REMOVAL OF PHOSPHATE FROM NATURAL WATER RESOURCES USING ACID TREATED COAL FLY ASH

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Abstract

The excess of phosphorus (P) in the environment can promote chemical pollution and harm ecosystems, especially water. The protection and restoration of natural lakes is increasingly important in countries with limited water resources in the world. The increasing release of phosphate-containing wastewater to natural water bodies such as natural lakes have caused eutrophication, which has become a globally concerning problem. In order to overcome accelerating eutrophication, therefore, there is a need to control and reduce the level of phosphate in water resources. The aim of this research was to detect the phosphate-uptake capacity from five eutrophic lakes at Yangon urban region using low cost of sorbents like modified coal fly ash. This research work conducted during August 2018 to April 2020. The amount of phosphate ion in water bodies was determined by using standard spectrophotometric method. According to the investigated data, phosphate-uptake capacity of acid treated coal fly ash was 97.86 percent, which was obtained by batch tests in laboratory. The results of this study showed that acid treated coal fly ash was effective in removal of phosphate ions in water bodies of natural lake. Thus, the results allow to evaluating the chances of successful lake restoration by applying acid treated coal fly ash to natural water bodies.

Keywords: Acid treated coal fly ash, eutrophication, phosphate ion, natural lakes

Introduction

Water is essential to life, the pollution of the lakes and rivers has become an international problem that has reached crisis proportions in many regions. In developing countries, human sewages and animal wastes often enter streams and lakes from restaurants, hotels, food shops and sport activities; it causes increasing nitrates and phosphates levels into surface water bodies. The phosphates stimulate the growth of aquatic algae, causing sudden spurts growth called algae blooms. Excess concentrations of phosphate ion in water cause eutrophication. There are two types of eutrophication: natural and cultural. Natural eutrophication is a natural aging process for most lakes and ponds. Cultural eutrophication happens when the amount of nutrients in the water and the water temperature are changed due to human activity and the eutrophication process begins to run at high speed. It is not only destroyed the aquatic life but also disrupts the balance of the aquatic ecosystem (Mustafa *et al.,* 2008). To control eutrophication, James (1997) has recommended that total phosphate should not exceed 0.025 mg per liter in lakes and reservoirs, and should not exceed 0.1 mg/L in streams and reservoirs. Therefore, it is necessary to remove the phosphate ion, before discharged wastes from water resources into natural water environment. During the past decades, various techniques, including biological treatment and chemical precipitation have been reported for phosphate removal. Adsorption is one of the techniques, which is comparatively more useful and economical for such removal (Ragheb, 2013). Sorption technique is an effective, reliable, and environmentally friendly treatment process for the removal of phosphorus from wastewater sources which otherwise can cause eutrophication of receiving waters.The principle of phosphorus removal from water consists in the formation of insoluble metal phosphates, namely calcium, iron and aluminum that influence concentrations of phosphorus in water (Benito *et al.,* 2001). The coal fly ash consists of Si, Al, Fe, Ca, and Mg, and therefore a good candidate material for phosphate

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removal from water (Mikendova *et al*., 2010). Recently, the acid treated coal fly ash has been used for the removal of phosphate ion.

Materials and Methods

Materials

The chemicals used were procured from British Drug House (BDH), England, Wako Co. Inc., Tokyo, Japan and Sigma-Aldrich, USA. The apparatus and instruments are conventional labware, glassware and modern equipment**.**

Sample Preparation of Coal Fly Ash

Coal fly ash sample was collected from Tigyit power plant located in South-west Shan State in Myanmar (PYO, 2011). It was taken systematically from a large number of material bags. Sampling was carried out by cone and quartering method. Sample was homogenized into small particles using a grinding mill and then made to obtain 250 μm mesh size. The obtained coal fly ash sample was dried at 105 °C in an oven for an hour. The samples were kept in plastic bags and placed in cold and dried place.

Preparation of Acid Treated Coal Fly Ash

The coal fly ash was treated with hydrochloric acid and optimal conditions were found to be 2 M HCl solution, the ratio of coal fly ash and acid solution is 1:2 (w/v) and 2 h for acid treated time at ambient temperature.

Sample Collection

The lake water samples were collected for three seasons and in the mornings from August 2018 to April 2019. The water samples were collected in clean new 1 L plastic bottles. The bottles were placed in a dark ice box and immediately taken to the laboratory. The water samples of five lakes were collected in Yangon urban region, Myanmar. The satellite data and townships of selected eutrophic lakes were shown in Table 1. The study duration of phosphate ion removal for eutrophic lakes is shown in Table 2.

Table 1 The Satellite Data and Townships of Selected Eutrophic Lakes

Sr. No	Samples	Latitude (N)	Longitude (E)	Lake	Townships
1	S_1	16.929678	96.119856	DSMA Campus Lake	Mingaladon
2	S_2	16.943986	96.105544	Inn Pounk Su Lake	Shwepyitha
3	S_3	16.841060	96.138428	Inya Lake	Kamayut
4	S_4	16.796817	96.161935	Kandawgyi Lake	Mingala Taungnyunt
5	S_5	16.793479	96.148985	Kan Taw Min Lake	Dagon

Table 2 Study Duration of Phosphate Ion Removal for Eutrophic Lakes

Study duration		
Year	**Season**	**Sampling date**
2018	Rainy	16.8.2018
	Cold	5.12.2018
2019	Hot	3.4.2019
	Rainy	11.8.2019
	Cold	15.12.2019
2020	Hot	4.4.2020

Standard Calibration Curve for Phosphate Ion by Using Spectrophotometric Method

The amount of phosphate ion in water bodies was determined by using standard spectrophotometric method at a wavelength of 880 nm. Ammonium molybdate and potassium antimonyl tartrate react in acid medium with orthophosphate to form a heteropolyacid- phosphomolybdic acid- that is reduced to intensely coloured molybdenum blue by ascorbic acid. The primary stage of the work, include the evaluation of calibration curve by using absorbance and concentration of standard phosphate solution (Arnold *et al*., 1992). The standard solutions of phosphate in different concentrations range between 0.2 mg L^{-1} to 1.2 mg L^{-1} were chosen. Standard solution (50 mL) was pipetted into a clean and dry beaker. A mixed reagent was prepared by adding 5 mL of ammonium molybdate solution, 50 mL of 2.5 M sulphuric acid, 5 mL of potassium antimonyl tartrate solution and 30 mL of ascorbic acid solution. Mixed reagent (8 mL) was added and the solution was then allowed to stand for 10 min. The absorbance of blue colour solution was measured by UV-visible spectrophotometer at 880 nm against a blank of distilled water.

Phosphate Sorption

A spectrophotometer was used to measure the intensity of residual colour of solutions after sorption. The residual colour index is expressed as absorbance.

Acid treated coal fly ash (0.1 g each) was added to 100 mL each of collected lake water samples and adjusted the pH at 5.5. The samples were equilibrated by continuous shaking on a rotating shaker (150 rpm) at ambient temperature for 90 min. The suspensions were filtrated. Mixed reagent (8 mL each) was added and the solutions were then allowed to stand for 10 min.

The absorbance of blue colour solution was measured by UV-visible spectrophotometer at 880 nm against a blank of distilled water

Results and Discussion

To determine phosphorus by a spectrophotometric method a calibration curve of standard phosphorus solution was constructed.The data for absorbance values for different concentration of potassium dihydrogen phosphate solution are shown in Table 3 and the corresponding calibration curve is shown in Figure 1. The calibration curve was used to calculate the amount of phosphate in water bodies against a series or standard phosphate concentrations.

Table 3 **Absorbance vs Concentration of Potassium Dihydrogen Phosphate Solution**

Concentration (mg L^{-1})	Absorbance at 880 nm
0.2	0.12
0.4	0.25
0.6	0.37
0.8	0.50
1.0	0.62
1.2	0.75

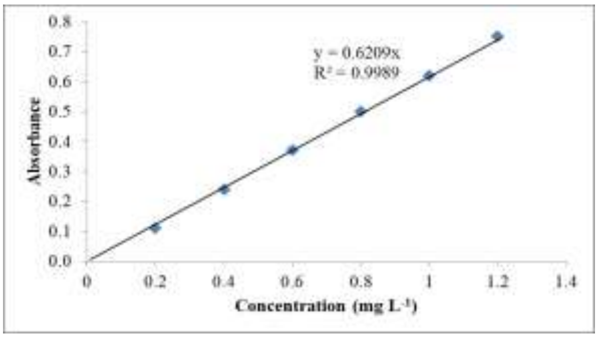


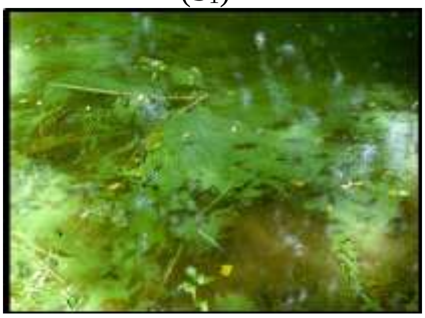
Figure 1 Calibration curve for potassium dihydrogen phosphate solution

The protection and restoration of lakes is increasingly important in countries with limited water resources. Eutrophication conditions of five lakes at Yangon urban region are presented in Figure 2. In this study, initial phosphate ion concentration of five lake water samples collected from different locations of Yangon urban region were determined. The initial phosphate concentrations are shown in Table 4. The phosphate concentrations after discharged with acid treated coal fly ash and percent removal of phosphate in selected lake waters are described in Tables 5 to 6 and Figures 3 to 8.


(S_1)


(S_2)


(S_3)


(S_4)


(S_5)

Figure 2 Eutrophication conditions of five lakes at Yangon urban region

Table 4 Initial Phosphate Ion Concentration of Lake Water Samples from Rainy Season (2018) to Hot Season (2020)

Sr. No	Lake water samples	Initial phosphate ion concentration (mg L^{-1})					
		Rainy season (2018)	Cold season (2018)	Summer season (2019)	Rainy season (2019)	Cold season (2019)	Summer season (2020)
1	S_1	0.2271	0.6732	0.9518	0.4123	0.2674	0.1917
2	S_2	0.1659	0.0548	0.0370	0.0605	0.0322	0.0515
3	S_3	0.0193	0.0338	0.0290	0.0596	0.0966	0.0970
4	S_4	0.0451	0.0531	0.1884	0.1514	0.1933	0.1966
5	S_5	0.1450	0.1498	0.7537	0.4107	0.6845	0.8117

$>$ 0.025 mg L^{-1} eutrophication level, James, 1997

From the resulting data, in sampling site S_1 (Defence Service Medical Academy), initial phosphate ion concentration significantly increased from rainy season (2018) to summer season (2019). It is because wastewater discharged from farming sites existed near the lake. And then, it decreased from rainy season (2019) to hot season (2020) because of the sustainability of lake during this period.

In sampling site S_2, initial phosphate ion concentration of Inn Pounk Su Lake water sample in rainy season (2018) significantly increased due to flooding. Here an urban sewer overflow due to heavy rain causing runoff likely containing phosphorus, nitrogen, ammonia, nitrates, and raw sewage into the lake nearby waterways.

In sampling site S_3, initial phosphate ion concentration of Inya Lake water sample gradually increased from rainy season (2018) to hot season (2019). And then, it significantly increased from rainy season (2019) to hot season (2020). Because popular recreational center, many restaurants and food shops at lake side of Inya Lake, and a new hospital and hotels were recently constructed.

In sampling site S_4, initial phosphate ion concentration of Kandawgyi Lake water sample significantly increased from rainy season (2018) to hot season (2020). At the Kandawgyi Lake (recreation center of Yangon) environment, existing hotels, restaurants, shopping mall, amusement arcade, health club and playground exist at the lake side of Kandawgyi.

In sampling site S_5, initial phosphate ion concentration of Kan Taw Min Lake water sample significantly increased from rainy season (2018) to hot season (2020) due to the fact that some restaurants were located at the lake side of Kan Taw Min.

Environmental degradation due to the release of different pollutants into receiving lake waters has become of great importance. Thus, to maintain our environment in a good condition, lake waters must be treated. In this research work the removal of phosphate ion from lake waters was carried out by using acid treated coal fly ash. Acid treated coal fly ash was more favourable for phosphate adsorption onto the surfaces of aluminum and iron phases (Pengthamkeerati *et al.*, 2008). The acid treated coal fly ash generally showed larger specific surface area and higher pore volume. The sorption mechanism is formation of a variety of Al-, and Fe-phosphate minerals and sorbed phases of acid treated coal fly ash. The results of this study show that acid treated coal fly ash is effective in removal of phosphate ion contained in lake water samples. High phosphate removal rates greater than 90 % were obtained.

Table 5 Residual Phosphate Ion Concentration of Lake Water Samples during 2018 to 2020

Sr. No	Lake water samples	Residual phosphate ion concentration ($mg\ L^{-1}$)					
		Rainy season (2018)	Cold season (2018)	Summer season (2019)	Rainy season (2019)	Cold season (2019)	Summer season (2020)
1	S_1	0.0129	0.0433	0.0725	0.0258	0.0145	0.0048
2	S_2	0.0048	0.0016	0.0016	0.0016	0.0016	0.0016
3	S_3	0.0016	0.0016	0.0016	0.0032	0.0048	0.0048
4	S_4	0.0016	0.0016	0.0145	0.0097	0.0129	0.0113
5	S_5	0.0048	0.0032	0.0515	0.0306	0.0483	0.0644

Table 6 Percent Removal of Phosphate Ion in Lake Water Samples during 2018 to 2020

Sr. No	Lake water samples	Percent removal of phosphate ion (%)					
		Rainy season (2018)	Cold season (2018)	Summer season (2019)	Rainy season (2019)	Cold season (2019)	Summer season (2020)
1	S_1	94.32	92.82	92.38	93.74	94.58	97.49
2	S_2	97.11	97.08	95.68	97.36	95.03	96.89
3	S_3	91.71	95.27	94.48	94.63	95.03	95.05
4	S_4	96.45	96.99	92.30	93.59	93.33	94.25
5	S_5	96.69	97.86	93.17	92.55	92.94	92.07

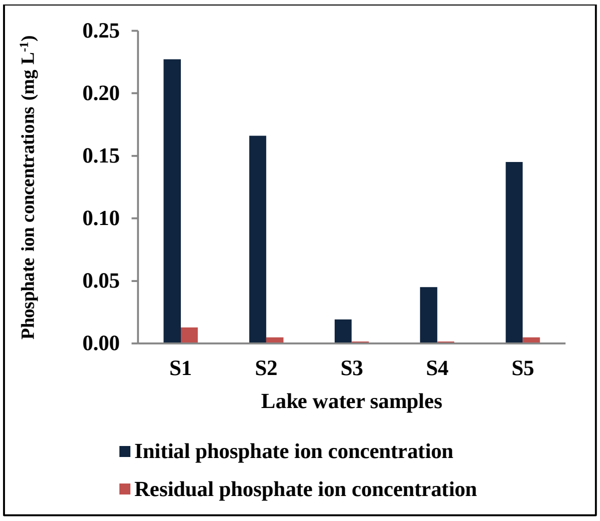


Figure 3 Graphical presentation of phosphate ion concentration before and after treated with acid treated coal fly ash in the lake waters samples during rainy season (2018)

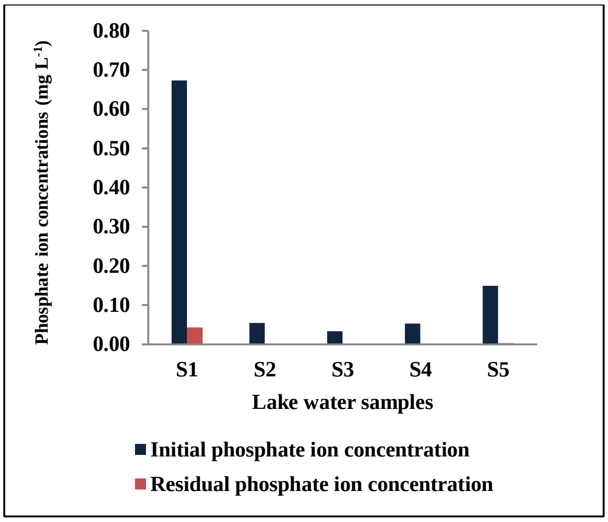


Figure 4 Graphical presentation of phosphate ion concentration before and after treated with acid treated coal fly ash in the lake waters samples during cold season (2018)

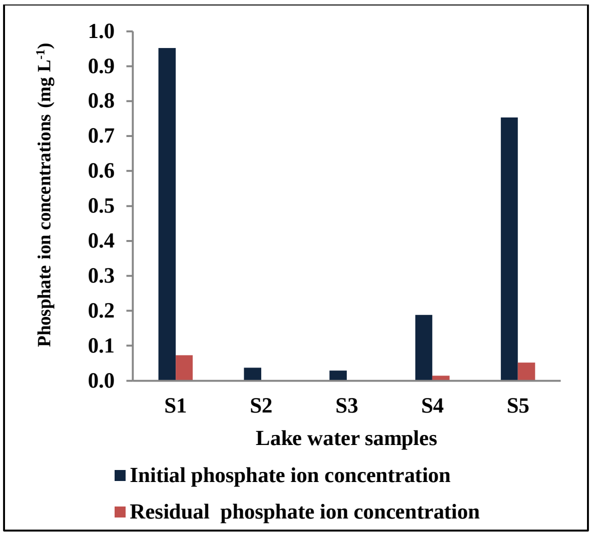


Figure 5 Graphical presentation of phosphate ion concentration before and after treated with acid treated coal fly ash in the lake waters samples during hot season (2019)

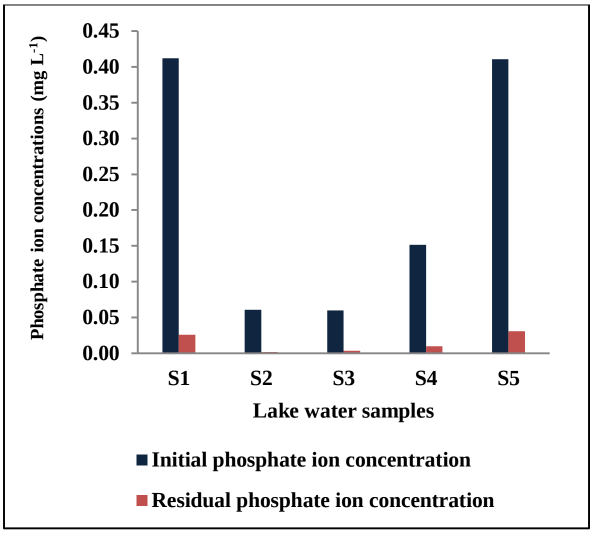


Figure 6 Graphical presentation of phosphate ion concentration before and after treated with acid treated coal fly ash in the lake waters samples during rainy season (2019)

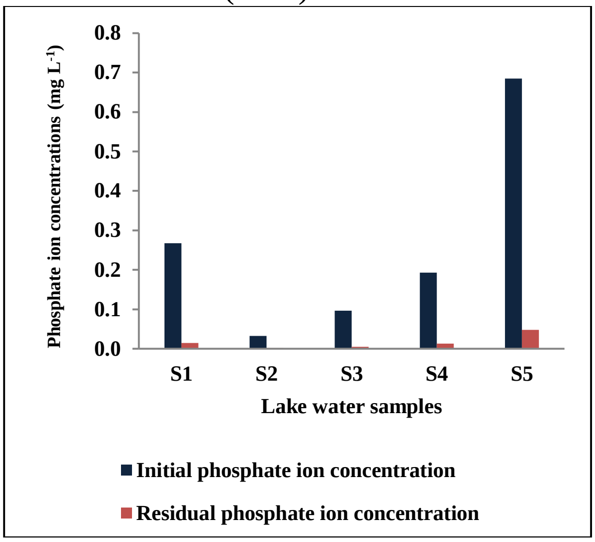


Figure 7 Graphical presentation of phosphate ion concentration before and after treated with acid treated coal fly ash in the lake waters samples during cold season (2019)

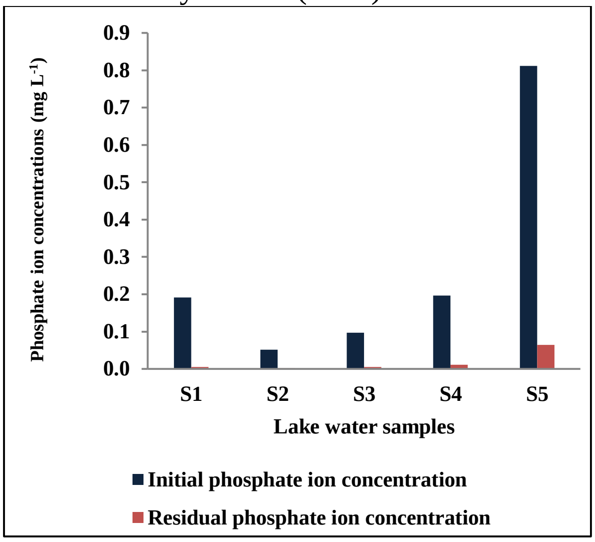


Figure 8 Graphical presentation of phosphate ion concentration before and after treated with acid treated coal fly ash in the lake waters samples during hot season (2020)

Conclusion

In this research, the process of sorption and precipitation is the main mechanism for using fly ash to remove phosphate ion from the lake waters. The sorption behaviours of the maximum percent removal of phosphate ion in lake waters were found to be 97.86 % by acid treated coal fly ash at 0.1 g/100 mL of dosage, pH 5.5 and 90 min of contact time at ambient temperature. Acid treated coal fly ash showed promising potential for controlling water bodies because of its low cost and high efficiency. Therefore, acid treated coal fly ash on the treatment of lake waters was obviously improved. The prevention of eutrophication requires the cooperation of different parts of our society including experts and scientists, farmers, environmental organizations, politicians and even the public.

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