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Removal of phosphate from Eshidiya industrial wastewater by sedimentation and enhanced sedimentation

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ABSTRACT

Treatment of industrial wastewater from Eshidiya phosphate mining in Jordan was studied in this work for reuse possibilities. The wastewater resulted from flotation cells contains sediments, mainly phosphate. Sedimentation and enhanced sedimentation using anionic polyelectrolyte and alum were used to remove the sediments. The optimum dosage of anionic polyelectrolyte was found to be 400 ppm corresponding to a turbidity of 3.3 NTU. The measured target zeta potential was found to be −58.7 mv at this dosage. Alum was found to be effective coagulant but after performing a preliminary sedimentation step to reduce the wastewater turbidity.

Keywords: Wastewater; Phosphate mining; Jordan; Flotation cells; Sedimentation; Anionic polyelectrolyte; Alum; Turbidity; Zeta potential

1. Introduction

Jordan is among a few countries in the world with lowest water resources availability. Water scarcity will become an even greater problem over the next two decades because population is likely to double and climate change would potentially cause reduction in precipitation, particularly in the Middle East region. Conservation and utilization of water resources is therefore a key issue facing national water authorities. In Eshidiya plant, which is a phosphate mining industry, large amount of water in many stages, mainly in flotation cells, is used to wash up clays and the undesired impurities in order to concentrate the phosphate content to above 70%. After the second and third expansion schemes at Eshidiya mine complex, more than one thousand cubic meter of washing water per hour is discharged, which contains about 20% solid impurities. The discharged water from phosphate industry is contaminated with dissolved and suspended solids such as phosphate, silicate, and chlorides ions.

Phosphorus is considered a key element causing eutrophication, which leads to abundant development of aquatic plants, growth of algae with some kinds of them being toxic, and balance disturbance of organisms present in water. This directly affects water quality through oxygen depletion, because of high biological oxygen demands, and acidification. This, in turn, harmfully affects fish and other aquatic life, microorganism and insects' growth and it causes natural resource degradation. Consequently, the removal of phosphates from surface waters is absolutely

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necessary to avoid any kind of problem, particularly near urban areas [1].

In wastewater treatment technology, various techniques have been employed for phosphate removal, including physical and chemical methods. Ultrafiltration is used for removal of phosphates, suspended solids, and colloidal matter. Phosphate was reduced from an average of 60–20 μg/l [2]. Chemical precipitation via coagulation has also been used Al-Soufi and Abdulrahman [3] studied the required amount of anionic polyelectrolyte for effective sedimentation. They found adding 450 ppm reduced phosphate ions by 79%. Hosni [4] investigated phosphate removal from synthetic aqueous phosphate solution, by precipitation with calcium hydroxide addition, in order to determine the optimal operating conditions. The optimal calcium ions/phosphate ions molar ratio and the time of precipitation were determined. They obtained 98% phosphate removal at Ca-to-P ratio of 2.07. Eskandarpour [5] used a magnetic filtration that is firstly applied to the phosphate removal from wastewater by using a ferric oxyhydroxide sulfate with high capacity of phosphate adsorption. It was found that high efficiency of phosphate removal was obtained in batch tests. Ahamad and Shaik [6] removed phosphate ions from wastewaters by precipitation with aluminum sulfate and calcium nitrate, respectively, with subsequent removal by a high-gradient magnetic separator; they obtained 80% removal. Liang-guo et al. [7] used adsorption of phosphate by using three modified inorganic bentonites: hydroxy-aluminum pillared bentonite (Al-Bent), hydroxy-iron pillared bentonite (Fe-Bent), and mixed hydroxy-iron-aluminum pillared bentonite (Fe-Al-Bent): they were prepared and characterized, and their phosphate adsorption capabilities were evaluated in batch experiments. Their results showed that the final adsorption efficiency was higher than 90%, suggesting that these structures are excellent adsorbents for effective phosphate removal from water.

The aim of this work is to study phosphate removal from actual Eshidiya phosphate mine wastewater by natural sedimentation followed by enhanced sedimentation employing anionic polyelectrolytes and alum at an optimum dosage. Zeta meter is used as a controller to determine the optimum dosage of polyelectrolyte needed.

2. Materials and method

In all experiments, actual wastewater from Eshidiya phosphate mine was used. The natural sedimentation was studied by taking a sample of Eshidiya wastewater and was gently mixed to obtain homogeneity before filling a graduated cylinder having one liter volume. As the suspended solids in the graduated cylinder started settling, an interface started to form; the turbidity of the clear water was measured every one hour.

In the enhanced sedimentation investigation, anionic polyelectrolytes (polystyrene sulfonic acids) and alum (aluminum sulfate) were used as coagulants. Different amounts of the coagulant were added into 100 ml of Eshidiya wastewater, under rapid mixing for 2 min to ensure dispersion throughout the solution to initiate coagulation. Then, slow mixing for 10 min was carried out for the flocculation process to take place. Every sample was then left for 15 min, until two layers were formed. A thick layer containing the settled phosphate together with the coagulants attached to it and a clear layer that represented the treated water. The zeta potential and the turbidity of the clear water were measured for each set of experiments.

3. Results and discussion

3.1. Natural sedimentation

The turbidity of Eshidiya wastewater was measured with time, up to 12 h, during sedimentation. The solids in the wastewater were left to settle slowly under their own weight, and the turbidity was measured with time. The phosphate concentration in the solution decreased to about 2 ppm, giving a turbidity of 3.6 NTU after 12 h of undergoing sedimentation without adding coagulants. The variation in turbidity with time is presented in Fig. 1. In the Eshidiya plant, the water is not allowed to settle freely as in the graduated cylinder due to mixing by movement of incoming water. Thus, the sedimentation process needs enhancement to achieve the desired settling in the

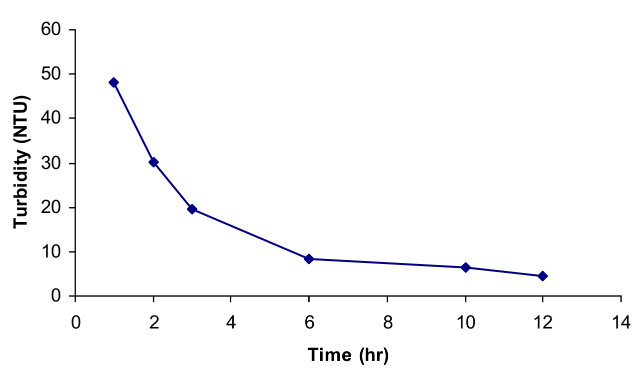

Fig. 1. The turbidity variation with time of wastewater due to sedimentation.

actual conditions of the pond receiving the wastewater.

3.2. Enhanced sedimentation

3.2.1. Determination of the optimum dosage of the anionic polyelectrolyte

Different amounts of anionic polyelectrolytes (from 200 up to 1,000 ppm) were added to the wastewater to enhance the sedimentation process. The turbidity and the corresponding zeta potential of the clear solution were measured. The results are shown in Table 1.

As shown in Fig. 2, the optimum dose of anionic polymer is the one at which the clear water has the lowest turbidity which was found to be 400 ppm. The corresponding zeta potential equals to −58.7 mv, which lies in the range of very good stability. As the readings of zeta potential get farther from zero, the stability increases and so the agglomeration decreases in the layer. The best-fit equation relating water turbidity to the polymer dose based on the experimental data is presented in Fig. 2. The curves shown in Fig. 3 illustrate that the optimum polyelectrolyte dosage which is 400 ppm, has the lowest turbidity of 3.3. At this dosage, the target-corresponding zeta potential equals to −58.7 mv.

The coagulation of colloids in the water by anionic polyelectrolyte polymer occurs by a chemical interaction or bridging. This polymer has many active sites leading to colloidal particles adhering to it, forming flocs, joining them together, and producing larger flocs that settle faster. This action of polymer bridging is called adsorption flocculation.

3.2.2. Determination of the optimum dosage of the alum

Alum was also used as coagulant to enhance sedimentation. Alum was found not being effective in turbid water. When the wastewater is not well settled, phosphate ions are dispersed, thus preventing attraction of colloids to alum, and so its efficiency as coagulant decreased. Different amounts of alum were added to the wastewater to enhance the sedimentation process after subjecting the wastewater to preliminary

Table 1
The dosage of anionic polymer and corresponding zeta potential

Polymer dose (ppm)	Supernatant turbidity (NTU)	Zeta potential (mv)
1,000	23	−42.2
800	19	−45.8
600	11	−49.6
500	5.6	−50.1
400	3.3	−58.7
300	4.6	−52.2
200	5.3	−55.4

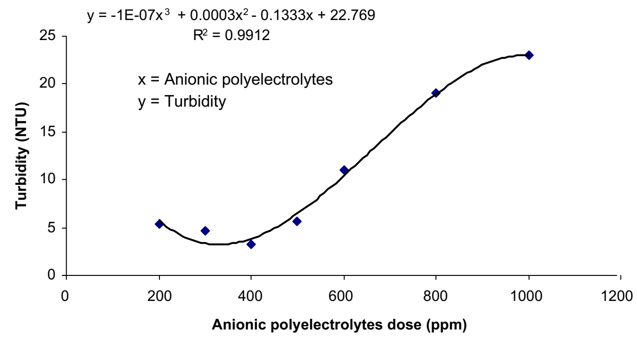

Fig. 2. The turbidity of the clear solution as a function of polyelectrolyte dosage.

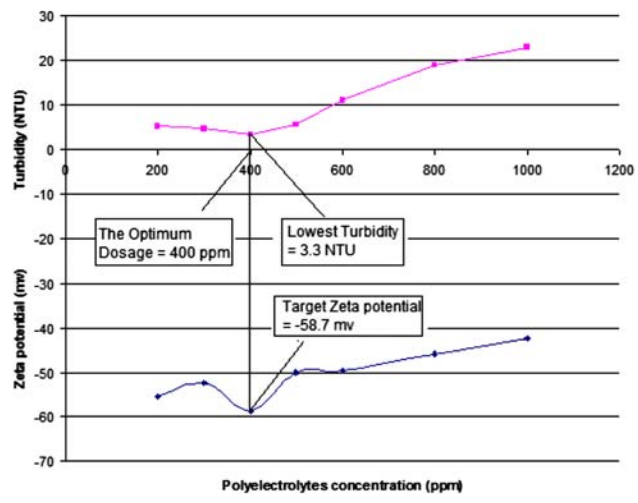

Fig. 3. Polyelectrolyte optimum dosage having the lowest turbidity and target zeta potential.

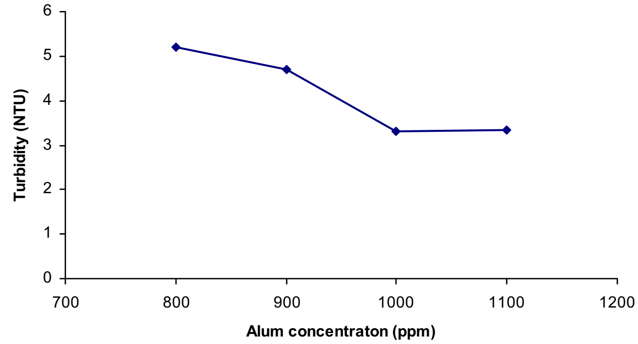

Fig. 4. Turbidity vs. alum dosage after 1 h of initial sedimentation: optimum dosage: 1,000 ppm.

sedimentation for various periods of time. As can be seen in Fig. 4, after 1 h of sedimentation, the optimum amount of alum needed to enhance sedimentation and achieve a turbidity of 3.3 NTU was 1,000 ppm. This is the same turbidity achieved by adding anionic polyelectrolyte at the optimum dosage. Fig. 5 presents the results after leaving the water to settle for 2 h. The optimum dosage of alum was 700 ppm in this case. As shown in Figs. 6–8, after 3, 6, and 10 h of sedimentation, the optimum dosage of alum was 400, 150, and 30, respectively. Table 2 summarizes sedimentation time and the optimum dosage. As the sedimentation period increased, the amount of alum dosage needed decreased.

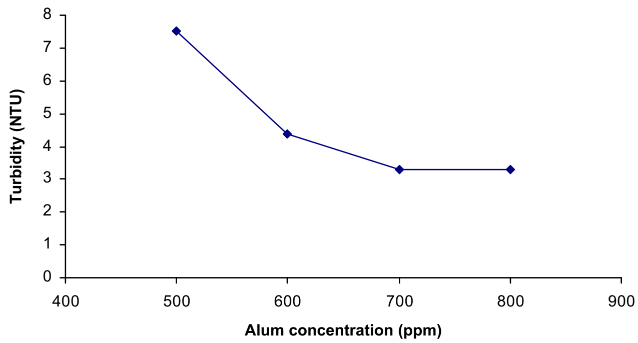

Fig. 5. Turbidity vs. alum dosage after 2 h of initial sedimentation: optimum dosage: 700 ppm.

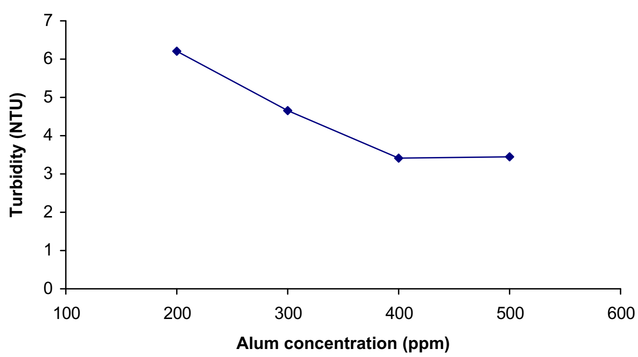

Fig. 6. Turbidity vs. alum dosage after 3 h of initial sedimentation: Optimum dosage: 400 ppm.

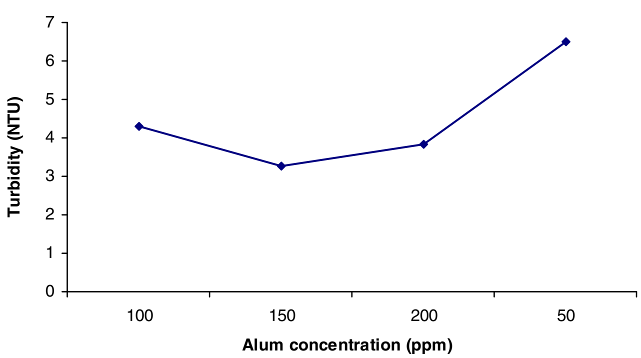

Fig. 7. Turbidity vs. alum dosage after 6 h of initial sedimentation: optimum dosage: 150 ppm.

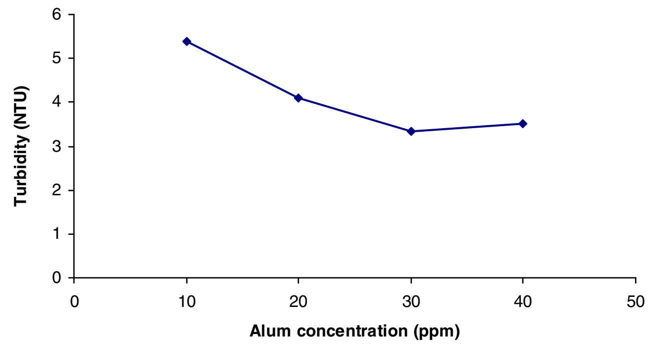

Fig. 8. Turbidity vs. alum dosage after 10 h of initial sedimentation: Optimum dosage: 30 ppm.

Table 2
The optimum dosage of alum at different initial sedimentation time

Initial sedimentation time (hr)	Optimum dosage (ppm)
1	1,000
2	700
3	400
6	150
10	30

4. Conclusions

In this paper, a technique for removal of phosphate from Eshidiya wastewater based on natural sedimentation followed by enhanced sedimentation by anionic and cationic polyelectrolytes and alum was developed. From the experimental study, it can be concluded that:

- Natural sedimentation of Eshidiya wastewater for twelve hours reduced the concentration of phosphate ions to 2 ppm.
- Anionic polyelectrolytes can be used for phosphate removal in an enhanced sedimentation step. The optimum dosage of anionic polyelectrolytes found to be 400 ppm with a target zeta potential of –58.7 mv, reducing turbidity to 3.3 NTU.
- Alum can be used as a coagulant in an enhanced sedimentation step. The optimum dosage depends on the period of initial sedimentation prior to this step.

- The anionic polyelectrolyte is more effective in enhanced sedimentation as far as the removal of phosphate ions from Eshidiya wastewater is concerned.

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References

[1] R.M. Harrison, Pollution: Causes, Effects, and Control, third ed., The Royal Society of Chemistry, London, 1996.
[2] A.M. Hoffman, M.M. Beumer, E.T. Baars, J.P. Van der Hoek, H.M.M. Koppers, Enhanced surface water treatment by ultrafiltration, Desalination 119 (1998) 113–125.
[3] N. Al-Soufi, R. Abdul Rahman, Zeta potential: A step to nano water, Graduation Project, Al-Balqa Applied University, Assalt, 2007.
[4] K. Hosni, Moussa S. Ben, A. Chachi, Amor M. Ben, The removal of phosphate ions by calcium hydroxide from synthetic waste water, Desalination 223 (2008) 337–343.
[5] A. Eskandarpour, K. Sassa, Y. Bando, M. Okido, S. Asai, Magnetic Removal of Phosphate from Wastewater Using Schwertmannite, Mater. Trans., Japan 47(7) (2006) 1832–1837.
[6] Ahamad M.H. Shaik, S.G. Dixit, Removal of phosphate from waters by precipitation and high gradient magnetic separation, Water Res. 26 (1992) 845–852.
[7] L. Yan, Y. Xu, H. Yu, X. Xin, Q. Wei, B. Du, Adsorption of phosphate from aqueous solution by hydroxy-aluminum, hydroxy-iron and hydroxy-iron-aluminum pillared bentonites, J. Hazard. Mater. 179 (2009) 244–250.