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Removal of Nitrate and Phosphate Ions from the Bafing River by an Adsorbent Obtained from the Shells of Mango Cores

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Abstract

The valorization of agricultural waste in the treatment of our rivers can be an alternative to waste management. This study deals with the use of mango kernel shells in the depollution of the Bafing River (rural commune of Tolo, Mamou prefecture) in the Republic of Guinea. Thus, the different concentrations of ions found in April (low water period) were determined and which are: a reduction of 35.64 mg/l (79.69%); a reduction of 41.53 mg/l (81.24%); and 47.53 mg/l (82.10%) and 3.83 mg/l (75.24%); 8.45 mg/l (81.72%); 11.67 mg/l (87.94%) at the sampling points P1, P2, and P3 respectively. In October (flood period), the concentrations found are 24.98 mg/l reductions (79.88%); 29.83 mg/l reduction (81.41%) and 35.15 mg/l (85.50%) at the same sampling points P1, P2 and P3, respectively. This study can be considered as a water treatment alternative for the village community of the Tolo sub-prefecture (Mamou prefecture).

Keywords

Adsorbent, Water, Removal, Nitrate and Phosphate

1. Introduction

For life to exist, three fundamental elements are required, namely water, energy and chemistry (Abdoul et al., 2016; Surkatti et al., 2021). The Republic of Guinea in West Africa, described as the water tower of Africa, has a rich and varied hydrological potential (Camara et al., 2017) characterized by a humid tropical climate marked by two seasons of equal duration (dry season and rainy season), varying between 5 to 7 months depending on the region (Direction Nationale de la Métrologie, 2015). Its hydrographic network is made up of 1161 rivers, i.e., 23 watersheds and 14 international rivers, including the Niger River, which covers nine countries in the subregion. The renewable surface water resources in the Republic of Guinea are estimated at 165 - 226 km^3/year (Sow, 2017), and groundwater are estimated at 72 km^3 (Camara et al., 2017). Unfortunately, they are all highly contaminated as a result of anthropic actions of human origin (agriculture, anarchic exploitation of mining resources, bush fires, unregulated installations of industrial units that discharge industrial waste into waterways, etc.), Proliferation of drilling in cities, which is a factor of destruction of the water table who making it fragile to pollution https://openjicareport.jica.go.jp/pdf/12233391.pdf. Thus, water sources in the Republic of Guinea must imperatively undergo basic treatment (clarification by elimination of suspended solids, disinfection by elimination of micro-organisms including pathogens, etc.) to be consumable (Sow, 2017). However, the management of water resources (ERM) is essentially based on a series of hydraulic development plans (PGAH, developed between 1978 and 1982. In the present case of the rural commune of Tolo, (Mamou Prefecture, Republic of Guinea), the life of the population is closely linked to the waters of the Bafing River, which irrigate the vast plains used for agriculture and livestock, as well as for domestic needs during the dry season when there is a water shortage in the locality. This rural commune is also home to the Ecole Nationale d'Agriculture et d'Elevage (ENAE), which uses the water from the Bafing River for practical work by students. Due to these intense anthropic and agricultural activities requiring the use of fertilizers (Naushad et al., 2018; Saravanan et al., 2014; Sharma et al., 2017), it is then necessary to regularly monitor the quality of the Bafing River waters in the rural commune of Tolo in the interest of the riparian populations. Numerous research works on adsorbents of diverse origins such as well as chemical precipitation (Kazadi Mbamba et al., 2019), physicochemical, and electrodialysis (Djouadi et al., 2018; Ebbers, et al., 2015) have been reported as methods to eliminate nitrates and phosphates and have given excellent results in the purification of water, gas (Alagha et al., 2020; Zubair et al., 2020). In addition, many studies have been postponed on the news adsorbents from agricultural mango seed oral monde derived, mango peel activated and used for removal phenol, methylene blue, batik waste industry, fluid nutrient and safranine in aqueous solutions (Nugroho et al., 2022; Akpen et al., 2014; Kanjilal et al., 2014; El Nasri et al., 2022., Malekbala et al., 2012). Indeed, we recently published an article on the production of a new adsorbent from mango nuts or shells collected in the urban commune of Mamou as part of water purification (Sow et al., 2022). As an extension of our studies, we report in this present work the use of mango kernel shells as adsorbents to remove nitrate and phosphate ions from the waters of the Bafing River.

2. Material and Methods

2.1. Presentation of the Study Area

The rural commune of Tolo is located 23 km from the center of the Prefecture of

Mamou on the Mamou-Dalaba national road. It is located to the east by the rural commune of Dounet, to the west by the rural commune of Bouliwel, to the north by the rural commune of Porédaka and to the south by the urban commune of Mamou. It has five districts for seventeen (17) sectors. The five districts are Tolo Centre, Gouba, Morondhé, Soumbalako and Siminko. The Rural Commune of Tolo is one of the thirteen (13) rural communes in the Mamou prefecture (Figure 1).

2.2. Framework of the Study

The following laboratories were the places which were used as framework of studies for this work:

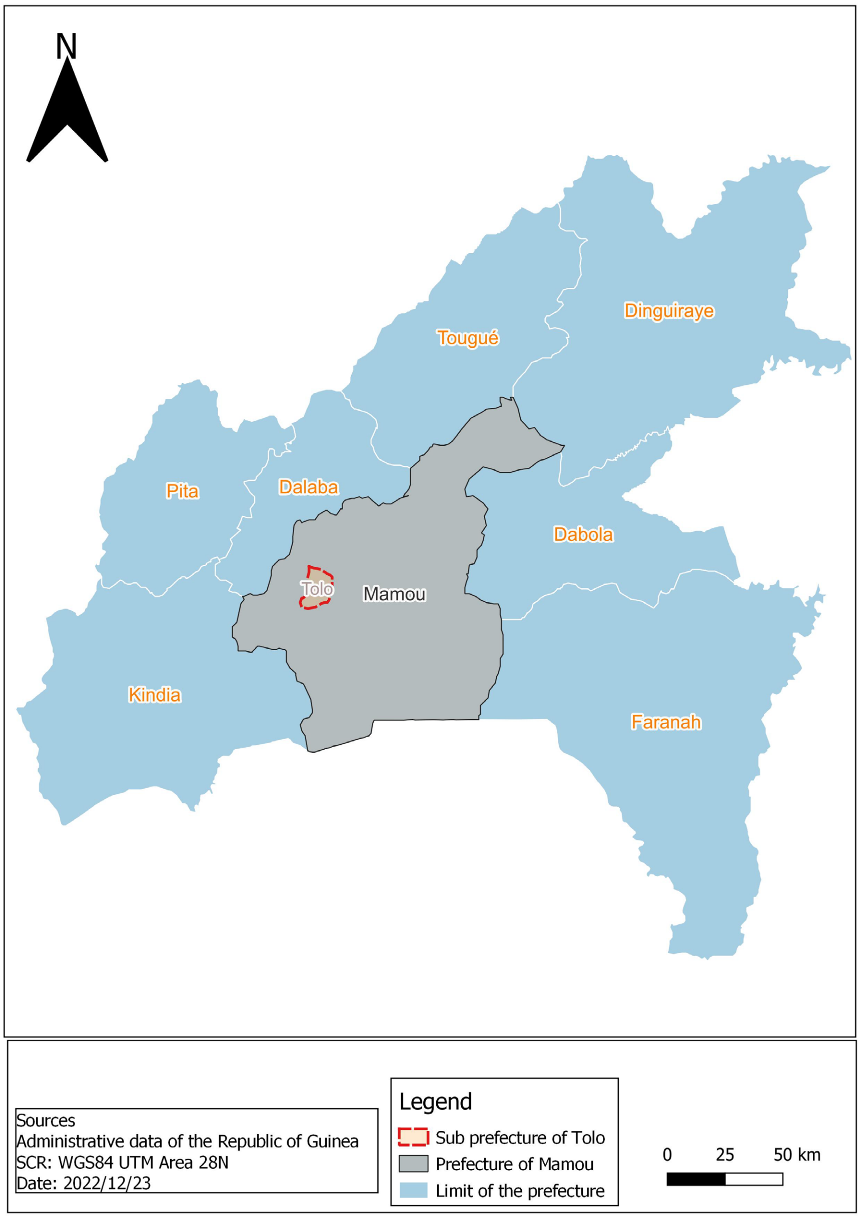

Figure 1. Map of the Mamou prefecture showing the Tolo Rural Commune.

1) The laboratory of chemistry of the Higher Institute of Technology of Mamou;

2) The laboratory of analytical chemistry of the University Gamal Abdel Nasser of Conakry;

3) The laboratory of the National Office of Quality Control of Matoto in Conakry.

2.3. Sampling and Equipment Used

Sampling took place from April 15 to 16 (dry season) 2022 (**Figure 2**) and then from October 10 to 11 (rainy season) 2022 (**Figure 3**) in Tolo in three (3) sampling points noted by: P1, P2 and P3. After sampling, the samples were conditioned and then taken to the laboratory for analysis. The equipment used was: 0.5 L sterile bottles, a cooler, latex gloves, markers, plastic shoes in boots, a camera, WTW Spectrophotometer photoLab7600 UV-VIS, beakers, cuvettes, beakers, graduated and volumetric pipettes, wash bottles, etc.

Figure 2. Photo of the river in dry season with the presence of algae.

Figure 3. Photo of the river in rainy season.

2.4. Material Used

The adsorbent (activated carbon) used in this work to remove these phosphate and nitrate ions demonstrated to be one the most the simple method and who give excellent results was obtained by the physical activation process (carbonization) of mango residues collected in the urban area of Mamou (Sow et al., 2022). The activated carbons were characterized in terms of iodine index (indicator of the adsorbent power of the carbon) (Prakas & Vinay, 2020), AWWA standard of powder activated carbon; Gueye et al., 2011). This allowed us to know the adsorbing properties of our activated carbons. However, a filtration device for the sample (water from the Bafing River) was used. The description of the phosphate and nitrate ion removal device is as follows.

2.5. Experimental Filtering Device

2.5.1. Description

The experimental device used is a simple device made by us (Sow et al., 2022). It consists of a bottle, connected to the cartridge by the connector (1) (filtration column) and the cartridge connected to the beaker by the connector (2) all in polymer. The sample contained in the bottle passes through the connector (1) to the filter (cartridge or filtration column) where the activated carbon powder made by us from the mango shells collected in the urban municipality of Mamou is placed. The filtered sample is collected, with the connector (2) in a 250 ml beaker placed below the cartridge. The entire device is supported by a support in bar in a vertical position allowing the rapid flow of the sample (**Figure 4**).

2.5.2. Procedure for Filtering

A 5 g quantity of charcoal based on the mango residue was taken and introduced

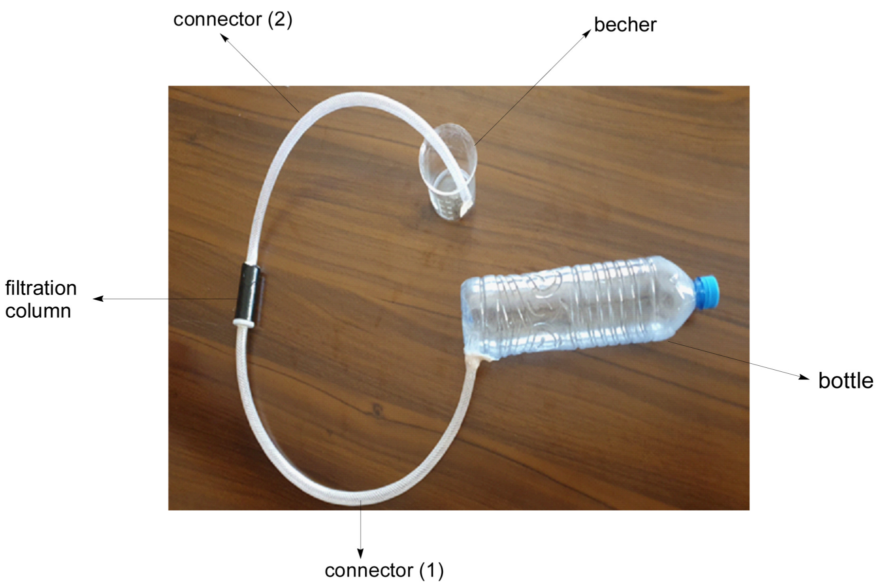

Figure 4. Photo of the water filtering device.

into the 50 ml cartridge connected to the flask by a polymer fitting (Figure 4). Then, a 500 ml volume of water (sample) was put into this flask for filtration. Drop by drop, the water flowed down through this connection to the cartridge where the carbon is located. The filtration continued for 45 minutes until the filtrate was obtained which allowed us to proceed with the analysis.

2.6. Experimental Method

After rinsing the cuvettes with distilled water, then the river water taken, 5 ml of the aliquot part (filtered water sample) was placed in the cuvette and introduced into the absorption spectrophotometric apparatus. Selected the chemical parameters to be determined (phosphate ions and nitrate ions). With the help of a button, start the spectrophotometric apparatus. The process consists in sending white polychromatic light through a monochromator. In an incident beam splitter, the light is separated into two beams. After absorption, the appariel automatically displayed the concentration of ions in milligrams per liter in the analyzed sample.

2.7. Determination of Nitrate and Phosphate Ion Concentration

For the determination of the concentration of these ions, we used the spectrophotometric apparatus of mark: (WTW Spectrophotometer photoLab7600 UV-VIS).

For the data processing, we used the Excel software.

3. Results

This study that we carried out gave us the following results: in the month of April (low water period), before the treatment by adsorption, the concentrations of nitrate ions are: 44.72 mg/l; 51.12 mg/l and 57.89 mg/l at points P1; P2 and P3 respectively (Figure 5). After treatment, we obtained: 9.08 mg/l at point P1, 9.59 mg/l at point P2 and 5.96 mg/l of nitrate ions with an average reduction of 83.55% (Figure 5 and Table 1). However, phosphate ions at the same period, the results are: 5.09 mg/l; 10.34 mg/l and 13.27 mg/l at points P1; P2 and P3 respectively (Figure 6). After treatment, the values are: 1.26 mg/l at point P1, 1.89 mg/l at point P2 and 1.60 mg/l at point P3 phosphate ions with an average of 81.64% (Figure 6 and Table 2).

In October (flood period), before treatment, nitrate concentrations are 31.27 mg/l; 36.64 mg/l and 41.11 mg/l at points P1; P2 and P3 respectively (Figure 7). After treatment, the nitrate ion concentrations are: 6.29 mg/l; 6.81 mg/l and 5.96 mg/l at points P1; P2 and P3 with an average of 82.26% (Figure 7 and Table 3). For phosphate ions at the same period, the results are: 4.93 mg/l; 10.32 mg/l and 13.12 mg/l at points P1; P2 and P3 respectively (Figure 8). After treatment, the concentrations were: 1.03 mg/l; 1.79 mg/l and 2.43 mg/l at points P1; P2 and P3 with an average of 81.08% (Figure 8 and Table 4).

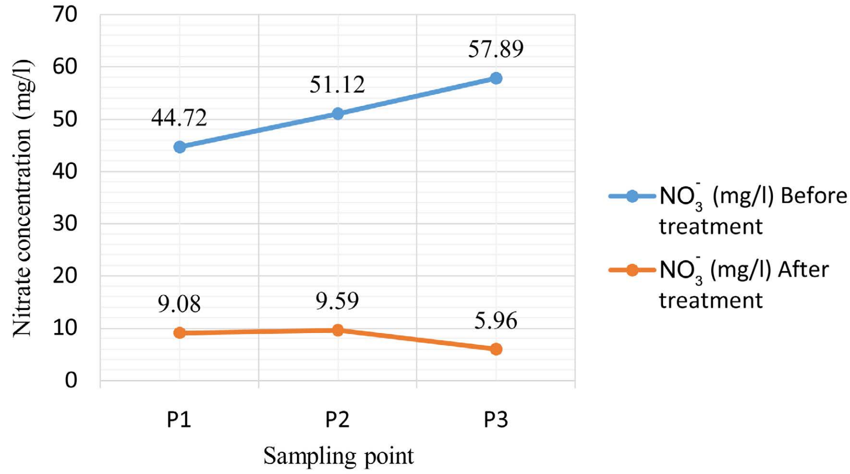

Figure 5. Nitrate ion concentrations in water samples analyzed in April 2022 before and after treatment.

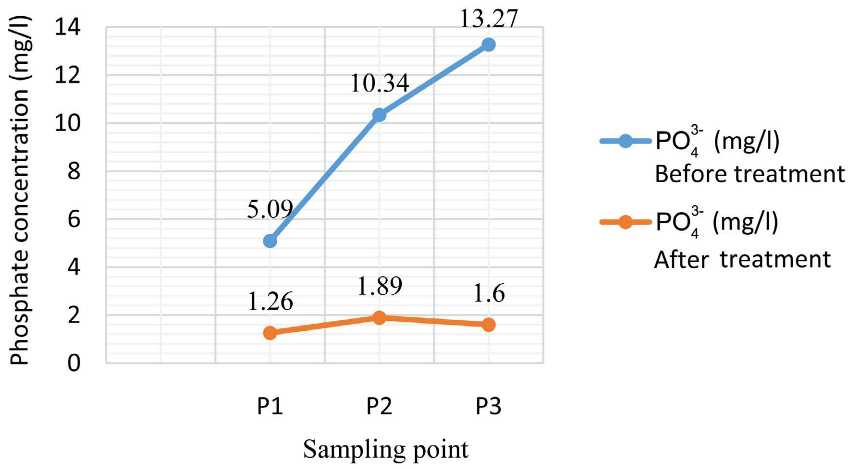

Figure 6. Phosphate ion concentrations in water samples analyzed in April 2022 before and after treatment.

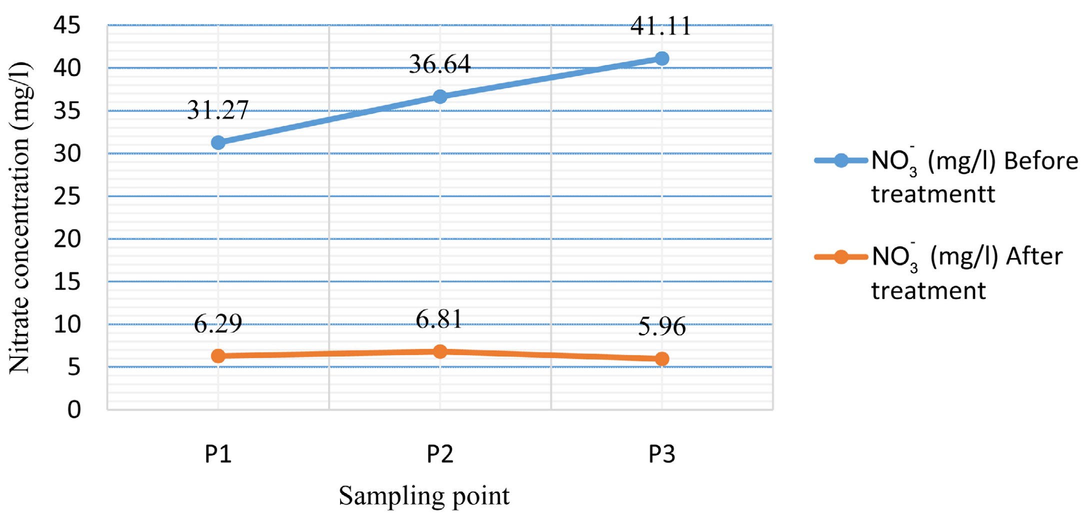

Figure 7. Nitrate ion concentrations in water samples analyzed in October 2022 before and after treatment.

Table 1. Percentage of nitrate ion removal (Month of April).

Sampling points	Before treatment (mg/l)	After treatment (mg/l)	Percentage reduction (%)	Average (%)
P1	44.72	9.08	79.70	
P2	51.12	9.59	81.24	83.55
P3	57.89	5.96	89.70	

Table 2. Percentage of phosphate ion removal (Month of April).

Sampling points	Before treatment (mg/l)	After treatment (mg/l)	Percentage reduction (%)	Average (%)
P1	5.09	1.26	75.25	
P2	10.34	1.89	81.72	81.64
P3	13.27	1.60	87.94	

Table 3. Percentage of nitrate ion removal (Month of October).

Sampling points	Before treatment (mg/l)	After treatment (mg/l)	Percentage reduction (%)	Average (%)
P1	31.27	6.29	79.88	
P2	36.64	6.81	81.41	82.26
P3	41.11	5.96	85.50	

Table 4. Percentage of phosphate ion removal (Month of October).

Sampling points	Before treatment (mg/l)	After treatment (mg/l)	Percentage reduction (%)	Average (%)
P1	4.93	1.03	79.11	
P2	10.32	1.79	82.66	81.08
P3	13.12	2.43	81.48	

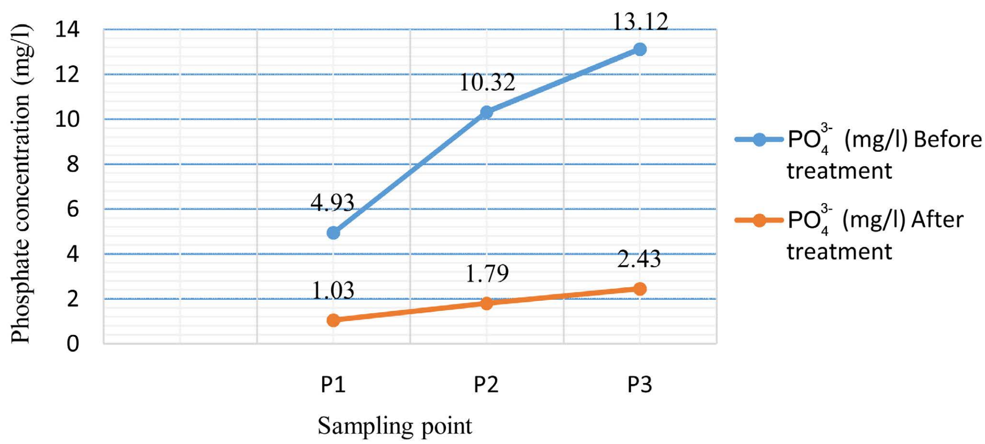

Figure 8. Phosphate ion concentrations in water samples analyzed in October 2022 before and after treatment.

4. Discussions

The values of nitrate ion concentrations at sampling points P1, P2 and P3 (April low water period) are: 44.72 mg/l, 51.12 mg/l and 57.89 mg/l respectively (**Figure 5**). These values are very high compared to the results obtained from (Sow, 2017) on the Niger rivers are: (12.58 mg/l) and Mafou (15.58 mg/l) without treatment. After treatment of the samples with activated carbon produced by us (Sow et al., 2022), the nitrate ion concentrations go from 44.72 mg/l to 9.08 mg/l (P1); from 51.12 mg/l to 9.59 mg/l (P2) and from 57.89 mg/l to 5.96 mg/l (P3) i.e., an average of (83.55%) of nitrate ions retained by the carbon used (**Figure 5** and **Table 1**). However, for phosphate ions, the concentration values at sampling points P1, P2 and P3 (April) before treatment are: 5.09 mg/l, 10.34 mg/l and 13.27 mg/l. After treatment, the concentration of phosphate ions increased from 5.09 mg/l to 1.26 mg/l (P1), 10.34 mg/l to 1.89 mg/l (P2) and 13.27 mg/l to 1.60 mg/l (P3), i.e. an average of (81.64%) (**Figure 6** and **Table 2**). These values are still high compared to those found by (Sow, 2017) and (Bouguerra, 2010) in the waters of the Niger (0.06 mg/l) and Mafou rivers (0.07 mg/l). Then at the flood period (water abundance), we also determined the values of nitrate and phosphate ion concentrations before and after treatment. The values are: 31.27 mg/l, 36.64 mg/l and 41.11 mg/l; 4.93 mg/l, 10.32 mg/l and 13.12 mg/l respectively. After treatment, the values increase from 31.27 mg/l to 6.29 mg/l (P1), from 36.64 mg/l to 6.81 mg/l (P2) and 41.11 mg/l to 5.96 mg/l (P3), i.e. an average of 82.26% (nitrate ions) (**Figure 7** and **Table 3**); for phosphate ions, the values go from 4.93 mg/l to 1.03 mg/l (P1), from 10.32 mg/l to 1.79 mg/l (P2) and from 13.12 mg/l to 2.43 mg/l (P3), i.e. an average of 81.08% (**Figure 8** and **Table 4**). Koua-Koffi et al. (2018) have shown that the higher the adsorption surface of the carbon, the higher its porosity and its solute adsorption capacity (Ghaddab Chames Edoha, 2021). In general, we note that before treatment of water samples with carbon, the shape of the different curves increases from P1 to P2, then from P2 to P3. After treatment, the curves are increasing from P1 to P2 and then decreasing from P2 to P3, except in **Figure 8** where the curve is increasing from P1 to P2 and then from P2 to P3. These variations would probably be related to the use of nitrogen and phosphate fertilizers by the riparian populations in agriculture, also to the intense anthropic activities. According to Bouguerra (2010), several other parameters can influence the adsorption capacity of the activated carbon used such as: the initial concentration of pollutant, temperature, pH etc. However, the strong presence of algae in the waters of the Bafing River, However, the strong presence of algae in the waters of the Bafing River is due to the high concentration of nitrate and phosphate ions (eutrophication phenomenon) (**Figure 2**).

5. Conclusion

In the present work, we process out tests of water treatment of the Bafing River, in the sub-prefecture of Tolo, prefecture of Mamou for the elimination of nitrate and phosphate ions. For this, we used activated carbon produced from the residues of mango pits collected in the urban commune of Mamou. Water samples taken from the Bafing River at points P1, P2 and P3 located respectively upstream, in the center and downstream of the center of the rural commune of Tolo were first analyzed and then treated by adsorption with activated carbon and analyzed again. The results obtained showed high efficiency of the activated carbon used. In April (low water period), at the sampling point P1, we obtained a reduction of 35.64 mg/l of nitrate concentration, i.e. 79.69%, at point P2, 41.53 mg/l of reduction, i.e. 81.24% and at point P3, 47.53 mg/l of reduction, i.e. 82.10%.

For phosphates, at the same period, we obtained at point P1, 3.83 mg/l of reduction or 75.24%, at point P2, 8.45 mg/l of reduction or 81.72% and at point P3, 11.67 mg/l of reduction or 87.94%. In October (flood period), at point P1, we obtained a 24.98 mg/l reduction in nitrate concentration, i.e. 79.88%, at point P2, 29.83 mg/l reduction, i.e. 81.41% and at point P3, 35.15 mg/l reduction, i.e. 85.50%.

For phosphates, at the same period, we obtained at point P1, 3.90 mg/l of reduction or 79.10%, at point P2, 8.53 mg/l of reduction or 82.65% and at point P3, 10.69 mg/l of reduction or 81.47%. The average is about 81.50% efficiency. Thus, it is worth noting the degradation of nitrates by bacteria leads to nitrite products that are harmful to human health and the environment. In case of excessive concentration, there are risks of cancer, methemoglobin and even death.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of the paper.

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