SWAN RIVER TRUST

River Science 13

The science behind the Swan-Canning Cleanup Program

Issue 13, October 2000

Oxygenating the Swan and Canning rivers

Overview

Oxygenation has been adopted as a river remediation technique by the Swan Canning Cleanup Program, which was implemented principally to reduce the occurrence of potentially toxic phytoplankton blooms on the Swan and Canning rivers. The main aim of the oxygenation projects is to modify river conditions to reduce the occurrence of phytoplankton blooms. On the Canning River two kilometres of river are currently oxygenated, and a mobile oxygenation barge is being tested on the Swan River.

This River Science explains what oxygenation is, why it is being considered as a management tool, and how it works. Subsequent editions of River Science will report on the progress of oxygenation projects on the Swan and Canning rivers.

The problems with our waterways

Human impacts on natural waterways have been significant and generally detrimental. When these impacts place an ecosystem under stress, we start to see changes in the composition of the ecosystem. On the Swan and Canning rivers the increasing frequency with which phytoplankton blooms have occurred indicates that these ecosystems are becoming increasingly stressed.

Phytoplankton are microscopic (up to 1-2 mm diameter) free-floating or weakly mobile aquatic plants. Because algae are a major component of phytoplankton, phytoplankton blooms are commonly known as algal blooms. However, two divisions of organisms in the phytoplankton (cyanophyta or 'blue-green' algae and dinophyta or 'red tides') that are of greatest concern because of their potential toxicity are not actually algae. Therefore, although in common usage an algal bloom and phytoplankton bloom are the same thing, phytoplankton is the more inclusive term for the organisms we are dealing with.

Although human impacts on waterways take many forms, in terms of understanding how oxygenation works and how it is being used to prevent phytoplankton blooms in Western Australia's rivers, we can focus on three:

1) **Increased levels of nutrients entering the waterway**. Urban environments have contributed to the increase in nutrient loads through the channelling of drainage water directly into the river, leaching of nutrients from fertilised lawns and industrial processes, and so on. Agricultural practices have also resulted in greater amounts of nutrients reaching waterways.

   High nutrient levels can change the species composition in the ecosystem, often resulting in the proliferation of one or a few species. A phytoplankton bloom is a good example of this.

Oxygenation plant on the Canning River. Pipes distributing oxygenated water are in the foreground. Behind them are the oxygen dissolver (left) and liquid oxygen vessel (right).

2) **High levels of organic matter entering and accumulating in waterways**. Unmodified waterways often have wetlands or dense fringing vegetation that filters out a lot of organic matter before it enters the main waterway. If these mechanisms are removed or decreased in efficiency more organic matter will enter the waterway.

   Bacteria decomposing the organic matter require oxygen. When there is high oxygen demand, oxygen levels in the water may drop below levels required to sustain aerobic organisms. The decomposition of organic matter provides a source of nutrients, but more importantly under low oxygen conditions nutrients are released from the sediment. This release of nutrients can trigger phytoplankton blooms. The mechanisms by which the nutrient release occurs is explained in greater detail in this River Science.

3) **Modification of flow regimes.** The damming of rivers creates large static water bodies upstream and reduces flow downstream of the dam. In either case, the consequent lack of water movement creates still conditions that are ideal for the rapid proliferation of phytoplankton. Lack of water movement also means that oxygen that dissolves in the surface water will not be mixed down to the bottom, resulting in low bottom water dissolved oxygen levels and subsequent nutrient release.

   This description particularly applies to the oxygen trial area of the Canning River, which is dammed upstream by the Canning dam and downstream in summer by the Kent St Weir. The Swan estuary has not been affected to the same extent, but there naturally occurring stratification also promotes low oxygen levels. For more information, refer to River Science issue number 14, which reports on the Swan River Oxygenation Barge trial.

In summary, the two main consequence of human intervention that have increased the occurrence of phytoplankton blooms are an abundant supply of nutrients and the creation of ideal growth conditions.

Where oxygenation fits in…

Now we have an understanding of the problems that our waterways suffer and how these are linked to phytoplankton blooms, we can look at how oxygenation fits in. It is important to understand that neither oxygenation, nor any other remediation technique is going to solve these problems in isolation. Remediation techniques such as oxygenation should be seen as part of an integrated solution, where the ultimate goal is to reduce the levels of nutrients entering the system. The Swan Canning Cleanup Program is such a solution, and readers wishing to learn more about the different approaches that are being used to tackle these problems should refer to the Swan Canning Cleanup Program Action Plan.

…and how it works

Oxygenation works by raising dissolved oxygen levels in a water body, and is therefore only effective when oxygen levels are already low. However, in summer low oxygen levels are common in both the Swan and Canning rivers.

When oxygen levels are high, aerobic decomposition and recycling processes can function efficiently and organic matter is rapidly mineralised and nutrients removed from the system. Getting these processes working efficiently is the key to successfully using oxygenation as a tool to reduce the occurrence of phytoplankton blooms.

The three main plant nutrients – carbon, nitrogen and phosphorus – are cycled differently through the ecosystem and are thus removed from the aquatic system in different ways. The explanations below focus on these removal pathways.

Carbon

In the presence of oxygen, the carbon in organic matter is converted to carbon dioxide by aerobic respiration. Major pathways for the removal of carbon dioxide from an aquatic ecosystem are loss to the atmosphere and precipitation as insoluble calcium carbonate. Oxygenation assists the rapid break down of organic matter by ensuring a ready supply of oxygen. Importantly, it also helps to prevent oxygen deficits that occur when there is a high demand for oxygen, thus maintaining an ecosystem suitable for invertebrates and fish, and preventing both the release of phosphorus from the sediment and the build up of plant-available nitrogen.

Nitrogen

Nitrogen is available to plants as ammonium, nitrate and dissolved organic compounds such as urea. During the decomposition process nitrogen in organic matter is converted to ammonium. The removal pathway for ammonium is via the different but complementary processes of nitrification and denitrification. The aerobic process of nitrification converts the ammonium to nitrate. The denitrification process, for which oxygen is not essential, then converts the nitrate to nitrogen gas. The nitrogen gas may be then lost to the atmosphere. Nitrogen held within particles or in organic form may also be removed from the ecosystem through scouring winter flows.

Oxygenation supports the nitrification process and thus assists the permanent removal of nitrogen from the ecosystem. In waters where the oxygen level is too low to support nitrification, ammonium concentrations build up, providing a nutrient source for phytoplankton blooms.

Phosphorus

Phosphorus enters the waterway in several forms, of which only soluble phosphate is available to plants. In the presence of oxygen soluble phosphates rapidly bind with other minerals, typically iron oxide, and are then no longer available to plants. When oxygen is not present, iron oxides become more soluble, and bound phosphorus likewise enters solution.

Unlike carbon and nitrogen, phosphorus is not commonly present as a gas and therefore cannot be lost to the atmosphere. The removal pathways for phosphorus are mineralisation and burial in sediments, or loss to the ocean, which mainly occurs when winter flooding scours out the river bed.

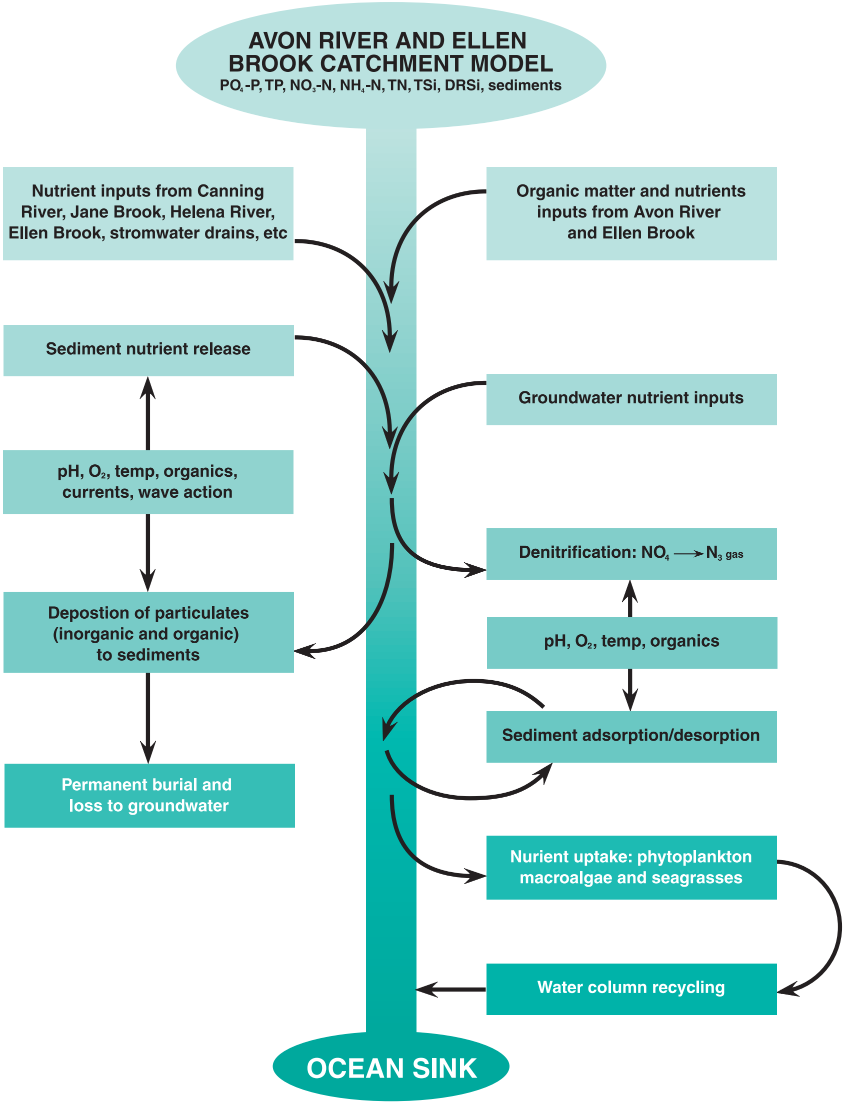

Figure 1: *Major estuarine biogeological chemical processes*

The processes by which nutrients enter the Swan Canning system, their interactions and their cycling make up a complicated picture. This illustration shows the number of cycles nutrients and sediments undergo before they are permanently buried, are removed by plants and animals or enter the indian ocean at Fremantle (PO_4-P: phosphate; TP: total phosphorus; NO_3-N: ammonium; TN: total nitrogen; Tsi: total silicon; DRSi: dissolved reactive silicon; temp: temperature).

Therefore oxygenation cannot remove phosphorus from the system, but it can temporarily suppress its release from the sediments.

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WATER AND RIVERS COMMISSION

Contributing to health of the Swan and Canning Rivers
A project of the Swan-Canning Cleanup Program

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Part of the oxygenated area of the Canning River. Rafts of the floating macrophytes azolla *and* lemna *like this are occasionally seen in summer.*

In summary, we can see that oxygenation helps the permanent removal of carbon and nitrogen from the ecosystem, and temporarily suppresses phosphorus release. All of these outcomes help prevent the conditions that lead to the formation of phytoplankton blooms. Anoxic events that result in mortality and the loss of biodiversity through the accumulation of the toxic by-products of anaerobic bacterial processes (eg hydrogen sulfide gas, methane, ammonia) and severe anoxia are also reduced.

Applying oxygenation to the Swan and Canning rivers

There are many techniques and devices by which oxygen concentrations in water can be increased. These can be broadly divided into those that use air (aeration) and those that use pure oxygen (oxygenation). The majority of both aeration and oxygenation devices were developed for use in industrial applications or large deep lakes and water supply reservoirs, and were thus not necessarily suited to the shallow rivers of the Swan coastal plain. An evaluation of the different techniques available recommended that initial trials use a sidestream oxygenation plant. This plant uses pure oxygen, the term ‘sidestream’ referring to the fact that de-oxygenated water is pumped out of the river to be oxygenated, and then returned to the river. The advantages of this technique are that it offers a large oxygen transfer capacity with minimal disturbance to bottom sediments or stratification, and allows the oxygenated water to be directed to the river bottom where it is most required.

The first oxygenation trial was conducted on the Canning River in 1997/98 (refer to Oxygenation Trial on the Canning River Western Australia: A Report on the 1997/98 Bacon Street Trial). Subsequent editions of River Science will report on the progress of this project, which ends in 2002. The Swan Barge oxygenation project, which began in 1999, ends in 2001.

Determining whether oxygenation has actually limited phytoplankton growth in the treatment areas is very difficult, due to the complexity of aquatic ecosystems and the myriad factors that affect phytoplankton growth. Because of this, monitoring programs have so far concentrated on linking increased dissolved oxygen levels to reductions in carbon, phosphorus and nitrogen. A full evaluation of the effect on phytoplankton growth will be made as the field component of the projects end.

For more information

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