Chemical Hazard Data Commons Working Paper[1]

Getting Hazard Right through Managing Chemical IDs

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Introduction

Chemical hazard assessment and robust alternatives assessment for safer substitutions are information-intensive efforts. They depend on the capacity to reliably identify the chemical components of products and materials, and to retrieve a wide range of information about those substances, including hazard and use information. Scientific organizations and public agencies have done substantial work to produce and evaluate scientific evidence of hazards associated with many substances, resulting in the publication of basic data, as well as highly refined authoritative lists of chemicals with recognized hazards. Public and private efforts in various industries are now attempting to link that information in detail with inventories of the substances they use, to assess potential hazards, and to guide transitions to inherently safer materials and products. These efforts include HBN's Pharos Project, the Health Product Declaration, and GreenBlue's Material IQ and CleanGredients databases.

The Chemical Hazard Data Commons seeks to support these efforts through tools that link inventoried substances with hazard information. Hazard and use information about a chemical is scattered among many diverse sources and currently requires substantial research to pull together into a full picture of a chemical's potential impacts across the range of possible health endpoints. The Data Commons proposes to greatly improve this process. By building on tools like Pharos that already automate list translation hazard indicators, the Data Commons will aggregate and organize a broader range of chemical data and assessments, and make it easier for community members to locate primary source documents.

The organization and retrieval of that information is guided by chemical substance identifiers. The dependable aggregation and communication of chemical hazard and use information relies on the consistent identification of substances, and on valid associations between substance identities and relevant knowledge. Yet, the existence of numerous different domain-specific naming systems to identify chemical substances poses significant challenges for the organization of information in the Data Commons. Ambiguities and discrepancies in the naming and identification of chemicals make it difficult for databases to reliably and consistently associate chemicals with the correct hazard information. These ambiguities come from a number of factors, examined below—including the existence of chemical

[1] See Lent, Tom, et al, *Toward Safer Products: Accelerating Change with a Chemical Hazard Data Commons* for an overview of the Chemical Hazard Data Commons project at https://commons.healthymaterials.net

"synonyms," the close association or grouping of similar chemicals, and hazards specific to certain physical forms of substances. Such factors can lead to important hazard and use information not being linked to substances that it should be associated with, or to spurious and irrelevant information being linked to substances where it doesn't belong. Data organization problems can hinder the efforts of those who provide or use information tools aimed at hazard assessment and substitution.

This working paper examines the infrastructural challenges of chemical identification, and suggests how better management of chemical identity—through a new internal open identifier system—will allow the Data Commons to make hazard data easier to use with greater validity and accuracy. We describe what is necessary to make the architecture of the Data Commons Platform robust and flexible, while maximizing users' freedom to interact with chemical data on their own terms.

Overview of chemical substance identifiers

Identifiers are names assigned in a controlled manner, governed by rules or naming conventions, and meant to uniquely refer to something. In this case, that "something" is a substance with given hazard properties. Defining unique chemical identity is not a trivial technical matter. Deciding what constitutes "one substance" and whether several chemicals are "the same substance" entails semantic and ontological choices, which are grounded in the perspectives and underlying assumptions of a given community of practice.[2]

Before we discuss these choices and their consequences, we will present a practical overview of the several ways that substances may be identified. All of these are used in practice, and each of them has advantages and limitations.

- **Names** encompass a range of vocabularies, from systematic names (which describe the chemical structure)[3] to commercial trade names and colloquial names established among specialized communities (which reveal nothing about the make-up of the substance). There are usually several names for a given substance; some substances have dozens of synonyms. Other proprietary substances are known only by cryptic trade names. Occasionally, the same name is associated with multiple substantively different chemicals. Although major efforts have been made to gather synonyms into databases such as ChemIDPlus, a common lexicon does not generally exist among different information users. All of these factors contribute to ambiguity and confusion, making it impractical to rely on chemical names when publishing or retrieving information, even within scientific communities.[4]
- **Molecular structure** is generally regarded as the most essential identifying feature of a chemical. Molecular structures may be represented digitally as strings of letters and numbers,

[2] Kent W. *Data and Reality: how we perceive and manage information in an imprecise world.* 3rd ed. Westfield, NJ: Technics Publications, LLC; 2012.
[3] Such as the widely-recognized naming conventions of the International Union of Pure and Applied Chemistry (IUPAC).
[4] Murray-Rust P, Mitchell JBO, Rzepa HS. 2005. Communication and re-use of chemical information in bioscience. BMC Bioinformatics 6:180; doi: 10.1186/1471-2105-6-180.

using formats such as InChI[5] and SMILES[6]. These representations constitute semantically meaningful chemical identifiers. InChI strings can encode more structural information than SMILES strings, and they are generated using a standardized, open algorithm that ensures that each unique structure has only one InChI.[7] For these reasons, InChI is preferred for identification of chemicals across different databases. A limitation shared by both systems is that they can only represent chemical compounds that have discrete molecular structures. Many industrially relevant substances do not have a known, discrete molecular structure because they are mixtures, polymers, minerals, or proprietary formulations.

- **Alphanumeric identifiers** are codes controlled by a central authority. This is the dominant form of chemical identification in large databases. Notable examples include Chemical Abstracts Service registry numbers (CASRN), the European Commission (EC) inventory numbers, US FDA Unique Ingredient Identifiers (UNII)[8], and PubChem compound IDs (CID)[9]. Each of these systems was developed for a particular purpose, which inevitably leaves some substances of interest for hazard assessment uncatalogued.
- **Uniform resource identifiers (URIs)** associate chemicals with alphanumeric identifiers, and simultaneously enable interaction with world-wide web representations of the substances. This identification methodology holds promise for the goals of the Data Commons, which seeks to link information about the same substance among different sources.

Factors that complicate substance identification for hazard

Synonyms

Just as there are synonymous chemical names in business and natural languages, there are also synonymous numeric identifiers created through the editing and maintenance of databases. The use of obscure synonyms can be problematic for hazard assessment. For example, we have found evidence that some businesses specifically choose to identify materials with CASRN that are not named in regulatory lists (which, rather than enumerating a whole set of related compounds, typically limit themselves to one or two representative CASRN).

Mixtures

Many industrially relevant substances comprise mixtures or materials of variable composition. Therefore, many commercial trade names, popular names, or identification numbers refer to mixtures of substances. In some cases, the intent of the identifier is to refer to an unnamed (perhaps uncharacterized) new substance produced by the reaction of the mixed chemicals—a new substance with a different hazard profile than the individual components. In other cases, however, the original

[5] InChI = IUPAC International Chemical Identifier. See: http://www.iupac.org/home/publications/e-resources/inchi.html
[6] SMILES = Simplified Molecular-Input Line-Entry System. See OpenSMILES, a community sponsored open-standards version of the SMILES language for chemistry: http://www.opensmiles.org
[7] InChI strings for complex molecules can become very long. They can be compressed into shorter 27-character InChIKeys to facilitate display and searching. Reversing the InChIKey to the actual molecular form requires a cross-index to the original InChI.
[8] http://www.fda.gov/ForIndustry/DataStandards/SubstanceRegistrationSystem-UniqueIngredientIdentifierUNII/default.htm
[9] http://pubchem.ncbi.nlm.nih.gov/help.html#fCompound

components of the mixture remain in the final product. This may be because they are mixed but do not react; alternatively, they may react but not fully, leaving residuals of the original components. Finally the mixture components may fully react but have the potential to degrade back to one or more of the original substances. In these latter three cases, the identity of the mixture alone does not lead to understanding its hazards. Knowledge of the identity of the original components of the mixture is needed to understand the hazards of the substance overall.

Groups

Many chemicals of concern to environmental health are characterized as groups or families of substances. For example, regulatory hazard information sources will sometimes identify a hazard as associated with a class of related chemicals, such as "lead-based compounds" or "DINP and all its isomers," rather than a single chemical or list of chemicals. In other cases, a name, like polyurethane or PVC, may actually refer to a system of polymerization that may encompass many different chemical components and additives. Without an agreed-upon definition for the identity of the group and a definitive list of members of the group, an individual compound may not be automatically associated with a hazard that is described in this way. No existing identifier systems include groups consistently, and many do not recognize groups at all.

Physical and structural features beyond molecular structure

Different physical forms of the same substance, such as respirable particles, fibers, vapors, or various types of nanoscale particles, may have very different hazard characteristics than the same substance in a generic physical form. For example, while bulk forms of silicon dioxide (e.g. sand) are benign, fine particles and fibers are harmful when inhaled. But chemical identifier systems tend to treat all physical forms of a substance with the same molecular structure as chemically equivalent, so they will fall under the same name or identifier number. In general, this reflects a chemistry-based perspective on unique identity, rather than a hazard-based perspective. However, this perspective is not consistently applied in practice. The CAS registry, for instance, makes distinctions between physical forms of substances in some cases (e.g. it distinguishes among numerous crystalline and mineral forms of inorganic compounds), but not others (e.g. nanoparticulate versus bulk forms of minerals).

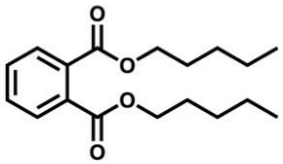
Uniqueness and closely related substances

While a regulatory agency will generally only list one CASRN to identify a chemical hazard association, some of those chemicals are identified by many different CASRNs—with the difference between the numbers only being due to how the substance was made, where it is found in nature, who registered it, or some other subtle difference. These differences may, or may not, affect the substance's hazard characteristics.

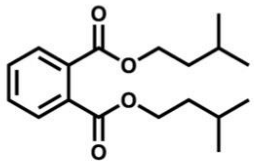
The image below shows an excerpt from the REACH regulation. It identifies a closely related set of four organic compounds in a single index entry. Those four compounds correspond to two EC numbers and three CASRN. Also shown are the molecular structures and structure-based identifiers that are unique to compounds [3] and [4].

REACH, Annex XVII

	Index No	EC No	CASRN
1,2-benzenedicarboxylic acid, dipentylester, branched and linear [1] n-pentyl-isopentylphthalate [2] di-n-pentyl phthalate [3] Diisopentylphthalate [4]	607-426-00-1	284-032-2 [1]-[2] 205-017-9 [3]-[4]	84777-06-0 [1]-[2] 131-18-0 [3] 42925-80-4 [4]



[3]



[4]

InChI=1S/C18H26O4/
c1-3-5-9-13-21-17(19)15-11-7-8-12-16(15)18(20)22
-14-10-6-4-2/h7-8,11-12H,3-6,9-10,13-14H2,1-2H3

InChIKey=IPKKHRVROFYTEK-UHFFFAOYSA-N

InChI=1S/C18H26O4/
c1-13(2)9-11-21-17(19)15-7-5-6-8-16(15)18(20)22-12-10-
14(3)4/h5-8,13-14H,9-12H2,1-4H3

InChIKey=JANBFCARANRIKJ-UHFFFAOYSA-N

In general, most chemicals are assigned a single CASRN or EC number. But the treatment of chemical "uniqueness" differs between CAS, EC, and other systems, so that there is not always a one-to-one correspondence between identifiers. Furthermore, the level of chemical specificity set by an identifier such as a CASRN may be inappropriate to the level of specificity that one actually intends to convey, as illustrated in the REACH example above.

Life-cycle/process history

Two substances with the identical molecular structure may have very different residuals associated with them that may be more important drivers of hazards than the primary molecule. How a chemical was extracted and manufactured—the chemicals involved and their role—is important not only to understand the potential hazards in or around the process, but also to identify which of these process chemicals may end up as residuals in the final product.

Proprietary identification systems

The proprietary nature of some identifiers or identifier systems is a fundamental problem for users of chemical information. Trade names and obfuscated naming systems, such as the Color Index, aim to keep the molecular composition of substances unknown to users, as trade secrets. This hampers efforts to identify links between relevant pieces of information.

Interestingly, although CASRN are widely used and recognized to be useful, the system itself is actually proprietary. Access to the official CAS registry and reference services must be bought at rates running hundreds of dollars per hour, and large-scale use or re-publication of CASRN datasets is prohibited. Lack of open access to the only truly authoritative source of CASRN identifiers causes widespread reliance on unofficial, free sources of identifying information—such as publications from businesses (e.g. MSDS) and

governments (e.g. regulations), which identify chemicals using CASRN.[10] This introduces and propagates errors that are difficult to detect. The simplest problematic situation occurs when CAS reassigns a chemical's registry number, and a variety of deprecated CASRN remain in use in public datasets. For example, there are approximately 50 deleted CASRN for titanium dioxide (TiO_2). In other cases, CASRN are inappropriately chosen to identify substances that are related or similar, but not identical.

Examples of identity and hazard confusion in practice

In building the Data Commons, the complicating factors described above are of concern to us because, in our work with datasets of product chemical ingredients and regulatory lists, we have observed cases in which confusion surrounding chemical identities can leads to misalignment of information about hazard properties. This non-exhaustive list gives examples of certain types of compounds that tend to be affected by the issue.

- Petroleum distillates and paraffinic oils: the CAS registry has tens to hundreds of distinct substances in this category, differentiated by refinery process characteristics. These substances vary somewhat in their hazard properties.[11]
- Polymers: the CAS registry may only have one identifier for a polymer that is really a diverse family of materials with highly distinct origins and contents.[12] Furthermore, some polymeric substances potentially consist of a mixture of monomers, oligomers, and polymer.
- Minerals: Many inorganic substances exist in numerous distinct crystal or mineral forms (such substances include borax, titanium dioxide and asbestos[13]). These distinctions may or may not reflect differences in material hazard.
- Isomeric mixtures of organic compounds: the above example of dipentyl esters is but one of many. Mixed isomerism is common in commodity organic chemicals, and there are often different CASRN for pure isomers and isomerically undefined, mixed, or "technical grade" materials. These isomeric differences may or may not affect hazard characteristics, but an authoritative hazard listing will typically only include one; thus, other isomers may not be linked to the hazard information.[14]

[10] And, more recently, also by a limited free web resource called Common Chemistry, which links 7900 CASRN to chemical names and associated Wikipedia articles: http://www.commonchemistry.org/

[11] Distillate Aromatic Extract (CAS No. 64742-04-7), for example, is a complex combination of hydrocarbons obtained as the extract from a solvent extraction process. It consists predominantly of aromatic hydrocarbons having carbon numbers predominantly in the range of C20 through C50. Many of these aromatic hydrocarbons are PBTs, although the DAE itself is not yet listed as such.

[12] PVC (CAS No. 9002-86-2) and polyurethane (CAS No. 64440-88-6) are prime examples of systems that have a single CAS identifier but thousands of potential variations in content (flame retardants, plasticizers, foaming agents, stabilizers, etc...)

[13] Tremolite can exist as both asbestiform and non-asbestiform, but this key distinction is not reflected in the CAS Registry or in hazard lists, thus creating potential for confusion in assessments.

[14] California's Office of Environmental Health Hazard Assessment (OEHHA) recently listed the phthalate DINP in their Proposition 65 List without a CASRN for exactly this reason in order to avoid a user assuming that a form of DINP was not included in the regulation.

These examples illustrate the need for a substance identification system that fully takes into account the attributes of substances that directly affect hazard properties.

Identifier requirements from a chemical hazard assessment perspective

There will never be a single, totally consistent, and universally agreed-upon chemical identifier system that works from all perspectives. Nevertheless, in order to address challenges identified above and make meaningful links between different pieces of chemical information in different systems, the data commons requires an identifier system that:

1. Provides unique open identification of substances based on structural characteristics that are intrinsically linked to toxicological characteristics;
2. Cross references between the other identification systems currently in use;
3. Accommodates unlimited aliasing to include the multiple systematic and commercial names that may be associated with any one substance;
4. Provides open identifiers for those types of entities and groupings that are not uniquely identified by any of the other systems currently (such as compound groups and nano forms);
5. Defines relationships between groups and forms of substances, which affects the association of hazard information;
6. Supports assignment of process specific identifiers to identify different process chemistry or life cycle pathways that will have implications for residuals and transformation products;
7. Taps the knowledge of the many participants in the Data Commons to undertake continual updating and refining of the system.

No currently existing identifier system meets these criteria. We therefore propose that the Data Commons must develop and use a purpose-built open chemical ID system. This system will first and foremost serve for internal organization, data alignment, transparency, and effective translation between commonly used identifiers (e.g. CASRNs). In the more complicated cases, the system will also serve to clear up ambiguities in chemical identities associated with data, to fill the gaps in existing systems by properly addressing the chemical groups and physical forms important to hazard. The potential broader usefulness of the ID system outside of the Data Commons technical implementation (such for identifying chemicals in documents and discourse) is secondary to meeting the immediate needs.

The design principles of the Chemical Hazard Data Commons are informed by similar efforts in chemical informatics.[15] Those efforts called for short, sequential alphanumeric identifiers created by a persistent non-profit organization to create an open identifier system (e.g., PubChem CIDs). The underlying principle is that openly discoverable and referenceable identifiers enable linking together relevant information about the substance. Open chemical informatics projects on the web have emphasized

[15] Murray-Rust P, Adams SE, Downing J, Townsend JA, Zhang Y. 2011. *The semantic architecture of the world-wide molecular matrix (WWMM).* Journal of Cheminformatics 3:42; doi: 10.1186/1758-2946-3-42.

individual chemical structures, properties, and reactions, whereas the Data Commons emphasizes known hazards, environmental fate, toxicology, production, and industrial use. The Data Commons is also unique in emphasizing the identification of groups of substances (and their members) which have similar toxicological traits.

A Substance Hazard Identification Number (SHIN) Registry for the Data Commons

As a means of addressing the technical concerns raised in this section, we propose the creation of a Substance Hazard Identification Number (SHIN) ID system and registry, for cross-referencing chemical hazard information in the Data Commons. SHIN will differ from other chemical ID mainly in one respect: it will be managed and curated by Chemical Hazard Data Commons participants, and its therefore its goals will aligned with its technical implementation. SHIN will use simple numeric identifiers for chemicals and related entities that are unique from a hazard perspective—substances or groups of substances characterized by molecular or other structural characteristics that give them specific toxicological or environmental impact characteristics. SHIN identifiers will also be used to generate URIs that provide direct access to data through the Data Commons Platform.

One of the goals of the SHIN registry is to build and maintain a strong cross-index of the primary existing identification systems, as well as chemical name synonyms. Table 1 provides an example of ID types that could be cross-referenced. In addition to those listed in this brief example, the Data Commons may also choose to build cross-references for any of several systems with useful information—such as the ATSDR Toxic Substances Portal, the ECHA C&L Inventory database, HSDB (Hazardous Substances Data Bank), Wikipedia, and so on.

Table 1: Identification systems proposed for cross reference in the Data Commons Substance Hazard Identification Number system	
Names:	Chemical name (selected from synonyms)
	IUPAC name
	Synonyms
Structural identifiers:	Standard InChIKey
	Standard InChI
	SMILES
	Molecular formula
Numeric system identifiers:	PubChem CID
	ChemSpider ID

	CASRN (multiple synonyms allowed)
	EC Number
	UniChem ID
	FDA UNII
	Medical Subject Headings (MeSH) ID

Cross-referencing with existing resources can be accomplished in several ways, such as trading identifiers with other organizations, or using structural identifiers such as InChI as a 'crosswalk,' to establish the required correspondences with other systems. Much of the cross-referencing between numeric identifiers and structural identifiers has already been established and curated by several of the major online systems (particularly PubChem, ChemSpider and ChemIDplus); the Data Commons will use their good work through ongoing connections, rather than replicate it from the ground up. Using the API services offered by several of these systems will help significantly by making automated data access and analysis possible. Nonetheless, with the identifiers in some of the aforementioned system numbering in the millions, the task of building a SHIN Registry may sound like a daunting task.

There is no need, however, for the SHIN registry to encompass all existing identified substances, nor all possible substance groups. The SHIN registry will be built incrementally and organically, as a part of the development of the Data Commons community as a whole. The creation of SHIN identifiers will begin with a small prototype dataset, which would serve as a test-bed and proof of concept. As the project grows to encompass some of the more ambitious ideas and tasks, the community will create standard protocols for addressing complexities. At any point in the project, the status of the SHIN registry and the structure of the system will be openly exposed for transparency and peer scrutiny.

The work that HBN's Pharos has already accomplished in organizing chemical hazard information can serve as a good starting point for the SHIN registry. The Pharos system has already established an internal reference system cross-referenced on CASRN for over 34,000 substances. It encompasses the substances associated with the GreenScreen List Translator and many other non-listed substances that are in active commerce as identified through disclosures in the building material industry. The Pharos system has also already built a registry of several hundred chemical compound groups as identified by authoritative hazard lists and populated many of them.

It is important to stress that SHIN will be primarily an internal identifier system for the Data Commons Platform; its purpose is to give the Platform a robust skeleton. As the Platform grows, SHIN could be used to facilitate interoperability between databases that participate in the Data Commons. However, SHIN could conceivably also become an identifier of choice for other non-database settings where information about chemicals is published.

***Data Commons Recommendation:* Create a Substance Hazard Identification Number (SHIN) registry to cross reference the major identification systems and provide identifiers for the substances and groups not addressed by the other systems. Use internally for the Data Commons Platform, and for hazard association between databases.

Group Hazard Associations

One of the most important contributions of the Data Commons SHIN system would be openly standardizing the identification of chemical substance groups that are significant for hazard assessment. The Pharos Project has already implemented a first-generation system of hazard groups, and is developing a more sophisticated extension. Building on our experience with Pharos, SHIN will be designed to support unlimited levels of group hierarchy, and to allow controlled inheritance of hazard data associations from groups to subgroups. For example, a substance in the group of organic arsenic compounds could inherit hazards associated with the parent group of all arsenic based compounds.

Crowdsourcing the improvement of the Data Commons

While we can use automated computational methods to greatly assist the construction of groups and their hazard relationships, there will inevitably need to be considerable amount of expert judgment work applied to this process on an ongoing basis as well. This is a good example of a task that could be accomplished well by "crowdsourced" collaborative efforts.

We propose that some portion—perhaps a significant portion—of efforts for data completeness, quality, and maintenance could be performed collaboratively in a distributed fashion. We are interested in piloting collaborative editing processes in the SHIN, where numerous small contributions from different people, made on an as-needed basis, can add up to robust improvements.

***Data Commons Recommendation:* Create a curated crowdsourcing system for resolving system challenges such as ambiguous chemical identifications, group associations and developing other attributes in the system.

Comments to be addressed in future revisions

General:

- Concerns about the proposed name "Substance Hazard Identification Number." Incorporating the word "hazard" seems to assume a negative impact rather than a neutral naming convention. Imagine that preferred chemicals would also be assigned an ID number, too, as well as alternative assessments and green chemistry.
- The details of how SHIN IDs will be assigned to chemicals.
    - The role of data submissions by collaborating organizations?
    - Engagement with chemists and government agencies?
    - Potential standardization (e.g. ANSI)?

- Gather community input on classes of substances that have consistently been a challenge to identify with existing ID systems—in other words, to expand the list of such compounds in this document [petroleum distillates, polymers, etc.].

Mixtures & materials:

- Mixtures: There is one thoughtful paragraphs on mixtures. I wish this had been expanded, as this is a sleeping giant in any taxonomy like this. We humans think that chemicals exist in some pure form so that we can test them. However, chemicals in products are most often mixtures and chemicals are always reacting and concentrating and diffusing in any dynamic environment. There will always be surprising trace substances in any product and our single identifier/single chemical is a potentially misleading concept.
- Organize data on the toxicity of specific chemical mixtures?
- Tracking down ingredients in commercial mixtures will be daunting—anticipate difficulties finding this data.
- Materials: The paper stays mostly at the level of chemicals. However, most designers, retailers, consumers, etc. that you list as potential users are confronted with questions about materials and products. It would be helpful to offer some means by which users of the Data Commons can get to the level of materials and products. This is not, as you know, a simple aggregation of chemicals, but some thought should go into this.
- A reviewer's intuition is that "XX% of all building/auto industry/other bulk or fine chemical user products are comprised of only N chemicals." (Check recent work by Meg Schwarzman & Mike Wilson on automotive industry surfactants: Journal of Occupational and Environmental Hygiene, 2007, 4: 301–310)

Open IDs, linking data, and collaboration:

- A Freebase-like system could help in tracking and managing all the inter-relations between different identities and chemicals/groups/compounds.
- We will need good ways of updating database links.
- How will quality control of the data be managed throughout the Data Commons as the number of contributors grows?
- The Platform may need to allow for flagging of issues or places where a given relationship (say, a synonym) is controversial. Research best practices for handling disputed data in other open collaborative or wiki-type systems.
- Crowdsourcing: A recent article in MIT Technology Review discussed the pros and cons of Wikipedia's system both in the early days and today; may be of interest (e.g. potential pitfalls to avoid or to design out): http://www.technologyreview.com/featuredstory/520446/the-decline-of-wikipedia/
- Crowdsourcing requires expert judgment. What is the incentive for experts to contribute to this crowdsourcing? How will they be compensated if this system aims to be made freely available (if that is indeed the aim)? Reviewers express doubt that an expert community would put in the effort required out of the goodness of their hearts or for the intrinsic reward...

- ToxServices assigns a unique GreenScreen number to each chemical GreenScreened.

Additional Comments Welcome

Please submit to Akos Kokai (akokai@berkeley.edu) and Tom Lent (tlent@healthybuilding.net)