Fractionation of Phosphorus in Surface Sediments Downstream of a Water Dam in Eastern Algeria

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Abstract

The mobility of phosphorus was examined in sediments sampled downstream Béni Haroun dam located in the northeast of Algeria. Sediment samples were collected in winter and spring 2010. They were characterized by the measurements of pH, electric conductivity, total phosphorus, organic carbon and heavy metals. In addition the infrared analysis was carried out. An analytical procedure involving sequential chemical extractions was used for the partitioning of phosphorus in several fractions. In the first scheme, five sedimentary phosphorus (P) reservoirs were separately quantified: loosely sorbed P, calcium bound P, metal oxides bound P, organic P and refractory P. In the second scheme, the distribution of inorganic phosphorus was estimated after removal of organic matter. The inorganic phosphorus mainly consisted of apatite fraction. The rank order of the different P extracts was the same for the two seasons. The contribution of each fraction was found to follow the order: apatite fraction > metals oxides fraction, organic fraction, residual fraction, exchangeable fraction.

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1. Introduction

As a main nutrient, phosphate is very essential for growth of organisms in most ecosystems. However, it is a major cause of eutrophication. In an aquatic environment, the phosphate sorption at the sediment-water interface is an important process affecting the phosphorus (P) transport and bioavailability.

However, total concentrations of phosphorus in sediments cannot predict the phosphorus availability since not all of the phosphorus fractions can be released from sediments into the overlying water. Some fractions are not responsible for its mobility. Generally, the factors governing P release from sediments comprise redox reactions, adsorption, mineral phase solubility and mineralization of organic matter. Several methods are used for the evaluation of phosphorus distribution in soils and sediments. Chemical fractionation, involving sequential extraction procedures, is based on differences in reactivity of solid phases to different extracting solutions [1]. The aim of the present study was to estimate the mobility and the bioavailability of phosphorus from sediments taken downstream of Beni Haroun water dam using a sequential extraction procedure.

2. Material and methods

All chemicals used in this study were of analytical grade reagent and no purification was used. All experimental vessels and storage containers were Pyrex glass.

2.1. Sediment sampling and characterization

Sediment samples were collected in winter and spring 2010 downstream of Béni haroun water dam located in the northeastern Algeria. The sediment samples were kept in plastic bags and transported to the laboratory, where they were dried and ground. After drying at 40°C, the samples were sieved using a sieve 0.315 mm mesh and stored in polyethylene bottles until they will be used.

2.1.1. Physicochemical Characterization

The measurements of pH and electrical conductivity were carried out in suspensions formed with distilled water. Organic carbon was determined by dichromate oxidation method. Total phosphorus was extracted after calcinations at 550°C by HCl (1M). Iron was determined after acid digestion by flame atomic absorption spectrometry with a Perkin Elmer 2380 spectrophotometer.

2.1.2. Infrared analyses

Characterization of the sediment samples were also achieved by infrared analysis. The samples were mixed with powdered KBr in an agate mortar and compressed into disk. The transmission infrared spectra were recorded in the 4000 to 400 cm⁻¹ range using a Hyper IR Shimatzu E spectrophotometer.

2.2. Phosphorus fractionation

Sequential extraction of various phosphorus fractions was carried out using two methods. The first operationally scheme was carried out to separate phosphorus into five fractions. The exchangeable fraction was extracted by NaHCO₃ (0.5M). Phosphorus bound to calcium (Ca–P) was extracted by HCl(1M). Phosphorus bound to iron and aluminum oxides (Fe/Al–P) was extracted by NaOH (0.5M). The organic fraction was evaluated by HCl(1M) extraction after calcination at 550°C of the residue recovered in the preceding step. Refractory phosphorus was determined by using NaOH (1M) at 85°C.
In the second method, the organic matter was removed by H₂O₂ [2]. The inorganic phosphorus was extracted in three steps: loosely sorbed P (NH₄Cl–P), metal oxides bound P (NaOH–P) and calcium bound P (HCl–P) [1]. It should be noted that all fractionation results are the average of several experiments.

2.3. Phosphate analyses

Phosphate concentrations were measured by the molybdenum blue method. The absorbance was measured at 700nm with a UV-1650PC Shimadzu spectrophotometer and compared to a standard curve [3].
3. Results and discussion

3.1. Sediments characterization

3.1.1. Physicochemical characterization

The results of physicochemical analysis are presented in Table 1. Sediment samples have an alkaline pH, which may be related to the presence of carbonates. They are characterized by a high concentration of iron, demonstrating the significant presence of iron oxyhydroxides. Total phosphorus content is greater in the sediment sampled in spring whereas organic matter is more important in winter.

Table 1: Physicochemical characteristics of sediments samples.

| Sediment sample | winter’s sample | spring’s sample |
|-----------------|-----------------|-----------------|
| pH              | 8.54            | 8.57            |
| Electrical conductivity (µs/cm) | 445             | 217             |
| Organic carbon (mg/kg)  | 41.5            | 18.4            |
| Total phosphorus (mg/kg)  | 349.32          | 460.22          |
| Iron (Fe) (g/kg)        | 26.4            | 25.9            |

3.1.2. Spectroscopic characterization - IR analyses

The IR spectrum of the sediment sample collected in spring is shown in Figure 1. The bands observed at 682.8 cm⁻¹, 790.8 cm⁻¹ and 1099.3 cm⁻¹ characterize the presence of aluminosilicates and iron oxides [4]. The one occurred at about 1400 cm⁻¹, reflects the presence of carbonates [5].

3.2. Phosphorus Fractionation

The global phosphorus sequential fractionation results are shown in Figure 2. The rank order of the different P extracts was the same for the two seasons. The exchangeable fraction is the lowest; the phosphorus associated to this fraction does not exceed 7% of the total phosphorus. The amount of phosphorus extracted in this step represents the fraction readily available for algal growth [6]. The contribution of the less available fraction extracted by NaOH-85°C and representing refractory and residual P is less than 10%. The more significant fraction is extracted by HCl in the second step, showing that the most abundant fraction is bound to apatite. This fraction is stable; the same contribution is observed for the two samples. According to the protocol used, phosphorus is mainly inorganic in the studied sediments. It represents the phosphorus loosely bound, associated to calcium and bound to oxides and hydroxides of aluminum and iron. In the three last fractions, phosphorus is distributed approximately in the same percentage.
In the second sequential extractions method, the distribution of inorganic phosphorus is evaluated in the presence and in the absence of organic matter. The relative contribution of each fraction expressed as percentage is presented in Fig. 3. The comparison of the NaOH-P at 25 °C fraction contribution to the total inorganic phosphorus in the presence of organic matter (method 1) and in its absence (method 2) shows a decrease. This result reveals that some phosphorus associated to organic matter is included in this fraction considered as an important source of bioavailability.
4. Conclusion

The sequential extractions of phosphorus in sediments collected downstream of Beni-Haroun water dam show that the readily available fraction is low but not negligible. The phosphorus content in sediments is mainly inorganic. It represents the two thirds of the total phosphorus. The phosphorus fraction bound to metal oxides can be over evaluated in the presence of the organic matter.

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