Phosphate recycling from saline sediments in constructed ponds

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Abstract

Solar salt fields are marine to hypersaline wetlands. Many of the species found within the constructed ponds are common to the adjacent coastal areas. The ponds act as natural accumulators of nutrients with the sediment, rich in organic material, gradually becoming deeper over time. The phosphate concentrations in the sediments were determined as part of a program studying the role of sediments in the biological cycle. Reactive phosphate in the sediment was found at concentrations up to 2000 ppb-PO4-P, which is 200 times the concentration in the water column. The organic phosphate concentrations similarly were very high. These results were evaluated in the context of known phosphate mass balances, and it was determined that, a significant proportion of the phosphate entering the closed system ends up in the sediment. The factors that may cause a wetland to vary in its efficiency as a phosphate trap are discussed.

Introduction

Wetlands are often defined in terms of water tables and hydric soils, with some notion of aquatic vegetation (for example Howard-Williams, 1985, Sememiuk 1987). The Ramsar Convention defined a wetland as any wet area whether artificial or natural, permanent or temporary, and fresh or saline (Department of Foreign Affairs 1975). Ramsar even went as far as to include marine areas to a depth of six metres within the definition of a wetland. The definitions encompass a exceptionally wide range of landforms within the concept of a wetland.

I consider wetlands as any intermittently submerged area in which the sediment/aquatic interaction is a dominant feature of the ecosystem. The sediment/aquatic interaction seems to be one character that is represented in all wetland types. Wetlands range from natural and artificial, and from freshwater to saline.

Saltfields are, by most definitions, artificial wetlands with a salinity range from seawater to hypersaline, and are very biologically active. When studying wetland processes, the variability of parameters and problems of access make it difficult to collect repeatable results. A saltfield has an advantage as a case study in that the ponds are actively managed and monitored, bringing greater stability to the study. Also, access is relatively simple with constructed roads to most areas. They often cover thousands of hectares, providing ample opportunity for detailed long term studies.

The concentrating ponds of a well designed saltfield are constructed to encourage biota with the specific intention of reducing nutrient transfer between ponds. In the case of the saltfield, this is done by maintaining a constant salinity and depth which has been shown to reduce nutrient transfer (Coleman and White 1993) This objective is similar to the nutrient reducing function of the many artificial wetlands constructed around Australia. Much of the work being done on saltfields is directly applicable to most wetlands.

In a previous paper, the nett movements of phosphates in the water column in two central Queensland saltfields were discussed (Coleman unpublished). It was shown that the phosphate concentration in the water column was reduced considerably as it flowed from pond to pond. For instance, reductions up to 90% of the flow through of reactive phosphate was recorded. The most efficient pond was the first in the series which also supported the most diverse and largest biomass The residence times of these ponds were two weeks for the summer period. However, the reduction was not consistent and in some cases a pond had a nett export of phosphates.

Removal of Phosphates

The ponds studied in the central Queensland saltfields were constructed on uniform level clay mudflats. The accretion of organic mud in the constructed ponds could be determined by digging. From the age of the ponds the rate of deposition was estimated at 25 cm over 30 years. This means that over the life of the field approximately 8mm of organic material was laid down each year. The organic content was measured as being between 10 and 30 percent by heating dried mud to 500 degrees Celsius. Analysis for Total Phosphate returned values between 37 and 60 ug PO4-P per gram of wet mud or 45 to 74 ppm of PO4-P. It can be calculated that 8mm of sediment (a year's growth) over a 50 ha pond, assuming a density of 1.2, would be 4800 tonnes. This converts to 249 kg of PO4-P per year being deposited in the sediment or 20 kg of PO4-P per month. this accumulation is roughly the same as what was documented in Coleman (unpublished). The Total Phosphate concentrations in the sediment are 200 times greater than the Total Phosphate in the water column (Table 1). The mechanism for the removal of the phosphates from the water column is undoubtedly the deposition of organic debris.

Availability of Phosphate in the Sediment

The reactive phosphate concentration in the sediment was measured at various sites using dialysis membrane to exclude solid material from the sample container buried in the sediment for several weeks. A long immersion period was needed to enable for the phosphate concentration brine in the container to equilibrate with the interstitial brine's phosphate concentration. The mud was sampled at several depths, and the results indicated that the highest concentration of reactive phosphate was 5 to 10 centimetres beneath the sediment surface (Figure1).

The availability of these phosphates to the water column or even the overlying cyanobacterial mat, appears to depend on a number of parameters. Namely:

I. Continuity of the algal/cyanobacterial mat. The mat is less permeable to water/brine movement and cyanobacterial mats have been shown to adsorb reactive phosphates (unpublished data).

II. Anaerobic activity within the mat. As the depth of mud increases the opportunity for a permanent anaerobic zone increases. In Figure 2 below, the western side of Pond 2B had much deeper sediment deposits (+40cm) compared the eastern side of the pond (10 cm). The concentration of reactive phosphates in the deeper sediment is greater on the western side of Pond 2. Mechanical disturbances destroy the integrity of the sediment making it more difficult for an anaerobic zone to form. Also, the frequency and duration of flooding influences the anaerobic activity in the sediment. For instance, ponds that have been dried for several months have not reformed the same anaerobic structure for several years after being reflooded.

III. Movement of the anaerobic zone into the water column. The factors that influence the movement of the anaerobic zone into the water column and hence release phosphate into the water column are, the intensity of light, depth of water, turbidity, and photosynthesis activity of the algal mat. The release may be due to anaerobic action on organic material but is just as likely to be chemical release from adsorption due to the more acid conditions experienced in saline anaerobic conditions.

IV. Chemical fixing of phosphates in the sediment. Free calcium strongly bonds phosphate and removes phosphates from the biological cycles unless the pH is low. Aluminium, iron and carbonate compounds can also physically remove phosphates but these associations are very pH dependent. Most sediments in wetlands will become acid at some stage.

Summary

The recycling of phosphates into the water column from the sediment and becoming available to plankton is the primary method of phosphate migration through constructed saline wetlands. However, substantial amounts can also flow on as mobilised detritus from the sediment, especially during peak flow periods. This may "clean" the wetlands for improved future phosphate removal, but on a more global scale, does little to reduce the nutrient load on the oceans and lakes. The design of the wetland for phosphate removal must include areas of low water velocity and sediment traps. These areas should be accessible to allow sediment removal, harvest of biomass or be so designed for increased sediment heights over time.

References

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Table 1.Movement of phosphate through a central Queensland saltfield

		Phosphate (ug/L)		*Phosphate (kg)*		*Loss from water column (PO4-P kg)*	
Pond	Outflow rate (ML/month)	Reactive	Total	Reactive	Total	Reactive	Total
Sea	508	158	568	89.74	288.54		
A	417	34	226	7.68	94.24	91.44%	67.34%
C	321	36	199	7.16	63.88	6.77%	32.22%
D	256	29	256	7.42	65.54	-3.63%	-2.59%
2A	175	31	217	6.73	37.98	9.39%	42.05%
2B	123	45	203	9.14	24.97	-35.80%	34.25%
3	105	32	213	6.82	22.37	25.39%	10.43%
4	90	45	225	10.13	20.25	-48.55%	9.46%

Figure 1
Reactive Phosphate

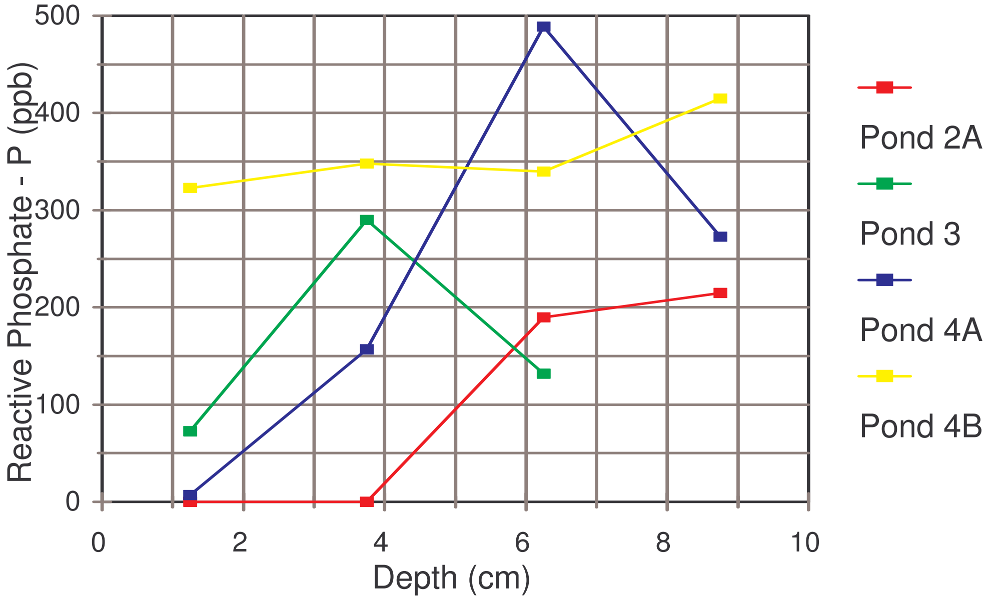

Figure 2
Reactive Phosphate