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Questions and comments about removal of nitrogen and phosphorus from Winnipeg sewage

Lake Winnipeg is a complex system affected by several changes at the same time. Climate warming, invasions by new species, loss or near loss of existing species with consequent changes in food web structure, and regulation of water flows and levels all affect the lake. The most obvious current problem is the algal bloom that we see most years, sometimes covering much of the lake. These blooms are evidence of excess biological production, called eutrophication, and they have probably always occurred in Lake Winnipeg. In recent decades, however, they have increased in size and frequency, a trend confirmed by images made from satellites and by cores of sediment from the bottom of the lake. The remarkable productivity of the algae is reflected throughout the food chain all the way up to the excellent recent yields of walleye in the commercial fishery. Growth of algae requires light and nutrients; we can do little about the light but the Government of Manitoba has begun several initiatives to reduce the supplies of nutrients.

On Dec. 12, Dwight Williamson (Director, Water Science and Management Branch, Manitoba Water Stewardship) presented a PowerPoint slide presentation "*Restoring the Health of Lake Winnipeg: Science, Policy, and Implications for Wastewater Treatment from the Controversial Control of both Nitrogen and Phosphorus.*" He cited numerous "new" scientific reports and reviewed several "old" reports to explain the reasons behind Manitoba's plan to require removal of nitrogen and phosphorus from Winnipeg sewage. Several knowledgeable scientists have been consulted about nutrient removal (Gregg Brunskill, Murray Charlton, Robert Hecky, Hedy Kling, Brian Kotak, Lyle Lockhart, Greg McCullough, Alex Salki, David Schindler, Michael Stainton, Sue Watson, Harold Welch) and they have offered comments and questions. Based on these consultations we have learned that scientists have different views and experiences on issues of sewage treatment and on effects of supplies of nitrogen and phosphorus to lakes. There are points of agreement with Manitoba's plan and points of disagreement. Whether any given scientific study is "old" or "new" matters less than whether it is sound and whether it applies to Lake Winnipeg.

Matters of agreement

There is broad scientific agreement on several matters relevant to the remediation of Lake Winnipeg:

The first area of agreement is that lakes respond in their own unique ways that are not always predictable from laboratory data or even from other lakes. While there are some helpful generalities, there is no substitute for studies on the actual lake of interest. Many bioassays are conducted on bottled samples of lake water but, while these are useful for establishing what mechanisms may exist, by their artificial nature, they cannot reflect the variable, long-term changes that occur continuously in lakes. Similarly there are many statistical correlations among variables in lakes. Neither of these lines of enquiry can provide proof of a cause/effect relationship within a real lake

The second area of agreement is that removal of phosphorus will help control excess algae in Lake Winnipeg. All algae and indeed all living things need phosphorus. They cannot make it for themselves and there is nothing else that can replace it. (e.g. *Lake Winnipeg Stewardship Board* recommendation 11.5) Consequently, restricting inputs of phosphorus will eventually reduce concentrations in the lake and that will eventually result in fewer algae. It will be a slow process (decades) since we have to overcome decades of overloading with phosphorus but it will work. It is important to understand that there are different forms of phosphorus which differ in how 'bioavailable' they are for algal growth. Sewage contains very high proportions of bioavailable phosphorus. So while the total phosphorus input from the City of Winnipeg is small in comparison with that from the rest of the watershed, nevertheless it is an important source, and removal of phosphorus by the city is an essential step in efforts to control the algal blooms.

There is another reason for removing phosphorus and that is to recover it and sell it. Phosphorus is essential for agricultural crops and has great value in commerce. Furthermore, world supplies of phosphorus are limited to a small number of mining areas and shortages can be anticipated although the timing of these is still debated. While solubilization of phosphorus recovered from city sewage is environmentally demanding, the environmental and economic issues involved with recycling this phosphorus should be explored.

Thirdly, our best current estimates of nutrient loading *(Manitoba Water Stewardship)* indicate that about 8000 tonnes of phosphorus and 96000 tonnes of nitrogen are added to Lake Winnipeg annually. The City of Winnipeg contributes about 400 tonnes (5%) of phosphorus and 3700 tonnes (4%) of nitrogen, with the remaining 95 – 96% of these nutrients coming from other sources in the watershed or from atmospheric sources. Twenty percent of the nitrogen input into Lake Winnipeg comes from the atmosphere in precipitation (10%) or through fixation (10%) by blue-green algae. Clearly, the major sources are beyond the city and effective controls on amounts entering the lake will derive not only from actions in the city but also from actions in the watershed, principally the Red River watershed which supplies about 54 % of the inputs of phosphorus and 30 % of the inputs of nitrogen in spite of the fact that it supplies only 11 % of the water.

Finally, preliminary studies reveal that 75% of phosphorus and 58% of nitrogen loaded annually to Lake Winnipeg are retained in the lake, largely in the bottom mud (*Lake Winnipeg Stewardship Board Report*). This has been happening for decades and it has build up a legacy of nutrients that can be recycled from the mud, especially under conditions of low oxygen, to nourish algae now and for some time into the future.

Matters of disagreement

The main area of disagreement focuses on which nutrient management strategy, either removal of phosphorus alone (recommended by scientists) or removal of phosphorus and nitrogen together (recommended by the provincial regulator), will be of greater benefit to the lake.

Removal of nitrogen is scientifically questionable for several reasons. Nitrogen is just as essential for life as phosphorus but its sources are different; indeed living things need more nitrogen than phosphorus. There are lakes where algal production can be controlled by nitrogen (provided there is enough phosphorus) but Lake Winnipeg is not one of them.

The algal community in Lake Winnipeg consists of many species with different modes of growth, including several blue-green algal species (correctly called cyanobacteria) that can obtain their nitrogen from nitrogen gas which comprises about 80 per cent of the atmosphere. Taking nitrogen from the air and making it into forms needed for growth is often called "fixing" nitrogen. Species that can fix nitrogen are at an advantage whenever a shortage of nitrogen develops, a situation which occurs in Lake Winnipeg.

In spring, with increasing amounts of sunlight and warmth, the diatoms and other non-nitrogen-fixing species begin to grow rapidly using whatever nitrogen and phosphorus is available in the water. These algae form the base of the food chain leading to the fish. Some cyanobacteria species are present all the time, even under the ice in winter, but their numbers are small and they all compete for the same pool of nutrients. As the numbers of non-fixing algae expand, they begin to deplete available nitrogen which becomes the nutrient limiting their continued growth. But because there is still phosphorus available, the advantage shifts to species that can fix nitrogen, usually *Aphanizomenon* and *Anabaena* species, which accumulate as surface blooms during much of the summer. These cyanobacteria species flourish particularly well during hot summer weather which is why they are becoming globally more problematic as the earth's climate warms. They can reach such high biomass that they themselves become limited by the depleted phosphorus in the layers of water they occupy. Then these nitrogen- fixing types begin to die back releasing their nutrients (P and N and others). When this happens, other types of cyanobacteria which do not fix N, such as *Microcystis*, are in a good position to take advantage of the nitrogen released from the decomposing fixers. Almost all cyanophyte species, both fixers and non-fixers have been found to produce toxins which even in very low concentrations may affect human and animal health so it is important to minimize cyanophyte growth and development. Reduction in available nitrogen encourages a sequence of cyanophyte species following the initial success of the diatoms.

Removal of nitrogen from Winnipeg sewage waste waters will decrease the availability of nitrogen for spring growth of diatoms and other non-fixing species. Until the excessive loading of phosphorus to the lake is curtailed, mid-summer nitrogen limitation will persist for non-fixing species, and blue-green algae including the known toxin producer, *Microcystis,* will continue to dominate the summer-fall algal community.

Lake Erie experienced a serious problem with algal blooms in the 1970s and that was largely controlled by removal of phosphorus by sewage treatment plants. Inputs of phosphorus to Lake Erie were dominated by point sources, municipal sewage plants, unlike our situation here where inputs are dominated by non-point sources scattered throughout a giant watershed. Inputs of nitrogen to Lake Erie were never controlled. Lake Erie never had the abundance of cyanobacteria that Lake Winnipeg has.

Confusion arises from the assumption that the nutrient ratios that control day to day competition among algal species are the same ones that govern what species will eventually dominate and how much algae is produced on a lake-wide basis in response to nutrient addition.

The scientists we consulted know of no example where removal of nitrogen alone or removal of both nitrogen and phosphorus together has controlled eutrophication of a lake with blue-green algae better than removal of phosphorus alone. A 37-year eutrophication experiment at the Experimental Lakes Area (Lake 227) southeast of Kenora showed that eutrophication could not be controlled by reducing the inputs of nitrogen. Eliminating nitrogen sources from the lake increased, rather than reduced symptoms of eutrophication because that favoured nitrogen-fixing cyanobacteria (see abstract appended).

It is also important in considering case histories of lakes to recognize that algae need light. Light can be limited by particulate matter in the water, as appears to be the case in the South Basin of Lake Winnipeg most of the time. High concentrations of algal cells can limit the light that can penetrate into the water below them. Many of the blue-green species in the lake can regulate their buoyancy in order to move up and down in the water and position themselves better for capturing the available light for photosynthesis.

The second area of disagreement is on the cost/benefit of removing nitrogen. The major source of phosphorus to Lake Winnipeg is the Red River. In the past two decades flows in the Red River have been the highest on record and these high flows have transported more phosphorus from rural landscapes to Lake Winnipeg. One scientist remarked that, "The solution to phosphorus loading by the Red River is a 10-year drought in the Red River watershed." Increasingly the nutrient chemistry of Lake Winnipeg has come to reflect that of the Red River in spite of its small contribution to the total inputs of water. Furthermore, there is a relationship between the proportionate flow of the Red River relative to other sources and the size and frequency of algal blooms.

While control of phosphorus from the city is vital, it is also extremely important to control phosphorus from rural sources if we hope to remediate Lake Winnipeg in a cost-effective manner. Control of nitrogen from the city entails huge costs but little or no benefit to the lake. At current Red River flows, Winnipeg contributes around 4% of the nitrogen load while nitrogen fixation by the cyanophytes contributes about 10% of the nitrogen. The money to be spent on control of nitrogen from Winnipeg will provide greater benefit to the lake if it is spent instead on the control of phosphorus from the rural landscape.

It is technically feasible for Winnipeg to phase its sewage treatment upgrade by installing phosphorus removal immediately and then adding nitrogen removal later in the unlikely event that it should become necessary.

Questions about objectives: The scientists are not exactly clear on the reasoning behind the target nutrient loadings currently proposed by the provincial government. For example, control of nitrogen may be deemed necessary for reasons unconnected to Lake

Winnipeg. Some jurisdictions have found that reduction in discharges of nitrogen as ammonia are needed to reduce toxicity of sewage effluent immediately downstream from points where it is discharged into rivers. Such a goal, however worthy it might be, has little relevance for Lake Winnipeg. If that is the reason for the removal of some or all of the nitrogen in the sewage, then Manitoba should state it as such.

Questions on consultations with experts: We are informed that the *Lake Winnipeg Stewardship Board* planned to hold meetings with internationally recognized authorities to help derive scientifically defensible nutrient loading plans. Unfortunately, those meetings did not occur. Broadly based scientific consultations need to be undertaken before final plans are made.

Recommendation

Based on the questions and comments provided by knowledgeable scientists, The Lake Winnipeg Foundation commends Manitoba for its plan to require removal of phosphorus from Winnipeg sewage. However, the removal of nitrogen is not as simple. The costs are enormous. We heard the case for removal of nitrogen and the case against removal of nitrogen deserves to be heard. Lake Winnipeg Foundation calls for a rigorous scientific review of the costs and benefits, both ecological and economic, of removing nitrogen.

In the interests of making scientific information available as widely as possible, the Lake Winnipeg Foundation has begun plans to host an open, public forum on these issues. Further details about these issues and about plans for the public forum will be available on the Lake Winnipeg Foundation web site (www.lakewinnipegfoundation.org) as arrangements are completed.

Abstract of paper submitted for journal publication
Abstract made available by the senior author

Controlling Eutrophication by Controlling Nitrogen Input: Results of a 37 Year Experiment

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One Sentence Summary: A 37 year whole lake experiment revealed that eutrophication of lakes cannot be decreased by controlling inputs of nitrogen, even when there is physiological evidence of extreme nitrogen limitation in phytoplankton.

Lake 227, a small lake in the Precambrian Shield at the Experimental Lakes Area (ELA), northwestern Ontario, Canada, has been the subject of a 37 year fertilization experiment. From 1969-2005, the lake was fertilized with constant inputs of phosphorus and decreasing inputs of nitrogen. For the final 16 years (1990-2005), the lake was fertilized with phosphorus alone, to test whether reducing nitrogen inputs could control eutrophication. Nitrogen-fixing Cyanobacteria were increasingly favored after fertilization with nitrogen was reduced. Although the phytoplankton community always showed extreme nitrogen limitation, nitrogen fixation was sufficient to allow biomass to remain in proportion to phosphorus, and the lake remains highly eutrophic. Eliminating nitrogen sources from Lake 227 increased, rather than reduced symptoms of eutrophication in the lake by favoring nitrogen-fixing Cyanobacteria. We conclude that reducing nitrogen inputs to other lakes, and probably to estuaries, will be equally ineffective. To reduce eutrophication, the focus of management should be on decreasing inputs of phosphorus.