A laboratory study of sediment phosphorus flux in The Latian Dam reservoir

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Abstract

The Latian dam is located on the Jajrood River in the northeast of Tehran the capital of Iran. It is one of the most important water supply reservoirs in this city and supplies 30 percent of the total water demand of 11 million people in this city. This research measures phosphorus release from sediments of Latian Dam and the role of the tubifex in phosphorus release. Because of sediment composition variation, sediment sample were taken from two points in the Latian dam. The sediments were analyzed for total phosphorus, the form of phosphorus and release rate under different conditions of water column and the absence or present of tubifex. The results show that the amount of phosphorus are equal in the two points of the dam but the sediments that have clay in their texture have a greater phosphorus release rate than the sediments that have sand in their texture in anoxic periods. Furthermore in the Latian Reservoir the tubifex has been shown to contribute significantly to the phosphorus release.

Key words

Anoxic – Oxic- Phosphorus – Release Rate – Tubifex

1. Introduction

The effect of aquatic sediments on the nutrient quality of overlying water has been studied extensively for more than half a century (Mortimer 1941, 1942). In some restoration programs that have been completed, in spite of the diversion of external inputs, nutrient quality in the reservoir did not improve to the desired levels (Welch, 1977, Larsen et al, 1979). Studies showed that the retention of high nutrient levels in overlying water was due to the flux from the aquatic sediment (Rossi and Premazzi, 1991). The nutrient may be released from the sediments if the overlying water qualities change (Fukushima et al., 1984; Furumai et al., 1989). Mechanisms for reintroduction include advection, ion exchange, molecular diffusion, and biologically mediated changes. The characteristic of sediments, as well as overlying water quality will affect the release rate (Lee et al, 2003). The dissolved oxygen (DO) level, pH values, temperature, sediment composition and bioturbation were believed to be the governing factor of the sediment nutrient flux (Appan, 1996).

The aim of this research is to investigate the effect of DO level, sediment composition and tubifex role on the Latian Dam Reservoir sediment phosphorus flux in a laboratory set-up. Tests were conducted on sediments from two points of the reservoir with different compositions under both oxic and anoxic conditions. Furthermore, the effect of tubifex on phosphorus release rate was investigated by addition of formalin in pre mentioned similar conditions. Three Perspex columns were used as reaction chamber over 45 days under controlled conditions.

2. Background

The Latian Dam is located on Jajrood River in the northeast of Tehran the capital of Iran. It is one of the most important water supply reservoirs in this city and supplies 30 percent of the total water demand of 11 million people in this city. The Latian Reservoir is a moderately eutrophic, with an area of 3.3 km2 and a drainage area of 670 km2. The average and the maximum depth are 22 and 45 m respectively. To improve water quality of this reservoir it will be necessary to reduce the nutrient source especially phosphorus. For knowing the importance of the external and internal phosphorus load of the reservoir and the main parameter in internal phosphorus load, it is necessary to have information about sediment phosphorus release and factors affecting this release rate.

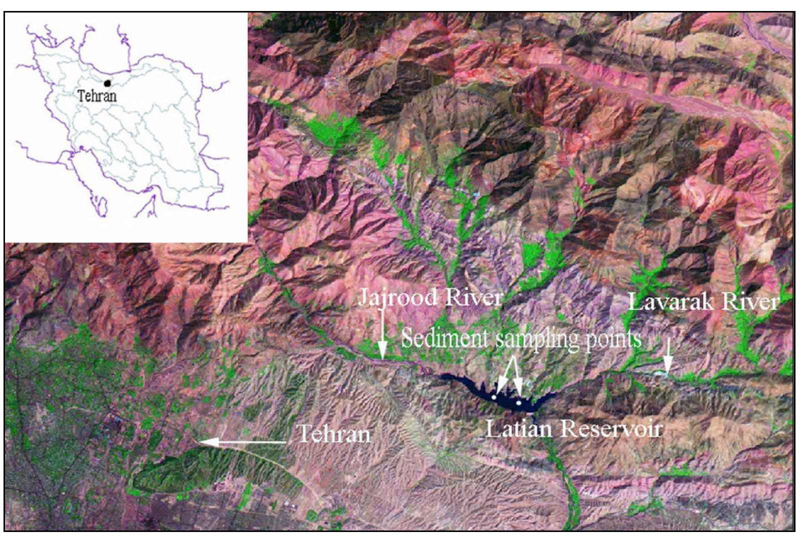

Figure-1 Latian Reservoir position in Iran and sediment sampling points.

The previous sedimentology study showed two different sediment compositions in the reservoir of the Latian Dam (Sharif 2002). One of the sediment compositions has much sand in their texture because it is located in the inlet of the reservoir and others have much clay in its composition because they are from the deepest point of the reservoir. The species of olighochate worms living in this dam reservoir is tubifex. The tubifex is related to the family of tubificade. This worm is native in freshwater sediment and living in tubes at the muddy bottom of lakes and streams. The tubes are made of mud and minerals glued by mucus. Tubifex sink in to sediment and use organic material as food. Tubifex respires with the help of its tail. It supposedly facilitates ventilation in stagnant muddy water by projecting its posterior end out of the tube and waving it about water (Wolf et al., 1986).

3. Materials and Methods

3.1. Sampling and analysis of sediments

Sediment samples were collected from two points of the reservoir in June 2004. An Ekman dredge sampler was used to collect the surface sediment samples (the top 15 cm). These samples were carefully placed in a black plastic bag and kept in an ice – box having a temperature of less than 4°C. At this temperature, biological activity is significantly reduced or completely prevented (HMSO, 1980). Analytical tests for Total Phosphorus (TP) and Total Soluble Phosphorus (TSP) were performed according to the standard methods (APHA, 1992). Phosphorus type was determined using the procedure of Hieltjes and Lijklema (1980).The procedure successively extracts phosphorus from sediments using different solvents and conditions. The fractionations are called adsorbed–P (Ads–P, extractable by NH_4CL), non-apatite–P (NAI–P, extractable by NaOH after Ads–P extraction), apatite–P (A–P, extractable by HCl after NAI–P extraction), and residual–P (R–P, non-extractable, calculated by difference with TP. The trend from Ads-P to R-P generally corresponds to bioavailability in the environment under normal conditions. Large change in environmental conditions may change bioavailability. Furthermore, organic phosphorus extracted sodium hydroxide can be determined using a total phosphorus analysis from which the amount of phosphate is subtracted (total organic phosphorus in sediments is usually determined as the difference between total sediment phosphorus and the sum of inorganic fraction).

Reservoir water were collected at a level of about 0.5 m above the sediment surface using a water sampler and stored in 20 liter polyethylene containers. These samples were immediately transported to the environmental laboratory in the school of civil engineering at Sharif University of Technology.

3.2. Experimental set – up

Three sets of Perspex columns, 180 mm diameter - 9800 mm high were used as the reaction chamber for the simulation experiment. These columns were wrapped in aluminum foil to simulate the dark condition at the bottom of the reservoir. The air distributor device was placed 10 cm above the sediment so as to create a completely mixed system and avoid stratification of the overlying water but, at the same time, not disturbing the sediment in the columns. Throughout the experiments the temperature of the overlying water in all the columns varied from 22 °C to 24 °C .As the pH levels were maintained between 8.0-8.5 similar to reservoir condition. As mentioned before, because of sediment composition variation in column 1, we used sediments with clay composition which were related to the deepest point of the dam. The Jajrood inlet sediments, which have much sand in their texture were placed in column 2; and in column 3 we used sediments similar to column 1 (deepest point sediments) but the overlying water of this column was treated with formalin (0.03%) to investigate tubifex effect on phosphorus release. Samplings from columns were taken 4 days after sediment loading in the columns.

3.3. Loading of sediment samples and aeration arrangement

The sediment samples were carefully loaded in to the column to 20 cm. The rest of the column was very carefully filled with the reservoirs water. The laboratory set up started by anoxic phase than followed by aerobic phase for 20 days. For the oxic period, water above the sediments was aerated using a commercially available aerator. Nitrogen (N_2) gas was chosen as an inert gas before loading to anoxic columns. Over the two periods of experiment, the DO level of all oxic columns was maintained at 7 mg/L to 8 mg/L. In the anoxic reaction columns, the DO levels were maintained at below 1.0 mg/L for all the period.

Figure 2. Schematic of experimental set-up

4. Results and discussion

4.1. Phosphorus type

Total phosphorus concentrations in sediments dry weight for both points are 187-200(µg/g.d.sed). Table 1 shows the phosphorus fractionation result in the Latian Reservoir sediment at inlet and the deepest sediment of the reservoir. The greater part of the phosphorus fractionation related to A-P and lowest part related to Ads-P. The percent of phosphorus fractionations of the two points is similar and the difference is in organic –

P which may be related to phosphorus that come from the body of killed microorganism that accumulated in the deepest part of the reservoir.

Table1. Percent of phosphorus fraction in two point of sampling at the Latian reservoir

Sampling position	Inlet sediment(Jajrood river)	Deepest point of reservoir
Ads-P	3.8	3
NAI-P	8	3.6
A-P	63.9	62.3
R-P	9.3	8.5
Organic-P	15.6	22.5

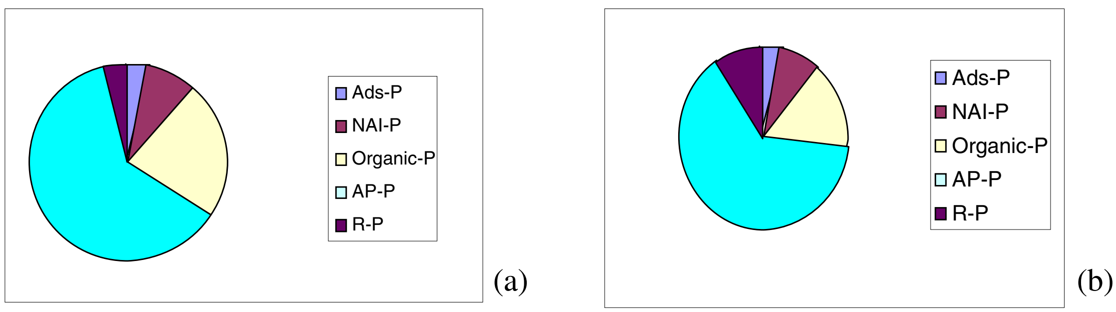

Figure3. Phosphorus fractionation in sediment at deepest point (a) and Jajrood inlet of The Latian (b).

<u>4.2. Phosphorus release studies</u>

Figure 4 and 5 show the total phosphorus and total soluble phosphorus concentrations in over lying water in columns. These experiments start with anoxic period. Since in this set-up sampling starts, 4 days after sediment loading, start point of the vertical axis is different. In both columns 1 and 2 phosphorus release increases during anoxic periods and the release rate in column 1 is greater than column 2. In column 3, formalin is added in the third day of experiment to observe the coherence between columns 1 and 3. Soon after formalin addition, the concentration of phosphorus and total soluble phosphorus decrease sharply. On day 8, phosphorus concentrations in column 3 increased for 3 days. It seems that it is related to phosphorus release from killed tubifex. By the start of an oxic period, phosphorus concentrations in column 1 and 2 decreased while no significant change seen in column 3.

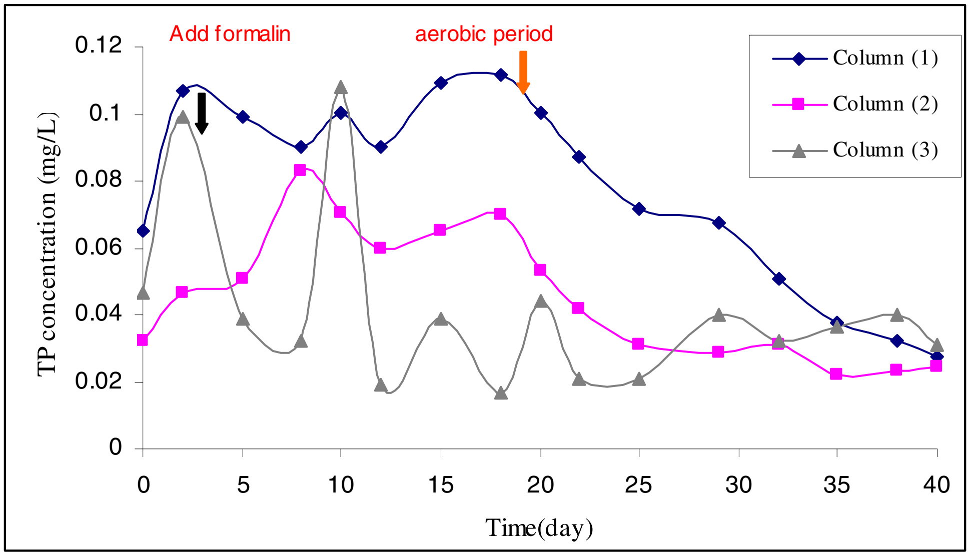

Figure 4. Total phosphorus concentrations of overlying water.

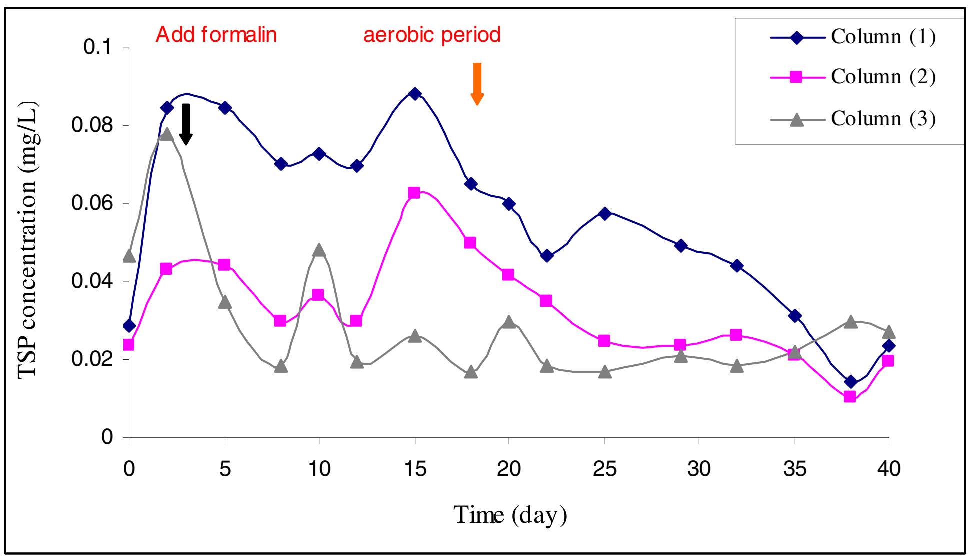

Figure 5. Total soluble phosphorus concentrations of overlying water

Table 2 shows TP and TSP release rates that were calculated for each column. Positive rate means that phosphorus was released from sediment to the overlying water and negative rate is vice versa. Total phosphorus and total soluble phosphorus release rate in column (1), that was related to the deepest point of reservoir were grater than column (2). The column which was treated with formalin had a negative rate in each state (oxic and anoxic), which showed the tubifex importance in the phosphorus release rate.

Table 2. Mean TP and TSP release rate under different condition.

Condition	pH	TP release rate (mg/m^2.day)		TSP release rate (mg/m^2.day)	
		Anoxic	Oxic	Anoxic	Oxic
Column(1)	8.5	0.91	-1.8	0.53	-0.65
Column(2)	8.5	0.36	0.17	0.16	0.09
Column(3)	8.5	-0.81	-0.67	-0.46	-0.25

5. Conclusions

The results indicate that under oxic conditions the calcareous sediments serve as a sink for phosphorus to the overlying water. The presence of tubificids in sediment had the greatest effect on sediment P release rates of the factors investigated. The result of fractionation shows the organic materials and the bioavailability phosphorus fractionation suitable for tubifix in May. At this time , reservoir DO concentrations reduce below 2 mg/L and make a good condition for phosphorus release. It seems that the tubifex effects on phosphorus release were related to two factors. First, this microorganism feeds on organic material and causes phosphorus binding with this material release. Second because of the movement of this species on the surface and depth of sediment, it gives the opportunity for the phosphorus in bound NAI-P to release when overlying water DO concentration decreases (Wetzel 1999). Analysis of the two hypotheses reveals that (@ $P<0.05$) phosphorus release rate is the function of sediment composition and tubifex activity in the Latian Reservoir Dam.

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