>
<td>Rukkonen et al., 1987</td>
<td>N/A</td>
<td>5 Landfill Sites (Finland)</td>
<td>6 months</td>
<td>Concentrations</td>
<td>None</td>
<td></td>
<td>Good information on landfill conditions and potential exposures</td>
</tr>
<tr>
<td>Wilkins, 1994</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Concentrations of VOCs</td>
<td>None</td>
<td></td>
<td>Provides information on potential exposures due to household waste</td>
</tr>
<tr>
<td>Keep America Beautiful, Inc., 1996</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>None</td>
<td>None</td>
<td></td>
<td>Overview of integrated waste management; good background information</td>
</tr>
<tr>
<td>Nielsen et al., 1994</td>
<td>N/A</td>
<td>N/A</td>
<td>2 weeks</td>
<td>Concentrations</td>
<td>None</td>
<td></td>
<td>Examined fungus, bacteria</td>
</tr>
<tr>
<td>Heida et al., 1995</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Concentrations of fungi and bacteria</td>
<td>None</td>
<td></td>
<td>Detected high levels of bacteria and fungi which could cause health effects</td>
</tr>
<tr>
<td>Deportes et al., 1997</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Concentrations and components of MSW compost</td>
<td>None</td>
<td></td>
<td>Some background on composting procedure and composition</td>
</tr>
<tr>
<td>Citation</td>
<td># of Subjects</td>
<td>Description of Subjects</td>
<td>Time Period</td>
<td>Statistics</td>
<td>Health Effects</td>
<td>Selected Magnitude</td>
<td>Other Comments</td>
</tr>
<tr>
<td>---------------------</td>
<td>---------------</td>
<td>-------------------------</td>
<td>-------------</td>
<td>------------</td>
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</tr>
<tr>
<td>Kim et al., 1995</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Concentrations of VOCs</td>
<td>None</td>
<td>Composition and background on compost</td>
<td></td>
</tr>
<tr>
<td>Tisdell and Breslin, 1995</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Concentrations of heavy metals</td>
<td>None</td>
<td>Offered information on 3 facilities and examined differences</td>
<td></td>
</tr>
<tr>
<td>He et al., 1995</td>
<td>N/A</td>
<td>N/A</td>
<td>2 months</td>
<td>Concentrations</td>
<td>None</td>
<td>Examined physical and chemical properties of 9 incinerator plants</td>
<td></td>
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<tr>
<td>Anderson, 1987</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Prevalence, projections and figures</td>
<td>Reviews potential health effects</td>
<td>A review article that examines three case studies of communities exposed to hazardous and solid waste</td>
<td></td>
</tr>
<tr>
<td>Pahren, 1987</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>ORs and concentrations</td>
<td>Reviews potential and detected health effects</td>
<td>Concentrates mostly on health effects due to microorganism exposure</td>
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</tr>
<tr>
<td>Landrigan, 1983</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>None</td>
<td>None</td>
<td>Examine study design related to workers and exposures; makes recommendations</td>
<td></td>
</tr>
<tr>
<td>Hasselriis and Licata, 1996</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Concentrations</td>
<td>None</td>
<td>Examines heavy metal concentrations related to incinerators</td>
<td></td>
</tr>
<tr>
<td>Reams and</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>None</td>
<td>Discusses some</td>
<td></td>
</tr>
<tr>
<td>Citation</td>
<td># of Subjects</td>
<td>Description of Subjects</td>
<td>Time Period</td>
<td>Statistics</td>
<td>Health Effects</td>
<td>Selected Magnitude</td>
<td>Other Comments</td>
</tr>
<tr>
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<td>-------------</td>
<td>------------</td>
<td>----------------</td>
<td>--------------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Templet, 1996</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Concentrations</td>
<td>None</td>
<td></td>
<td>aspects related to community and incinerator sites</td>
</tr>
<tr>
<td>Wiles, 1996</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Concentrations</td>
<td>None</td>
<td></td>
<td>Some background on incinerators and ash components</td>
</tr>
<tr>
<td>Marty, 1993</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Concentrations</td>
<td>None</td>
<td></td>
<td>Composition of incinerator ash and related concentrations</td>
</tr>
<tr>
<td>Rumbold et al, 1997</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>Concentrations</td>
<td>No human health effects, examined birds</td>
<td></td>
<td>Examined effects of exposure and accumulation of metals in birds</td>
</tr>
<tr>
<td>Berebyi, 1996</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>None</td>
<td></td>
<td>Good background on incinerators; policy information, procedure and equipment</td>
</tr>
<tr>
<td>Travis and Cook, 1989</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>A review of health effects</td>
<td></td>
<td>A review of health effects and hazardous incineration exposures</td>
</tr>
<tr>
<td>Valberg et al., 1996</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>None</td>
<td></td>
<td>Examined the assessment that needs to be done before operations at an incinerator plant; some background information</td>
</tr>
<tr>
<td>Mitchell, 1998</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>None</td>
<td></td>
<td>A review of the hazardous waste</td>
</tr>
<tr>
<td>Citation</td>
<td># of Subjects</td>
<td>Description of Subjects</td>
<td>Time Period</td>
<td>Statistics</td>
<td>Health Effects</td>
<td>Selected Magnitude</td>
<td>Other Comments</td>
</tr>
<tr>
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<td>---------------</td>
<td>--------------------------</td>
<td>-------------------------------</td>
<td>-----------------------------</td>
<td>-------------------------------</td>
<td>-------------------</td>
<td>--------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Callender et al., 1997</td>
<td>28 males</td>
<td>Hazardous Waste Incinerator Plant Workers (North Carolina)</td>
<td>N/A</td>
<td>%s and projections related to income</td>
<td>Neurological, cardiovascular, respiratory, pulmonary, dermal</td>
<td>$3 million in medical, $14-15 million lost</td>
<td>Good information on the working conditions and health effects of a hazardous waste incinerator; only one site</td>
</tr>
<tr>
<td>Kimbrough and Simonds, 1986</td>
<td>N/A</td>
<td>Hazardous Waste Workers</td>
<td>N/A</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Good perspective on how to examine data</td>
</tr>
<tr>
<td>Abatemarco et al., 1995</td>
<td>842 (750 males and 92 females)</td>
<td>White Collar and Blue Collar Hazardous Waste Workers in a Training Program</td>
<td>September 1989 to September 1991</td>
<td>%s related to what was learned in the training classes</td>
<td>None</td>
<td>None</td>
<td>Helps reinforce the amount of information workers get from training interventions</td>
</tr>
<tr>
<td>Ferguson and Martin, 1985</td>
<td>N/A</td>
<td>Hazardous Waste Workers</td>
<td>N/A</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Good information regarding the guidelines related to hazardous waste</td>
</tr>
<tr>
<td>Gochfield, 1990</td>
<td>N/A</td>
<td>Hazardous Waste Workers</td>
<td>N/A</td>
<td>Concentrations of sulfurs and VOCs</td>
<td>Respiratory, dermal, cancer, neurological (municipal solid waste workers &gt; hazardous waste workers)</td>
<td>None</td>
<td>Cited one case study; mostly background on hazardous waste workers</td>
</tr>
<tr>
<td>Favata et al., 1990</td>
<td>N/A</td>
<td>Hazardous Waste Workers</td>
<td>N/A</td>
<td>%s related to ECGs, sensitivity, and specificity</td>
<td>Dermal, cardiovascular, neurological, death</td>
<td>None</td>
<td>Information on heat stress and its effects on hazardous waste workers</td>
</tr>
<tr>
<td>Levine, 1990</td>
<td>N/A</td>
<td>Hazardous Waste Workers</td>
<td>N/A</td>
<td>None</td>
<td>None</td>
<td>Information on hazardous waste site surveillance; personal protective gear</td>
<td></td>
</tr>
</tbody>
</table>
## APPENDIX B: DETAILED DESCRIPTION OF CODES USED

Table B.1. Nature of Injury Codes

<table>
<thead>
<tr>
<th>Code</th>
<th>Value</th>
<th>Narrative Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Physical Injury</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Amputation</td>
<td>Cut off extremity, digit, protruding part of body, usually by surgery, i.e. leg, arm</td>
</tr>
<tr>
<td>2</td>
<td>Burn</td>
<td>(Heat) burns or scald. The effect of contact with hot substances. (Chemical) burns. Tissue damage resulting from the corrosive action chemicals, fume, etc. (acids, alkalies)</td>
</tr>
<tr>
<td>3</td>
<td>Concussion</td>
<td>Brain, cerebral</td>
</tr>
<tr>
<td>4</td>
<td>Contusion</td>
<td>Bruise – intact skin surface. Hematoma</td>
</tr>
<tr>
<td>5</td>
<td>Crushing</td>
<td>To grind, pound or break into small bits</td>
</tr>
<tr>
<td>6</td>
<td>Dislocation</td>
<td>Pinched nerve, slipped/ruptured disc, herniated disc, sciatica, complete tear, HNP subluxation, MD dislocation</td>
</tr>
<tr>
<td>7</td>
<td>Electric Sock</td>
<td>Electrocution</td>
</tr>
<tr>
<td>8</td>
<td>Fracture</td>
<td>Breaking of a bone or cartilage</td>
</tr>
<tr>
<td>9</td>
<td>Hearing Loss</td>
<td>Hearing loss, traumatic</td>
</tr>
<tr>
<td>10</td>
<td>Heat Prostration</td>
<td>Heat stroke, sun stroke, heat exhaustion, heat cramps and other effects of environmental heat. Does not include sunburn</td>
</tr>
<tr>
<td>11</td>
<td>Hernia</td>
<td>The abnormal protrusion of an organ or part through the containing wall of its cavity</td>
</tr>
<tr>
<td>12</td>
<td>Infection</td>
<td>The invasion of a host by organisms such as bacteria, fungi, viruses, protozoa or insects, with or without manifest diseases</td>
</tr>
<tr>
<td>13</td>
<td>Laceration</td>
<td>Cut, scratches, abrasions, superficial wounds, calluses, wound by tearing</td>
</tr>
<tr>
<td>14</td>
<td>Myocardial Infarction</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Puncture</td>
<td>A hole made by the piercing of pointed instrument</td>
</tr>
<tr>
<td>16</td>
<td>Strain/sprain</td>
<td>Internal derangement. A trauma or wrenching of joint, producing pain and disability depending upon degree of injury or ligaments, and trauma to the muscle or the musculotendinous unit from violent contraction or excessive forcible stretch</td>
</tr>
<tr>
<td>17</td>
<td>Vision loss</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Other leading injuries</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Occupational Diseases</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>All other injuries</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Multiple Injuries</td>
<td></td>
</tr>
</tbody>
</table>
Table B.2. Body Part Codes

<table>
<thead>
<tr>
<th>PART 1 – HEAD</th>
<th>Code</th>
<th>Value</th>
<th>Narrative Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td></td>
<td>Multiple Head</td>
<td>Any combination of below parts</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>Skull</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>Brain</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>Ear(s)</td>
<td>Includes: hearing, inside eardrum</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>Eye(s)</td>
<td>Includes: optic nerves, vision, eye lids</td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>Nose</td>
<td>Includes: nasal passage, sinus, sense of smell</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>Soft Tissue</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>Facial Bones</td>
<td>Includes: Jaw</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td>Multiple Upper Extremities</td>
<td>Any combination of below parts, excluding hands and wrists combined</td>
</tr>
<tr>
<td>31</td>
<td></td>
<td>Upper Arm</td>
<td>Humerus and corresponding muscles, excluding clavicle and scapula</td>
</tr>
<tr>
<td>32</td>
<td></td>
<td>Elbow</td>
<td>Radial head</td>
</tr>
<tr>
<td>33</td>
<td></td>
<td>Lower Arm</td>
<td>Forearm – radius, ulna and corresponding muscles</td>
</tr>
<tr>
<td>34</td>
<td></td>
<td>Wrist</td>
<td>Carpals and corresponding muscles</td>
</tr>
<tr>
<td>35</td>
<td></td>
<td>Hand</td>
<td>Metacarpals and corresponding muscles (excluding wrist and fingers)</td>
</tr>
<tr>
<td>36</td>
<td></td>
<td>Finger(s)</td>
<td>Other than thumb and corresponding muscles</td>
</tr>
<tr>
<td>37</td>
<td></td>
<td>Thumb</td>
<td></td>
</tr>
<tr>
<td>38</td>
<td></td>
<td>Shoulder(s)</td>
<td>Armpit, rotator cuff, trapezilus, clavicle, scapula</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PART 2 – NECK</th>
<th>Code</th>
<th>Value</th>
<th>Narrative Description</th>
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</thead>
<tbody>
<tr>
<td>20</td>
<td>25</td>
<td>Multiple Neck</td>
<td>Any combination of below parts</td>
</tr>
<tr>
<td>20</td>
<td>25</td>
<td>Soft Tissue</td>
<td>Other than larynx or trachea</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PART 1 – UPPER EXTREMITIES</th>
<th>Code</th>
<th>Value</th>
<th>Narrative Description</th>
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</thead>
<tbody>
<tr>
<td>40</td>
<td></td>
<td>Multiple Trunk</td>
<td>Any combination of below parts</td>
</tr>
<tr>
<td>41</td>
<td></td>
<td>Upper Back</td>
<td>(Thoracic area) Upper back muscles, excluding vertebrae, disc, spinal cord</td>
</tr>
<tr>
<td>42</td>
<td></td>
<td>Lower Back</td>
<td>(Lumbar area and lumbo sacral) Lower back muscles, excluding sacrum, coccyx, pelvis, vertebrae, disc, spinal cord</td>
</tr>
<tr>
<td>43</td>
<td></td>
<td>Disc</td>
<td>Spinal column cartilage other than cervical segment</td>
</tr>
<tr>
<td>44</td>
<td></td>
<td>Chest</td>
<td>Including ribs, sternum, soft tissue</td>
</tr>
<tr>
<td>45</td>
<td></td>
<td>Sacrum and Coccyx</td>
<td>Pinal nine vertebrae-fused</td>
</tr>
<tr>
<td>46</td>
<td></td>
<td>Pelvis</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td></td>
<td>Internal Organs</td>
<td>Other than heart and lungs</td>
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<tr>
<td>61</td>
<td></td>
<td>Abdomen</td>
<td>Excluding injury to internal organs</td>
</tr>
<tr>
<td>61</td>
<td></td>
<td>Including Groin</td>
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<table>
<thead>
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<th>PART IV – TRUNK</th>
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<th>Narrative Description</th>
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<tr>
<td>50</td>
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<td>Multiple Lower Extremities</td>
<td>Any combination of below parts</td>
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</table>

<table>
<thead>
<tr>
<th>PART V – LOWER EXTREMITIES</th>
<th>Code</th>
<th>Value</th>
<th>Narrative Description</th>
</tr>
</thead>
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<td>Code</td>
<td>Value</td>
<td>Description</td>
<td></td>
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<tr>
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<td>-----------------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>Hip</td>
<td></td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>Upper Leg</td>
<td>Femur and corresponding muscles</td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>Knee</td>
<td>Patella</td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>Lower Leg</td>
<td>Tibia, Fibula and corresponding muscles</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>Ankle</td>
<td>Tarsals</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>Foot</td>
<td>Metatarsals, heel, Achilles tendon and corresponding muscles – excluding ankle or toes</td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>Toe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>Multiple Body parts (including Body Systems &amp; Body Parts)</td>
<td>Applies when more than one major body part has been affected, such as an arm and a leg and multiple internal organs</td>
<td></td>
</tr>
</tbody>
</table>

PART VI – MULTIPLE BODY PARTS

Table B.3. Summarized Body Location Code (Arbody code)

<table>
<thead>
<tr>
<th>Code</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Head</td>
<td>Part I in Table 2.3</td>
</tr>
<tr>
<td>2</td>
<td>Neck</td>
<td>Part II in Table 2.3</td>
</tr>
<tr>
<td>3</td>
<td>Upper Extremities</td>
<td>Part III in Table 2.3</td>
</tr>
<tr>
<td>4</td>
<td>Trunk</td>
<td>Part VI in Table 2.3</td>
</tr>
<tr>
<td>5</td>
<td>Lower Extremities</td>
<td>Part V in Table 2.3</td>
</tr>
<tr>
<td>6</td>
<td>Back Injury</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Miscellaneous</td>
<td></td>
</tr>
</tbody>
</table>
### Table B.4. Accident Type Codes

<table>
<thead>
<tr>
<th>Code</th>
<th>Value</th>
<th>Narrative Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Hot Objects or Substances</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Fire or Flame</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Steam or Hot Fluid</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Dust, Gases, Fumes, or Vapors</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Contact with, NOC</td>
<td></td>
</tr>
<tr>
<td>84</td>
<td>Electrical Current</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Machine or Machinery</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Object Handled</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Caught in, under or between, NOC</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Broken Glass</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Hand Tool, Utensil Not Powered</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Object Being Lifted or Handled</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Powered Hand Tool, Appliance</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Cut, Puncture, Scrape, NOC</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>From Different Level</td>
<td>Off wall, catwalk, bridge, etc.</td>
</tr>
<tr>
<td>26</td>
<td>From Ladder or Scaffolding</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>From Liquid or Grease Spills</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Into Openings</td>
<td>Shafts, excavations, floor openings, etc</td>
</tr>
<tr>
<td>29</td>
<td>On Same Level</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Slipped, do not fall</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Fall, Slip, or Trip, NOC</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>Collision or Sideswipe with another vehicle</td>
<td>Both vehicle in motion</td>
</tr>
<tr>
<td>46</td>
<td>Collision with a Fixed Object</td>
<td>Standing vehicle or stationary object</td>
</tr>
<tr>
<td>48</td>
<td>Vehicle Upset</td>
<td>Overturned or jackknifed</td>
</tr>
<tr>
<td>50</td>
<td>Motor vehicle, NOC</td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>Twisting</td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>Jumping</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>Holding or Carrying</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>Lifting</td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>Pushing or Pulling</td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>Reaching</td>
<td></td>
</tr>
<tr>
<td>59</td>
<td>Using Toll or Machinery</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>Strain or Injury by, NOC</td>
<td></td>
</tr>
<tr>
<td>65</td>
<td>Moving Part of Machine</td>
<td></td>
</tr>
<tr>
<td>Code</td>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>------</td>
<td>-------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>Burn/Scald-Heat/Cold exposure</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Caught in or between</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>Cut, puncture, scrape</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>Fall or slip injury</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>Motor vehicle</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>Strain or sprain</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>Striking against/stepping on</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>Struck or injured by</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>Rubbed or abraded by</td>
</tr>
<tr>
<td>10</td>
<td>10</td>
<td>Miscellaneous causes</td>
</tr>
</tbody>
</table>

Table B.5. Summarized Accident Type Code (Arcause code)
Table B.6. Disability Type Code

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Temporary partial</td>
</tr>
<tr>
<td>2</td>
<td>Temporary total</td>
</tr>
<tr>
<td>3</td>
<td>Permanent impairment only</td>
</tr>
<tr>
<td>4</td>
<td>Wages loss only</td>
</tr>
<tr>
<td>5</td>
<td>Wage loss and permanent impairment</td>
</tr>
<tr>
<td>6</td>
<td>Impairment income</td>
</tr>
<tr>
<td>7</td>
<td>Supplemental income</td>
</tr>
<tr>
<td>8</td>
<td>Permanent total</td>
</tr>
<tr>
<td>9</td>
<td>Death</td>
</tr>
<tr>
<td>10</td>
<td>Settled, no indemnity recorded</td>
</tr>
<tr>
<td>11</td>
<td>Lost time, no indemnity recorded</td>
</tr>
</tbody>
</table>
APPENDIX C. FURTHER RESULTS OF THE STATISTICAL ANALYSIS OF WORKERS’ COMPENSATION DATA (CODES ARE DESCRIBED IN APPENDIX B)

Figure C.1. Causes of contusions in collection, landfill, and incinerator workers.
Figure C.2. Causes of fractures in collection, landfill, and incinerator workers
Figure C.3. Causes of fractures in SIC 5093 workers.
Figure C.4. Distribution of body locations injured by collection, landfill and incinerator workers.
Figure C.5. Distribution of body locations injured by recycling workers.
Figure C.6. Contused body locations (SIC 4953 and 4212)
Figure C.7. Contused body locations (SIC 5093)
Figure C.8. Fractured body locations (SIC 5093)
Figure C.9. Lacerated body locations (SIC 5093)
Figure C.10. Accident type distribution (SIC 4953 and 4212)
Figure C.11. Accident type distribution (SIC 5093)
Figure C.12. Distribution of injuries to CLI workers by disability type.
Figure C.13. Distribution of injuries to recycling workers by disability type.
Figure C.14. Seasonal distribution of injuries to SIC 5093 workers.
Figure C.15. Daily distribution of injuries to SIC 5093 workers.
Figure C.16. Distribution of injuries by age of SIC 4953/4212 workers.
Figure C.17. Distribution of injuries by age of SIC 5093 workers.
Figure C.18. Distribution of injuries by gender of SIC 4953/4212 workers.
Figure C.19. Distribution of injuries by gender of SIC 5093 workers.
Figure C.20. Waste collected per year by counties (SIC 4953/4212)
Figure C.21. Waste recycled per year by counties
Figure C.22  Injury numbers per year by counties (SIC 4953/4212)
Figure C.23. Injury numbers per year by counties (SIC 5093)
## APPENDIX D. VALUES OF PARAMETERS* USED TO COMPUTE PROBABILITY DISTRIBUTIONS (EQUATION 2.1)

Table D.1. Values of Parameters of Probability Distributions for Numbers and Costs of Workers’ Compensation Claims in Florida

<table>
<thead>
<tr>
<th>SIC</th>
<th>Workers</th>
<th>Injury</th>
<th>$\lambda$</th>
<th>$\beta_n$</th>
<th>$n_i$</th>
<th>Mean of ln($Z_f - 50$)</th>
<th>Std. Dev. of ln($Z_f - 50$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4953/4212</td>
<td>All</td>
<td>All</td>
<td>410.6</td>
<td>2/342.2</td>
<td>342.2</td>
<td>8.6205</td>
<td>1.8254</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Strain/sprain</td>
<td>195.8</td>
<td>2/163.2</td>
<td>163.2</td>
<td>8.5185</td>
<td>1.8375</td>
</tr>
<tr>
<td>4953/4212</td>
<td>Collectors</td>
<td>All</td>
<td>174.3</td>
<td>2/228.6</td>
<td>228.6</td>
<td>8.5691</td>
<td>1.8328</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Strain/sprain</td>
<td>132</td>
<td>2/110</td>
<td>110</td>
<td>8.4787</td>
<td>1.9024</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Contusion</td>
<td>28.8</td>
<td>2/24</td>
<td>24.0</td>
<td>8.5939</td>
<td>1.6616</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fracture</td>
<td>16.8</td>
<td>2/14</td>
<td>14.0</td>
<td>9.3840</td>
<td>1.4719</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Laceration</td>
<td>19.0</td>
<td>2/15.8</td>
<td>15.8</td>
<td>6.6225</td>
<td>0.5665</td>
</tr>
<tr>
<td>5093</td>
<td>Recyclers</td>
<td>All</td>
<td>85.4</td>
<td>2/71.2</td>
<td>71.2</td>
<td>8.6289</td>
<td>1.8883</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Strain/sprain</td>
<td>26.9</td>
<td>2/22.4</td>
<td>22.4</td>
<td>8.7302</td>
<td>1.7642</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Contusion</td>
<td>12.0</td>
<td>2/10.0</td>
<td>10.0</td>
<td>9.1328</td>
<td>1.9230</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fracture</td>
<td>10.3</td>
<td>2/8.6</td>
<td>8.6</td>
<td>8.4255</td>
<td>1.9344</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Laceration</td>
<td>9.6</td>
<td>2/8.0</td>
<td>8.0</td>
<td>8.2210</td>
<td>1.7633</td>
</tr>
<tr>
<td>4953</td>
<td>Laborers</td>
<td>Strain/sprain</td>
<td>7.4</td>
<td>2/6.2</td>
<td>6.2</td>
<td>7.9020</td>
<td>1.5297</td>
</tr>
<tr>
<td>4953</td>
<td>Mechanics</td>
<td>Strain/sprain</td>
<td>9.6</td>
<td>2/8.0</td>
<td>8.0</td>
<td>8.3722</td>
<td>1.4155</td>
</tr>
<tr>
<td>4953</td>
<td>Equipment Operators</td>
<td>Strain/sprain</td>
<td>18.7</td>
<td>2/15.6</td>
<td>15.6</td>
<td>8.8018</td>
<td>1.6834</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Contusion</td>
<td>4.8</td>
<td>2/4.0</td>
<td>4.0</td>
<td>10.4019</td>
<td>2.1615</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fracture</td>
<td>3.4</td>
<td>2/2.8</td>
<td>2.8</td>
<td>7.5153</td>
<td>1.4092</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Laceration</td>
<td>2.9</td>
<td>2/2.4</td>
<td>2.4</td>
<td>7.9072</td>
<td>1.0465</td>
</tr>
</tbody>
</table>

*Parameter values assumed constant for all Workers’ Compensation claim distributions:
1. $\alpha_n = 2$
2. $I = 5$
3. $Z_0 = 50$ ($)
4. $Z_{max} = 10,000,000$ ($)

Table D.2. Values of Parameters of Probability Distributions for Numbers of All Musculoskeletal and Dermal Injuries to Florida MSW Workers

<table>
<thead>
<tr>
<th>SIC</th>
<th>Workers</th>
<th>Injury</th>
<th>$\alpha_n$</th>
<th>$\beta_n$</th>
<th>$I$</th>
</tr>
</thead>
<tbody>
<tr>
<td>4953/4212</td>
<td>All</td>
<td>Musculoskeletal</td>
<td>6</td>
<td>0.0017</td>
<td>0</td>
</tr>
<tr>
<td>4953/4212</td>
<td>All</td>
<td>Dermal</td>
<td>6</td>
<td>0.0056</td>
<td>0</td>
</tr>
</tbody>
</table>
Figure E.1. Probability distribution for the annual number of Workers’ Compensation claims of all types to drivers and helpers.
Figure E.2. Probability distribution for the annual number of Workers’ Compensation claims for strains and sprains to all SIC 4953/4212 workers.
Figure E.3. Probability distribution for the annual number of Workers’ Compensation claims for strains and sprains to SIC 5093 workers.
Figure E.4. Probability distribution for the annual number of Workers’ Compensation claims for strains and sprains to drivers and helpers.
Figure E.5. Probability distribution for the annual number of Workers’ Compensation claims for contusions to drivers and helpers.
Figure E.6. Probability distribution for the annual number of Workers’ Compensation claims for contusions to SIC 5093 workers.
Figure E.7. Probability distribution for the annual number of Workers’ Compensation claims for lacerations to drivers and helpers.
Figure E.8. Probability distribution for the annual number of Workers’ Compensation claims for lacerations to SIC 5093 workers.
Figure E.9. Probability distribution for the annual number of Workers’ Compensation claims for fractures to drivers and helpers.
Figure E.10. Probability distribution for the annual number of Workers’ Compensation claims for fractures to drivers and helpers.
Figure E.11. Probability distribution for the annual number of Workers’ Compensation claims for strains and sprains to laborers.
Figure E.12. Probability distribution for the annual number of Workers’ Compensation claims for strains and sprains to mechanics
Figure E.13. Probability distribution for the annual number of Workers’ Compensation claims for strains and sprains to equipment operators
Figure E.14. Probability distribution for the annual number of Workers’ Compensation claims for contusions to equipment operators
Figure E.15. Probability distribution for the annual number of Workers’ Compensation claims for fractures to equipment operators
Figure E.16. Probability distribution for the annual number of Workers’ Compensation claims for lacerations to equipment operators
Figure E.17. Probability distribution for the cost of individual Workers’ Compensation claims for strains and sprains, for SIC 4953/4212 workers.
Figure E.18. Probability distribution for the cost of individual Workers’ Compensation claims for strains and sprains to drivers and helpers.
Figure E.19. Probability distribution for the cost of individual Workers’ Compensation claims for strains and sprains to SIC 5093 workers.
APPENDIX F. PROBABILITY DISTRIBUTIONS FOR THE ANNUAL COST OF WORKERS’ COMPENSATION CLAIMS IN ADDITIONAL INJURY CATEGORIES

Figure F.1. Probability distribution for the annual cost of Workers’ Compensation claims for all injuries to drivers and helpers.
Figure F.2. Probability distribution for the annual cost of Workers’ Compensation claims for strains and sprains to SIC 4953/4212 workers.
Figure F.3. Probability distribution for the annual cost of Workers’ Compensation claims for strains and sprains to drivers and helpers.
Figure F.4. Probability distribution for the annual cost of Workers’ Compensation claims for strains and sprains to SIC 5093 workers.
Figure F.5. Probability distribution for the annual cost of Workers’ Compensation claims for contusions to drivers and helpers.
Figure F.6. Probability distribution for the annual cost of Workers’ Compensation claims for contusions to SIC 5093 workers.
Figure F.7. Probability distribution for the annual cost of Workers’ Compensation claims for fractures to drivers and helpers.
Figure F.8. Probability distribution for the annual cost of Workers’ Compensation claims for fractures to SIC 5093 workers.
Figure F.9. Probability distribution for the annual cost of Workers’ Compensation claims for lacerations to drivers and helpers.
Figure F.10. Probability distribution for the annual cost of Workers’ Compensation claims for lacerations to SIC 5093 workers.
Figure F.11. Probability distribution for the annual cost of Workers’ Compensation claims for strains and sprains to laborers
Figure F.12. Probability distribution for the annual cost of Workers’ Compensation claims for strains and sprains to mechanics
Figure F.13. Probability distribution for the annual cost of Workers’ Compensation claims for strains and sprains to equipment operators
Figure F.14. Probability distribution for the annual cost of Workers’ Compensation claims for contusions to equipment operators.
Figure F.15. Probability distribution for the annual cost of Workers’ Compensation claims for fractures to equipment operators
Figure F.16. Probability distribution for the annual cost of Workers’ Compensation claims for lacerations to equipment operators
APPENDIX G: FURTHER RESULTS OF THE COUNTYWIDE STATISTICAL ANALYSIS OF WORKERS’ COMPENSATION DATA

Figure G.1 Yearly trend of Workers’ Compensation cases

Total Cases:
- Florida = 1711
- Dade = 484
- Broward = 149
Figure G.2 Seasonality trend of Workers’ Compensation cases
Figure G.3 Date of injury
Figure G.4 Zip codes for Dade county
Figure G.5 Zip codes for Broward county

Total Cases = 149
Figure G.6 Body location of sprains and strains
Figure G.7 Causes of sprains and strain
Figure G.8 Body location of lacerations
Figure G.9 Causes of lacerations
Figure G.10 Body location of contusions
Figure G.11 Causes of contusions
Figure G.12 Body location of fractures

<table>
<thead>
<tr>
<th>Code</th>
<th>Value</th>
<th>Code</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Multiple Head Injury</td>
<td>37</td>
<td>Thumb</td>
</tr>
<tr>
<td>11</td>
<td>Skull</td>
<td>42</td>
<td>Low Back Area</td>
</tr>
<tr>
<td>15</td>
<td>Nose</td>
<td>44</td>
<td>Chest</td>
</tr>
<tr>
<td>19</td>
<td>Facial Bones</td>
<td>46</td>
<td>Pelvis</td>
</tr>
<tr>
<td>25</td>
<td>Soft Tissue Neck</td>
<td>50</td>
<td>Multiple Lower Extremities</td>
</tr>
<tr>
<td>30</td>
<td>Multiple Upper Extremities</td>
<td>52</td>
<td>Thigh</td>
</tr>
<tr>
<td>31</td>
<td>Upper Arm</td>
<td>53</td>
<td>Knee</td>
</tr>
<tr>
<td>32</td>
<td>Elbow</td>
<td>54</td>
<td>Lower Leg</td>
</tr>
<tr>
<td>33</td>
<td>Lower Arm</td>
<td>55</td>
<td>Ankle</td>
</tr>
<tr>
<td>34</td>
<td>Wrist</td>
<td>56</td>
<td>Foot</td>
</tr>
<tr>
<td>35</td>
<td>Hand</td>
<td>57</td>
<td>Toe(s)</td>
</tr>
<tr>
<td>36</td>
<td>Finger(s)</td>
<td>90</td>
<td>Multiple Body Parts</td>
</tr>
</tbody>
</table>

Total Cases:
Florida = 113
Dade = 18
Broward = 9
Figure G.13 Causes of fractures
Figure G.14 Company type for fractures

Total Cases:
Dade = 18
Broward = 9

<table>
<thead>
<tr>
<th>Company Type</th>
<th>Dade</th>
<th>Broward</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public</td>
<td>4 Cases</td>
<td>1 Case</td>
</tr>
<tr>
<td>Private</td>
<td>11 Cases</td>
<td>4 Cases</td>
</tr>
</tbody>
</table>

% of Total Fractures
APPENDIX H: SURVEY QUESTIONNAIRE

H.1. Interview Questions for Environmental Health and Safety  

To: Collection Personnel

1. Are you a permanent or temporary employee?
   - Permanent
   - Temporary

2. Do you have two or more years of experience as a waste collector?
   - Two or more
   - Less than two

3. Do collectors usually follow established safety procedures?
   - Yes
   - No

4. If not, why not?
   - Not aware of risks
   - To save time
   - To save discomfort
   - Do not care
   - Other

5. What kinds of personal protective equipment are you required to wear?
   - Gloves
   - Boots
   - Uniform
   - Goggles
   - Back Support
   - Others

6. How many workers usually wear the personal protective equipment during work?
   - All workers
   - Most workers
   - Some workers
   - Only a few workers
   - None
7. If not, why not?

- Not aware of risks
- To save time
- To save discomfort
- Do not care
- Other

8. Are there negative incentives for you to work safely?

- Enforced disciplinary action
- Documentation and follow up
- Others (please specify) ________________________________

9. Are there positive incentives for you to work safely?

- Recognition
- Rewards of time
- Rewards of money
- Others (please specify) ________________________________

10. What do you think are the main reasons for injuries and fatalities among collectors?

- Lack of visibility around trucks
- Insufficient training
- Nonobservance of safety procedures
- Nature of the work
- Improper disposal of waste by residents
- Lack of proper personal protective equipment
- Carelessly passing motorists
- Weather
- Switching driver and helper
- Incentives to work quickly
- Lack of provision for temporary job change due to fatigue or illness
- Other (please specify) ________________________________

11. Which of the following injuries have you experienced over the past 12 months?

- Strain/Sprain
- Fracture
- Contusion (Bruise)
- Laceration
- Others (please specify)
- None

12. Which of the following illnesses have you experienced over the last 12 months?
13. For how many workers do you think language is a significant barrier to following safety procedures (e.g. signs, safety manuals)?

- All workers
- Most workers
- Some workers
- A few workers
- None

14. What do you think is the most dangerous part of your work? What worries you the most?

15. What should the employee do to prevent work injuries?

16. If your partner is seriously hurt, what are you supposed to do?

17. If you were in charge, what would you do to make collectors’ jobs safer and healthier?

H.2. Interview Questions for Environmental Health and Safety

To: SAFETY PERSONNEL

A. Organization Profile

1. What types of solid waste does your organization collect?

- Garbage
- Trash
- Recyclable waste
- Commercial waste
- Yard Waste
- Others -- please specify

2. Your organization is:

- Private
- Public
3. How many collectors does your organization employ? ______

4. How many years has the average collector been working for your organization? ______

5. On average, how many hours do collectors work in one day? ______

6. On average, how many hours do collectors collect in one day? ______

7. On average, how many tons of waste does a worker collect in one day? ______

8. How many of your workers do not speak English well? ______

9. How many man-hours of temporary collectors do you use per year? ______

10. What is the source of your temporary workers? ______

11. How many workers (including driver) are there in a crew on average?
   - One
   - Two
   - Three
   - More than three

12. How many collection trucks (trash and garbage) operate each day? ______

13. What types of trucks are operated?
   - Front loading percent ______
   - Rear loading percent ______
     - Manual loading percent ______
     - Mechanical loading percent ______
   - Side loading percent ______
     - Manual loading percent ______
     - Mechanical loading percent ______

14. On average, what is your vehicle age? ______

B. SAFETY

1. Do you have a designated health and safety officer in the organization?
   - Yes. Is it a full time position?
     - Yes
     - No
   - No
2. Is there a safety committee in your organization?
   - Yes. Who is on the committee?
     - Employees
     - Supervisors
     - Safety supervisors
     - Top management
   - No

3. How often does the safety committee meet?
   - Daily
   - Weekly
   - Biweekly
   - Monthly
   - Bi-monthly
   - Quarterly
   - Semiannually
   - Annually
   - None

4. Do you have a safety program specifically for the waste collectors?
   - Yes
   - No (Skip question #5)

5. What critical issues does your safety program target?
   - Weather
   - Lifting
   - Backing Vehicle
   - Sharps and chemicals
   - Safety equipment
   - Passing motor vehicle
   - Safety procedure
   - Infectious agent
   - Others -- please specify

6. Do you have an incentive program (positive/negative) to encourage good safety records?
   - Yes. What are the principal components?
     - Enforced disciplinary action
     - Documentation and follow up
     - Recognition
7. Do workers usually follow established safety procedures?
   - Yes.
   - No. Why not?
     - Not aware of risks
     - To save time
     - To save discomfort
     - Do not care
     - Others -- please specify

8. Do you identify the direct (e.g., claim dollars paid) and indirect costs (e.g., lost productivity, lost earnings from damaged equipment) of accidents and injuries?
   - Yes
   - No

9. Give the number of times per year each type of training is provided to permanent collectors:
   - Group instruction
   - Video tape
   - Safety meetings
   - Warning signs
   - On-site guidance
   - Others -- please specify

10. Give the number of times per year each type of training is provided to temporary collectors:
    - Group instruction
    - Video tape
    - Safety meetings
    - Warning signs
    - On-site guidance
    - Others -- please specify

11. Who conducts health and safety training for temporary workers?
    - Your organization
    - Temporary labor agency
    - None
12. Do you ask your employees what would make their jobs safer?

- Yes, How?
  - Safety meeting
  - Suggestion box
  - Random field survey
  - During observation
- No

13. If yes, what do they most frequently respond?

14. Do you routinely go out on route or on site and observe work practices?

- Daily
- Weekly
- Biweekly
- Monthly
- yearly
- Never

15. If so, what action do you normally take?

- Discuss with employee on spot
- Discuss with supervisor
- Document your observations
- Follow-up with employee
- Follow-up with supervisor
- Others -- please specify

16. What safety equipment is available/required to be worn by collectors?

Available: Required:
- Gloves
- Boots
- Uniform
- Goggles
- Back Support
- Others

17. On average, what is the number of injuries (OSHA 200 or SAF 200 recordable) per year for waste collectors at your organization? _______

18. What are the major injury types experienced by your employees?

- Strain/sprain
Fracture
Contusion (bruise)
Laceration
Others

19. Do you feel that any of the following illnesses occur to your collectors as a result of their work?

- Skin diseases (rashes)
- Respiratory diseases (asthma, chronic bronchitis)
- Allergies
- Gastrointestinal diseases (diarrhea)
- Other
- None

20. If so, how can such diseases be prevented?

21. Workers’ Compensation data indicate that workers are more frequently injured on Mondays. Is this true for your facility?

- Yes
- No

22. If so, please give possible reasons.

23. What do you think are the main reasons for injuries and fatalities?

- Nonobservance of safety procedures
- Insufficient training
- Nature of the work
- Improper disposal of waste by residents
- Lack of proper personal protective equipment
- Carelessly passing motorists
- Weather
- Switching driver and helper
- Incentives to work quickly
- Lack of provision for temporary job change due to fatigue or illness

24. If you were in charge, what would you do to make collectors’ jobs safer and healthier?

25. What measures could be taken to reduce risks to collectors of:

   Sharp/hazardous materials in waste ____________________.
   Infectious materials in waste ____________________.
   Backing & visibility around collection vehicle ____________________.
   Weather (e.g., visibility & traction in rain) ____________________.
Heavy lifting
Passing motorists
Inhalation of noxious fumes
APPENDIX I. FACT SHEET: THE OCCUPATIONAL EXPOSURES & RISKS OF FLORIDA MUNICIPAL SOLID WASTE WORKERS

What is Solid Waste?
Municipal solid waste includes non-hazardous wastes from households, commercial establishments, institutions, markets, and industries; in 1996, 55% of all municipal solid waste in Florida was generated by the commercial sector. It can include: paper, plastic, metals, food waste, glass, and yard waste. Unfortunately when improperly disposed of, municipal solid waste can include chemicals, medical and other hazardous waste. Municipal solid waste contents can vary from facility to facility, and even from day to day.

How Much Solid Waste is Generated?
An enormous amount of solid waste is produced each year in the United States. Since 1960, the volume of municipal solid waste has increased by 250%: from 88 million tons to over 208 million tons in 1995. This is equivalent to 4.34 pounds of trash per person per day in the United States. The US Environmental Protection Agency projects that by the year 2010, the amount of municipal solid waste generated will be up to 262 million tons. In 1996 in Florida, 23.7 million tons of municipal solid waste were collected; this amounts to 9.02 total pounds per person per day.

Figure 1. Municipal solid waste collected per year by counties in Florida

What is Solid Waste Management?
Various methods are used to deal with the huge amount of waste produced worldwide: source reduction, recycling, composting, landfilling, and waste-to-energy (combustion or incineration). In 1994, 62% of US municipal solid waste was landfilled, 17% recycled, 16% converted to
energy, and 1% incinerated; in 1996, 43% of Florida waste was landfilled, 40% recycled, and 17% combusted.

**What are the Human Exposures & Health Risks of Solid Waste?**

Human exposure may take place at nearly every step along the way: from the generation of the solid waste to its disposal. The population at greatest risk for highest and most concentrated exposures is the solid waste industry worker. These workers include:

- *Refuse or garbage collectors*
- *Landfill workers*
- *Compost workers*
- *Recycling workers*
- *Incinerator workers*

Little research has been published on either the exposures or the possible health effects of the solid waste industry worker. Table 1 summarizes the major exposures and reported health effects of solid waste workers.

Table 1. Summary of the reported exposures and related reported health effects of solid waste workers

<table>
<thead>
<tr>
<th>Major Exposures</th>
<th>Type of Solid Waste Worker</th>
<th>Reported Health Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy traffic</td>
<td>Refuse Collectors, Landfill Workers</td>
<td>Pedestrian accidents; broken bones, bruising, crushing; death</td>
</tr>
<tr>
<td>Machinery</td>
<td>Refuse Collectors, Incinerator Workers</td>
<td>Crushed body parts, broken bones, amputations musculoskeletal aches, sprains, disorders of the neck, shoulder and back Noise-induced hearing loss</td>
</tr>
<tr>
<td>Heavy lifting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chemicals improperly disposed of (heavy metals, PAHs, solvents)</td>
<td>Refuse Collectors, Incinerator Workers, Recycling Workers</td>
<td>Burns, fires, explosions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eye and skin irritation; ?cancer</td>
</tr>
<tr>
<td>Sharp and broken objects</td>
<td></td>
<td>Lacerations, punctures, abrasions</td>
</tr>
<tr>
<td>Aerosols from waste:</td>
<td>Refuse Collectors, Incinerator Workers, Landfill Workers, Recycling Workers, Compost Workers</td>
<td>Eye irritation</td>
</tr>
<tr>
<td>Dust</td>
<td></td>
<td>Organic dust toxic syndrome (ODTS), impaired lung function, dry cough, exercise induced dyspnea, asthma, chronic bronchitis</td>
</tr>
<tr>
<td>Microorganisms</td>
<td></td>
<td>Flu symptoms: headache, joint and muscle pain, nausea, fatigue</td>
</tr>
<tr>
<td>Endotoxins/Gram-negative bacteria</td>
<td></td>
<td>Acute gastrointestinal symptoms: diarrhea, nausea</td>
</tr>
<tr>
<td>Fungal spores</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In summary, solid waste workers are:

- exposed to significant levels of physical, chemical and biological toxins;
- suffer from health effects due to their occupational exposure;
• The majority of deaths among solid waste workers are related to vehicles and machinery;
• Injury, and musculoskeletal, dermal, and respiratory health effects, both acute and chronic;
• Younger, less experienced workers are at highest risk for injury;
• Engineering controls, monitoring of exposures, education, personal protection, and other interventions appear to be under-utilized in protecting solid waste workers from exposure and health effects;

What about Florida Solid Waste Workers?
An analysis of Workers Compensation data for solid waste workers in Florida revealed the following:
• In 1993, there were approximately 10,500 solid waste workers in Florida;
  • 4200 reported as recycling workers;
  • Of the remaining workers (collection, compost, landfill, and incinerator workers), at least 2400 reported as drivers and helpers:

Overall health problems in Florida:
• 90 deaths/100,000 solid waste workers/year
• Every solid waste worker in Florida can expect to suffer an average of 1 musculoskeletal or skin injury every 23 months;
  • 35.6 musculoskeletal injuries per 100 workers per year;
  • 17.1 skin injuries per 100 workers per year;
• Workers’ Compensation costs for solid waste workers average $12.6 million per year;
Solid waste worker subgroups:

- **Drivers and helpers** on collection routes were injured the most frequently of all solid waste workers;
  - lacerations, particularly of fingers and often by glass;
  - fractures, particularly in the foot; and
  - contusions, particularly to the knee;
- **Recycling workers** reported contusions and fractures, both often by being struck by a falling or flying object, and lacerations, all in varied body locations;
- Relative to the general workforce, recycling workers reported higher proportions of burns, injuries resulting from being caught in or between objects or equipment, injuries resulting from being cut, punctured, or scraped, and injuries resulting from being struck by objects and equipment;
- Relative to the general workforce, vehicular injuries were proportionally higher among collection, landfill, and incinerator workers as a group;
- **Solid waste workers in Miami-Dade County** reported 2-3x as many injuries per million tons of solid waste collected as workers in other metropolitan counties in Florida.

What are the Current Recommendations?
There are specific recommendations for reducing the exposures and occupational health effects experienced by the solid waste worker:
• Additional research is needed to further characterize the exposures and health effects of the solid waste workers;
  • Exposure characterization, including ergonomic factors;
  • Disease, not just, injury evaluation;
  • Prevention and intervention;
  • Community exposures and possible health effects;
• In the meantime, there is much to learn from the existing literature and regulation, especially for hazardous waste workers, to make preventive interventions for the solid waste worker:
  • Increased training and education of exposures and health risks for workers;
  • Increased education of the general public concerning appropriate disposal of all wastes;
  • Increased use of personal protective equipment by workers;
  • Review of machinery, including vehicles, to prevent injury and death;
  • Review of work practices, including vehicular handling and heavy loads, to prevent injury and death;

Sources of Information?

Although considerable work remains to be done to evaluate the occupational exposures and health effects of solid waste workers, the following articles do present some health and safety recommendations either directly applicable to this industry or drawn from the hazardous waste industry:

• Collection:


• Treatment:

• Hazardous Waste:


Florida Municipal Solid Waste Collectors: Occupational Risks & Prevention

This brochure highlights results of a two-year research study of occupational health and safety risks to municipal solid waste (MSW) workers. The study included analysis of five years of Workers’ Compensation data, survey of 251 garbage collectors and 4 supervisors in Florida, and a review of 161 published articles. Significant findings and recommendations for reducing injury are presented here along with sources of additional information.
How Much Solid Waste is Generated?

The amount of solid waste produced each year in the United States is enormous. Since 1960 the volume of municipal solid waste has increased by 250%, from 88 million tons to over 208 million tons in 1995. This is equivalent to 4.34 pounds of trash per person per day in the US. In 1996 in Florida, 23.7 million tons of municipal solid waste was collected; this amounts to 9.02 total pounds per person per day. While Florida’s population is increasing at a 1.3 % annual rate, per capita solid waste generation increased by 4.1% from 1990 to 1996. At this rate, new solid waste collected in Florida would fill the Tampa Bay Basin as delivered in compaction vehicles, in 76 years.

- ANSI-approved boots adapted to local weather conditions should be required.
- The effect of gloves on the incidence of rashes should be investigated.

Public Education

Multi-lingual mailings or inclusions with waste collection bills should be distributed to residents regarding:
- Procedures for passing collection vehicles, including special caution in inclement weather and low-visibility situations.
- Allowable waste constituents and maximum waste/container weight.
- Hazards of waste collection.

This project was sponsored by The Florida Center for Solid and Hazardous Waste Management. [http://www.floridacenter.org/](http://www.floridacenter.org/)

The Researchers were: James D. Englehardt (Associate Professor), Lora E. Fleming (Associate Professor), Judy A. Bean (Professor, University of Cincinnati), Huren An (Research Assistant), Nicolette John (Research Assistant), Jeff Rogers (Research Assistant and brochure design), Melissa Danits (Research Assistant), all at the University of Miami except as noted.

Full report online at [http://www.eng.miami.edu/~mswrisk](http://www.eng.miami.edu/~mswrisk)

For more information contact: Dr. James Englehardt, University of Miami, P.O. Box 248294, Coral Gables, Fl, 33124, (305) 284-5557

Sources of additional information:
• Further study of reported accumulation of malodorous airborne garbage emissions inside cabs, and of better ventilation/sealing of cabs to minimize such exposure.
• Flashing lights and signs on the upper sides and backs of trucks to warn motorists (similar to those used on school buses).

Workers and Administration

• Collectors should briefly test the weight of each container before lifting, to prepare for the load.
• Collectors should not mount trucks while moving.
• Trucks should be cleaned and inspected daily.
• Route supervisors, in addition to safety officers, should be accountable for injuries on their respective routes.
• Route supervisors should frequently visit routes and discuss proper/improper technique with workers on the spot.
• Safety procedures should be distributed, reviewed, and enforced.
• Incentives for safety compliance should be maintained and advertised.
• Workers should be instructed not to pick up containers weighing over 50 lbs. or obviously containing hazardous materials, but to leave an informative tag on the container for the resident.
• Scheduled medical surveillance and monitoring of workers should be implemented.

Training

• Training in teamwork and communication techniques within crews should be conducted.
• Continuous training in proper lifting and carrying techniques, constituents of MSW, potential hazards of exposure to aerosol contaminants, and techniques for inclement weather, should be augmented.
• MSW collection agencies should assume responsibility for health and safety training of temporary workers, and ensure training equivalent to that provided for permanent workers
• All training should be documented.

Applicable Personal Protective Equipment

• Reflective safety vests should be redesigned, or incorporated into uniforms, to prevent catching on trucks.

studies of the range of occupational exposures and potential health risks among Florida’s solid waste workers. Although not conclusive, these studies indicate the need for further exploration of risks to collectors.

Statistical Results

Analysis of Florida Workers’ Compensation data indicated high rates of mortality and injury to drivers and helpers. Danish worker surveys indicated high rates of illness. Total injury frequencies were assessed statistically from facility data, Workers’ Compensation data, literature sources, and medical judgment.

• An average of 9.8 Workers’ Compensation cases, involving greater than seven calendar days of lost work per 100 workers per year, was found for garbage collectors. This rate is 7.4 times the rate for the general Florida workforce.
• Mortality for MSW drivers and helpers was estimated at 90 ± 30 deaths per 100,000 workers per year, ranking in between rates reported for the second and third deadliest occupations (timber cutters and airplane pilots) nationally.
• Actual numbers of injuries were found to be an order of magnitude higher than the numbers of Workers’ Compensation claims. This statistical finding agreed with results of collector surveys conducted for this project.

Major Injury Types

Strains and Sprains
Especially to lower back (most common injury)
Caused by lifting

Lacerations
Especially to fingers
Often cuts from broken glass

Contusion
Of multiple body parts
Caused by fall or slip, striking a stationery object, or being struck by falling or flying object

Fracture
Especially of foot
Caused by being struck by, caught in/between, or falls/slips
Solid Waste Collector Survey Results

To learn more about injuries, causes, safety practices, and possible preventative measures we surveyed solid waste collectors, safety officers, and supervisory personnel. Collectors surveyed were primarily public sector employees in South Florida. A few results are highlighted below.

- Collectors reported not wearing colored/reflective safety vests due to their tendency to catch on equipment (trucks).

- The aspects of the job that worried the collectors the most were:
  - Improper residential disposal / What is in the waste (45.5%)
  - Carelessly passing motorists (40.3%)
  - Riding on the back of the truck / Getting hit by truck (10.3%)
  - Lifting and back injuries (5.6%)

Recommendations

Collection Vehicle Design

Items to consider regarding engineering design improvements for collection vehicles include:

- Vehicle design with respect to loading area, side versus rear, to reduce the incidence of workers pinned against trucks by passing motorists and being backed over by the collection vehicle.

- Devices to increase communication between drivers and collectors, such as (a) microphones/speakers and video equipment on the outside of trucks and inside cabs, and (b) cellular phones/radios for frequent communication between the supervisor/base and the driver.

- Design of sweeper devices with respect to shielding of the compaction area, and additional shielding, to reduce exposure of workers to objects, aerosols, and liquids.