Nutrient Pollution

Friends of the Chicago River
2019

Introduction:

Nitrogen and phosphorus are essential elements for life, but humans are using them in such great quantity that these nutrients are disrupting aquatic ecosystems when they run off into local waterways. Collectively referred to as nutrient pollution, nitrogen and phosphorus are the two nutrients of greatest concern because they prompt excessive algae growth. When algae die, the process of decay uses up oxygen in the water, leading to low levels of dissolved oxygen. This process, known as eutrophication, "…has been linked to fish kills, shifts in species composition, taste and odor in drinking-water, and blooms of harmful algae as well as hypoxia in freshwater systems and estuaries, such as the Gulf of Mexico and the Chesapeake Bay" (source).

Nutrient pollution has been hailed as the second leading cause of impairments to water quality in rivers, and the EPA claims that nitrogen and phosphorus could become one of the costliest and most challenging environmental problems in the US. External costs associated with nutrient pollution include impacts to tourism and recreation, commercial fishing, property values, human health, drinking water treatment costs, mitigation, and restoration.

Phosphorus

In the 1960s scientists and the general public became concerned about eutrophication, but scientists were uncertain and could not agree on which nutrient was the leading cause. "Algae require primarily carbon, nitrogen and phosphorus to grow...the rate of algal growth (i.e., productivity) is controlled/limited by the nutrient in least supply relative to the demand… In most temperate fresh waters, phosphorus is the limiting nutrient even though algal cells are less than 1% phosphorus (Wetzel 1983)."

In the 1960s it had been generally agreed that detergents accounted for up to 50% of phosphorus in wastewater nationwide. Once it was determined that phosphorus was the limiting nutrient, the laundry detergent industry responded by voluntarily reducing their phosphorus content (to 8.7%) and spent millions on research for a substitute. There were initial concerns that substitutes had carcinogenic effects, so the industry was not allowed to use them for years, until the EPA studied and determined that the risk of cancer was too small to justify any regulatory action. In the meantime, many municipalities had passed legislation banning phosphates from detergents. The detergent industry took many of these municipalities, including Chicago, to court in the hopes of preventing or delaying enforcement until their substitute was approved.

Because of wastewater treatment improvements and bans on/reduction of phosphorus in detergents, phosphorus loads from urban wastewater treatment plants have been greatly reduced. Now, urban runoff – a nonpoint source of nutrient pollution – is the main challenge for controlling pollution.

Nitrogen

Though phosphorus is the controlling nutrient in freshwater eutrophication and nitrogen primarily impacts marine environments, nitrogen still poses a threat to the Chicago River watershed and is, in fact, the element whose amount has increased the most due to human activity. Additionally, a study found that "… 5 to 50 percent of the nitrogen input from nonpoint sources was exported out of most watersheds" (source), which means that nitrogen not addressed in the Chicago River watershed impacts the Gulf of Mexico's Dead Zone.

Sources of nutrients

Runoff from fertilizers in agricultural land use are a large source of nutrient pollution. However, in an urban environment, such as the Chicago River watershed, sources of nutrients are more varied. Nutrient pollution is exacerbated by runoff of impervious city surfaces. Urban runoff can account for nearly all nutrient contributions in local streams, according to the Sierra Club. Stormwater carries pollutants from homes, such as lawn fertilizer, yard and pet waste, and certain soaps and detergents. Fossil fuels used in electric power generation, industry, and transportation have increased the amount of nitrogen in the air that is then brought to the earth's surface (including waterways) in a process called atmospheric deposition. Wastewater is the most prevalent source of nutrient pollution if nitrogen and phosphorus are not removed before discharge. 16% of nitrogen and 48% of phosphorus come from sewage effluent (including contributions from CSOs). Wastewater contains nitrogen and phosphorus from human waste, food and certain soaps and detergents.

Current Conditions of the Chicago River System

Current methods involve the use of inorganic chemicals or additional energy to remove and dispose of excess phosphorus. The MWRD is implementing and experimenting with methods that would instead recover and encourage reuse of this nutrient.

The MWRD: Ostara Nutrient Recovery Technologies Inc.

The MWRD partnered with Ostara Nutrient Recovery Technologies Inc. to recover phosphorous and nitrogen from wastewater at their Stickney Water Reclamation Plant (WRP). Nutrient recovery takes phosphorus and nitrogen that would otherwise be discarded and turns them into an environmentally friendly fertilizer for ecological and agricultural purposes. Ostara claims their process removes nearly 90% of phosphorus and 40% of ammonia (excess nitrogen causes ammonia to degrade water quality when it is discharged) from sludge dewatering liquid. As a result, the wastewater that gets discharged into the river is cleaner and closer to meeting nutrient water quality standards – according to the MWRD and Ostara.

Ostara's technology creates a high quality fertilizer (99.6% pure), Crystal Green, that is practically water insoluble and only releases when the plants need it (plant roots emit a chemical when they want to feed). Ostara provides all the equipment for the program; offers operations and maintenance assistance; and harvests, dries, packages, and markets Crystal Green for the MWRD.

The facility opened at Stickney in May of 2016 after a capital investment of between $30 and $35 million by the MWRD. It was projected that this investment would be repaid within 3 to 5 years. The MWRD spent $8-9 million annually on chemicals to treat their wastewater for nutrients, and – in addition to avoiding this cost – once they have repaid their investment, they were estimated to make $2.5 million in net revenue from the sale of fertilizer annually. However, the revenue has proven to be much less than anticipated. In MWRD's 2017 budget, "resource recovery" was budgeted at $4 million dollars, which was adjusted to $280,000 in 2018. The actual revenue generated in 2017 was $295,602. In the 2018 budget, the category was budgeted for $1,600,000 and then reduced to $600,000 in 2019. Actual revenue for 2018 has yet to be released, but in the 2019 budget the MWRD is now budgeting for only $600,000 from resource recovery. It is unclear why the revenue is not as robust as expected.

Friends advocates for the expansion of this system to the MWRD's other wastewater reclamation plants.

The MWRD: Algae Harvesting and Cultivation

Phycoremediation is the cultivation and harvesting of algae for the purpose of removing nutrients from wastewater. Typically, this process requires a great deal of land and harvesting is costly and energy intensive because of low algal cell densities and specialized technologies needed to separate microscopic cells from water. Biofilm algae systems grow algal cells on a surface that forms a biofilm, so the film can easily be scraped from the surface.

On a small-scale, the MWRD is experimenting with a revolving algal biofilm (RAB) or Revolving Biofilm Reactor in a greenhouse at the O'Brien plant. MWRD is working with Iowa State University, which has a patent on the technology, and Gross-Wen Technologies. The RAB system is efficient with space and increases sunlight exposure (thereby increasing algal productivity; adsorption of nutrients and metals is also increased). The algae that the plant produces can be harvested for biofuels, bioplastics, fertilizer (in a digester), or aquaculture feed. Studies of this system have showed promising results, but its viability as a business model is still being evaluated.

RAB facility at MWRD's O'Brien WRP

RAB mechanism

Harvesting by putting a tray against the revolving belt and gentling scraping off the algae

In January of 2017, a settlement between environmental groups (including Friends) and the MWRD was reached to conduct a study to determine what level of phosphorus would maintain a healthy Chicago River. The MWRD has an RFP out to study their phosphorus, and the contract will be awarded soon.

Current Standards

Though in 1998 the Clean Water Action Plan directed the EPA to develop nitrogen and phosphorous standards, it was up to individual states to adopt them; the state of Illinois didn't even so much as develop a work plan for nutrient criteria. The task of developing numeric water quality standards for total phosphorus (TP) is made difficult because there is a lack of correlation between nutrient concentration and environmental impact in surface water bodies in Illinois. Due to pressure from the USEPA, IEPA is working to determine if a supportable science-based numeric water quality standard can be established.

The current nutrient water quality standards in Illinois are 0.05 mg/L of total phosphorus in lakes and 10 mg/L of nitrate-nitrogen in stream segments and lakes designated as public water supplies. These standards were established in 1972. In 2006 the "interim P rule" set the limits at 1.0 mg/L > 1 MGD (million gallons per day) for new or expanding wastewater treatment plants.

Regulation

When dischargers renew their National Pollutant Discharge Elimination System (NPDES) permits, IEPA requires them to submit a feasibility study for reducing phosphorus levels and to implement phosphorus discharge optimization plans for existing facilities.

A Nutrient Assessment and Reduction Plan (NARP) can be included in the Special Conditions section of a discharge permit. NARPs require dischargers to identify nutrients and determine total maximum daily loads (TMDLs). "A TMDL can prescribe the minimum level of dissolved oxygen (DO) available in a body of water, which is directly related to nutrient levels" (source). Though limits on nitrogen and phosphorus pollution have not been set federally, they can be addressed in a TMDL implementation plan as part of the NPDES discharge permit.

NARPs are used to identify phosphorus input reductions from point and non-point sources to help ensure that DO, aquatic algae, and aquatic plant criteria are met. The EPA can require permittees to develop or be part of a watershed group that develops a NARP if their waterway is considered at risk of eutrophication. Participants of these watershed groups can include stakeholders such as environmental advocacy groups, water and wastewater facilities and concerned citizens.

Illinois Nutrient Loss Reduction Strategy

As a result of the 2008 Gulf Hypoxia Action Plan to address the "Dead Zone" in the Gulf of Mexico, 12 states in the Mississippi River Basin have been called on to decrease the amount of nutrient pollution in their waters. In response, Illinois developed a framework, the Nutrient Loss Reduction Strategy (NLRS) for lowering its pollution from nonpoint and point sources such as agriculture and urban stormwater runoff. There are a diverse group of stakeholders involved in implementing the NLRS including agriculture, wastewater treatment agencies, state and local government, nonprofits, academia, etc. These stakeholders bring their expertise in science, technology, and industry to inform their recommendation of viable solutions to nutrient pollution. They have formed several working groups like the Urban Stormwater Working Group, which has subgroups working on stormwater education resources and exploring ways to track stormwater best management practices. The goals of the NLRS are to reduce Illinois' phosphorus load by 25% and its nitrogen load by 15% by 2025 and an ultimate goal of 45% reduction in the loss of nutrients to the Mississippi River.

The Nutrient Science Advisory Committee (NSAC), comprised of six scientists, was created to recommend numeric water quality standards for nutrient pollution that protect aquatic life and human uses of Illinois waterbodies to the Illinois EPA. In December 2018, NSAC released a report: Recommendations for numeric nutrient criteria and eutrophication standards for Illinois streams and Rivers. Friends, along with our partners at the Illinois Chapter of the Sierra Club, the Mississippi River Collaborative, Openlands, and Prairie Rivers Network, submitted a comment letter April 2019. The comment recommended IEPA use NSAC's report to prepare a proposal for numeric water quality standards and submit the proposal to the Illinois Pollution Control Board as quickly as possible, while acknowledging that watershed groups can develop numeric phosphorus standards for their particular water bodies at a later time.

Reduction Methods

Though they are both nutrients, phosphorus and nitrogen do not respond equally to the same reduction methods. Chicago must first study what its sources of each nutrient are and then address them in that context. The most effective and economically efficient methods are those that prevent nutrients from entering the system at all. Then there are those methods which lessen the amount that end up in a waterway and those that lessen the impacts once nutrients are in a waterway. Regardless of the approach used, they should be watershed-appropriate and include an array of strategies.

Point source preventative strategies

Detergents

Banning the use of phosphorus-rich detergents and other chemicals reduces nutrient loads sent to wastewater treatment plants in the first place. Chicago has already done this, as discussed above.

Lawn care

A 2017 study from the University of Minnesota found lawn fertilizer (and pet waste, discussed below) to be a primary source of nutrient pollution in seven sub-watersheds in Saint Paul.

Street sweeping

A 2016 study conducted by the US Geological Survey (USGS) in Madison, Wisconsin found leaf litter to be a significant source of phosphorus in urban stormwater. During the study Madison used leaf blowers and street cleaning about once a week from late September to mid-November. In conjunction with municipal leaf collection and street cleaning, they raised public awareness to encourage residents to properly gather their leaves for pick-up. They found leaf removal to be an effective treatment and determined "…the efficiency, frequency, and timing of leaf removal and street cleaning [are] the primary factors to consider when developing a leaf management program" (source). Total and dissolved phosphorus loads were reduced by up to 84%, and nitrogen was reduced by up to 74%.

Pet Waste

Animal waste, just as with human waste, can be a contributing factor to nutrient pollution. Pet waste left on the ground can wash into storm drains or directly into waterways. One source reported that a single gram of dog waste can contain 23 million fecal coliform bacteria (source). Pet owners who bag their pet's waste can eliminate this potential source of pollution.

Methods to lessen nutrient load

Green Infrastructure

Green infrastructure can not only help prevent flooding and CSOs, but it can biologically degrade nutrients before they reach the waterway. There is a strong correlation between nutrient export and stormwater runoff, so to reduce the one would reduce the other.

Practices of installing streamside forests and marshes, or riparian buffers, along agricultural fields has been proven to help absorb nutrient pollution running off of farms. Friends promotes the creation of a blue / green corridor along the river for the numerous health, equity, and economic benefits. Perhaps this corridor could also serve to reduce nutrient pollution making its way into the Chicago River from urban runoff. If stormwater runoff meets natural areas for bioremediation, then water that flows directly into the river would be cleaner before entering.

Of the many types of GI that exist, bioretention and shallow marsh systems have been shown to have higher denitrification rates. Permeable pavements have been shown to reduce 0-94% of nutrients. One study suggested that GI is most effective for nitrogen but does not have a very significant impact on phosphorus.

Wetlands

Wetlands are a potential solution to eutrophication because nitrate gets transformed into a gas that discharges into the air and phosphorus can be absorbed by the soils and taken up by plants. Wetlands can only hold a limited amount of phosphorus, so "it is necessary to add more new soils within the wetland from remnant plant stems, leaves, root debris, and indecomposable parts of dead algae, bacteria, fungi, and invertebrates" (wiki). One method suggests building up wetlands at the end of discharge pipes for additional filtration before the effluent enters a river.

Bioremediation

Bioremediation is the process of removing hazardous substances from soil, water, and air through the use of microorganisms and plants or their enzymes. This process can be used to address any number of pollutants (greenhouse gases, heavy metals, sewage, etc.) in any number of environments (groundwater, surface water, soil, air). Aquatic plants, aquatic animals, microorganisms, and microbial dosing are methods that have been used in waterways. The MWRD already uses bioremediation during its wastewater treatment by encouraging bacteria to grow.

Upgrades to stormwater systems and sewage treatment plants

The City of Chicago is getting financial assistance from the IEPA (Water Pollution Control Loan Program) for some of the updates they are making to their system. The MWRD has Master Plans for their Stickney, Calumet, and O'Brien WRP for improvements through 2040.

Methods for lessening impact

Denitrification

A common approach to nitrate removal in surface water is biological denitrification: microbes metabolize oxygen from oxidized nitrogen (denitrifiers) and release nitrogen gas as a result. "…denitrification is an important wastewater treatment because it converts a dangerous contaminant into a benign gas that can be discharged with no environmental impact."

Barley Straw

One method of combating algae growth is to place Barley Straw along the edges of waterbodies because it releases a chemical that inhibits new algal growth as it degrades. Other straws have been tried, but there is something about barley straw that has been the only one proven effective (it mimics one or more properties of wetlands; it contains phenolic materials responsible for the brown color of the water that has been shown to suppress algal growth).This method however does not remove nutrients.

Success, though, seems to be inconsistent for reasons that remain unclear to researchers. Some factors that determine success include: "…starting treatment well in advance of bloom development, adequate straw dosage, adequate aeration of the straw, proper positioning of the straw in the body of water, adequate water circulation, and perhaps the type (cultivar) of barley used and the conditions under which the barley was grown." There seem to be two ways to apply this method: in the water and along the water. In the water would address nutrient overload already in the water and along the water would address nutrient loads from runoff. It's only effective for up to six months, so it needs to be replaced regularly. Ultimately this is not a method for reducing the amount of nutrients in a body of water, but it seems like it can prevent algal blooms, which would preserve DO.

Dredging

Dredging can reduce internal phosphorus cycling by removing phosphorus trapped in sediment at the bottom of a river. Phosphorus trapped in sediment can probably explain why the Dead Zone is still bad this summer, even though farmers did not apply as much fertilizer as usual because of the heavy rain storms this spring. Because the Dead Zone is just as bad as usual, this could mean that there are dormant nutrients that were flushed out to the Mississippi.

However, dredging can be the very reason that nutrients trapped in sediment are released into the water and therefore cause algal blooms. Additionally, this does not seem like a long-term solution since runoff and erosion events can quickly replenish nutrient concentrations in replaced sediments.

In general, this does not necessarily seem like a route we want to advocate for, however, since dredging does already happen on a fairly regular basis, maybe we could find a way to make it more useful to us/less harmful to water quality. I don't know if there is a specific way you have to dredge in order to include a focus on phosphorus removal.

Additional Strategy

Nutrient Trading or Water Quality Trading

Nutrient trading allows one source of nutrient pollution (wastewater treatment plants, for example) to sell credits - if they discharge below their requirements - to a source that is struggling to meet their own requirements. The intention is not to even out discharged pollution so that one source can continue exceeding the requirements. Instead, nutrient trading allows a discharger who may not be able to meet their requirements by the deadline (because of economic, time, etc. constraints) to remain in compliance.

Since the 1990s, the US EPA has supported water quality trading for achieving compliance. The EPA "believes that market-based approaches such as water quality trading provide greater flexibility and have potential to achieve water quality and environmental benefits greater than would otherwise be achieved under more traditional regulatory approaches…[T]he policy is intended to encourage voluntary trading programs that facilitate implementation of TMDLs, reduce the costs of compliance with CWA regulations, establish incentives for voluntary reductions and promote watershed-based initiatives" (source).

The EPA provided a *Water Quality Trading Policy* in 2003 and a *Water Quality Toolkit for Permit Writers* in 2009 to assist state, tribal, and EPA NPDES permitting authorities and other stakeholders in implementing water quality trading. February 2019 the EPA issued a memorandum updating their policy. The update acknowledges that the 2003 policy was too prescriptive and that it should be modernized to reflect the improvements made in technologies and practices since then. Also included in this memo are six broad market-based principles the EPA suggests: implement programs on a watershed scale, adaptive management strategies for implementation, simplicity and flexibility in implementing baseline concepts, bank water quality credits and offsets for future use, single projects may generate credits for multiple markets, take advantage of existing financing opportunities to assist with deployment of nonpoint land use practices.

Herbicide
Copper sulfate herbicide treatment: lasts five years but is not feasible where total alkalinity is less than 50 mg/L because fish pop will be sensitive. What's the difference between hypolimnetic withdrawal and dredging?

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