Nutrient capping: the perfect partner for enhancing the effectiveness of diffuse pollution management in lakes

M.M. Gibbs

National Institute of water & Atmospheric Research, PO Box 11115 Hamilton, New Zealand

Nutrient capping is a technique that inactivates nutrients accumulating in the lake sediments, preventing their subsequent release and use by planktonic algae for growth. In highly degraded lakes, nutrient capping can give a “kick start” to lake rehabilitation and is the perfect partner to management strategies reducing diffuse sources of nutrients from land.

While capping agents can block nitrogen, most of these products are designed to block phosphorus (P), which is released as phosphate from lake sediments under anoxic conditions. P is released from sediment at a rate limited by microbial decomposition of organic matter and the reduction of Fe and Mn salts to their soluble forms — typically around 30-40 mg P m^{-2} d^{-1} but can be > 80 mg P m^{-2} d^{-1} in highly eutrophic lakes (Burger et al., 2007; Gibbs et al., 2011). The longer the period of anoxia, the more P is released and the higher the P concentration in the bottom water when the lake mixes. Re-oxygenation, using aerators, can reverse the release process and the P will be sequestered back into the sediment. However, in highly eutrophic lakes, the internal P load released from the sediments in summer can be greater than the annual external load from diffuse sources in the catchment.

There is a range of nutrient capping agents that permanently bind P. Most fall into one of two categories: 1) products designed to prevent the release of P from lake sediments and 2) products designed to remove the P from the water column. Decision support and risk assessment frameworks are available to help select the best product for a specific lake and aid assessment of the treatment required to manage the potential nutrient loads in the sediment (Hickey & Gibbs 2009). In many instances, nutrient capping is applied at a rate sufficient to lock up and thus inactivate all P that could be released, effectively resetting the internal P load to zero. Once bound by the P-inactivation agent, that P is gone forever.

This has the potential to enhance the effectiveness of diffuse pollution management strategies implemented in the catchment. However, catchment remediation measures take time to work and nutrients from diffuse sources will continue to enter the lake via groundwater, fuelling algal growth for many years after the source has been reduced or removed (Gibbs 1991; Vant & Smith 2002; Hamilton 2005; Morgenstern & Gordon 2006; Morgenstern 2007). This means that the effectiveness of the nutrient capping treatment will be progressively negated through burial and much of the inactivation capacity of the capping material may be wasted. Consequently, the integration of catchment and in-lake management strategies may be better served by applying several smaller treatments designed to more closely match the nutrient loads on and in the lake at one or more yearly intervals.

Against this background, there are a number of decisions to be made before implementing a nutrient-capping programme. The primary decision is whether to:

1. cap the sediment with a P-inactivation agent when all the P is in the sediment, or
2. apply a P-inactivation agent to the water column to adsorb the P which has been released from the sediment and cause it to settle on the lake bed.

This decision will determine when the treatment(s) are to be made and what product formulation is to be used.

Option 1 is better suited to deeper lakes that thermally stratify strongly in summer, and where the product is less likely to drift into the aerobic littoral zone. The management decision is then whether to treat the sediment with enough P-inactivation agent to bind all available P in the sediment or use just enough to bind the amount of P that could be released during the low oxygen events each year for several years. The dose required is calculated based on the number of years between retreatment. The estimate uses data specific to the lake and is a function of the total available P load in the sediment, the rate of P release, the external P load, the sediment accumulation or burial rate, the maximum P-binding capacity of the capping product used and the thickness of the sediment layer through which that product is able to adsorb phosphate efficiently. Treatment would be in winter when the lake is completely mixed.

Option 2 is better suited to shallower lakes that may have several thermal stratification and anoxic events during summer. For best results, the product should be applied directly into the bottom waters during each stratified period in summer. This has the advantage of treating only the water with elevated P concentrations and preventing product drift into the aerated littoral zone. The decision then is which product should be used and what proportion of the soluble phosphate should be removed.

Cost/benefit considerations are also important and, based on product cost and the cost of application, these may determine which product to use for a specific lake and whether to use a single large treatment or multiple smaller treatments spreading the cost over several financial periods. Other considerations include non-target side effects on microbial and benthic macro-faunal communities (Gibbs & Özkundakci 2011), toxicity effects enhanced by water chemistry (alkalinity and hardness) (Gibbs et al., 2001), and whether it is socially and culturally acceptable to treat a specific lake with a specific product.

With the rehabilitation of highly eutrophic lakes, the internal P load cannot be ignored and catchment management of diffuse pollution sources will not be sufficient to rehabilitate the lake. Without catchment management nutrient capping will provide only temporary rehabilitation. Implemented together, these techniques are perfect partners for the rehabilitation of degraded lakes.

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