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Comparing the Efficacy Rates of Lime and Poly Aluminum Chloride Coagulants in Cadmium Removal from the Landfill Leachate by Chemical Precipitation

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ABSTRACT

Aims Chemical precipitation is a simple, efficient, and cost-effective method for eliminating heavy metals found in landfill leachate. The aim of the present study was to compare the efficacy rates of cadmium removal with the coagulants like poly aluminum chloride and lime using chemical precipitation method.

Materials & Methods In this experimental study, the raw studied samples were collected from the landfill located in Kahrizak, Iran, in May 2014. The elimination rates of cadmium at 1000, 1500 and 2000mg/l concentrations of lime; at 100, 150 200mg/l concentrations of poly aluminum chloride; at 7, 9, 11 pH levels; and during 20, 40 and 60min of the reaction time were studied. Data were analyzed in SPSS 16 software using ANOVA, independent T and repeated measurement tests.

Findings The maximum elimination rate of cadmium in both lime and poly aluminum chloride were seen at pH=11. The maximum rates of cadmium removal occurred at minute 40 in 2000mg/l concentration of lime (99.4%) and 200mg/l concentration of poly aluminum chloride (98%).

Conclusion Both lime and poly aluminum chloride have the best cadmium removal rate from leachate at pH=11 after 40 minutes of precipitation process. Being more inexpensive and easily available than poly aluminum chloride, lime is considered as an appropriate coagulant.

Keywords Cadmium, Calcium Hydroxide; Aluminum Compounds; Chemical Precipitation

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Introduction

Leachate is a sort of wastewater having high concentrations of organic and inorganic compounds and sometimes toxic agents; its disposal to the environment can cause great challenges for the authorities because of using municipal landfills for the final discharge [1]. Dissolved heavy metals that can threat the health of all living creatures, particularly human beings, because of their bioaccumulation potential are of the most important issues of leachate [2].

These heavy metals (include lead, cadmium, zinc, mercury, etc.) which can't break down like organic pollutants through chemical or biological processes in the environment can concentrate in food chains, resulting in the increasing of the metals accumulation in creatures located at the top trophic levels rather than the ones found at the low levels, e.g. those settled in the air or water. This causes damage to the plants and it could endanger the health of animals and humans [3] and their effects vary from mental retardation to central nervous system damages [4].

Generally, about 25,000 tons of cadmium is discharged into the environment annually. Cadmium can be used as stabilizer in the production of PVC contained products, dyes and pigments. Human activities such as production of industrial leachates and artificial phosphate fertilizers are the main source of cadmium releases [5]. Exposure to cadmium causes a range of acute and chronic effects in humans [6]. Its presence in the body can create some untoward effects as diarrhea, abdominal pain and vomiting, bone fracture, infertility, damage to the central nervous system, damage to the immune system, psychological disorder, renal failure and cancer [7].

Many methods have been proposed to eliminate heavy metals, including chemical precipitation, ion exchange, adsorption, reverse osmosis, bio-elimination, etc. These methods have been accepted due to economic and technical reasons, mostly at home and abroad. They not only reduce the volume of the leachate production but also improve the quality of the elimination [8-10]. Among them, hydroxide precipitation or chemical precipitation has been more widely used [11]. Coagulation and precipitation processes usually facilitate treating raw leachate and the pre-treatment for biological treatment. They are used for eliminating heavy metals and non-biodegradable materials from the leachate [12].

Calcium hydroxide (lime) may be considered as an appropriate economical coagulant, due to no need for changing the leachate pH level to optimum that reduces the expenses of the process and improves the efficacy rates of cadmium elimination [13]. Lime has been utilized in 1 to 15g/l for the treatment of landfill leachate. Chemical precipitation with lime causes the pH level and the leachate hardness to be increased and reduces COD (20-40%). It is an appropriate method for eliminating heavy metals (90%), and also reduces the color (70-90%), turbidity, and the suspended solids [14]. The removal rate of heavy metals such as cadmium has been reported up to 75-88% by Parvaresh *et al.* using chemical precipitation by lime [3].

In recent years, new types of inorganic coagulants have been introduced; inorganic polymer flocculants (IPFs). Poly Aluminum Chloride (PAC) is one of the most important types of IPFs being more used than others. The benefits are high efficacy at a wide range of pH levels and better performance at different temperatures; especially at low ones [13]. PAC, as a synthetic polymer, not only can eliminate heavy metals, but also can be an active ingredient in the removal of dye, suspended solid, COD and ammonia nitrogen from the leachate [15]. In addition, PAC, as a high efficient coagulant in water treatment, has been replaced the commercial aluminum coagulants [16]. Mahvi *et al.* have shown that the efficacy rates for eliminating heavy metals by PAC are 65 to 85% [17]. Generally speaking, the precipitation of heavy metals in the form of hydroxide, carbonate and sulfide can have the efficacy rates up to 75% [18].

The chemical precipitation of cadmium as hydroxide was conducted in a simple process being feasible with increased pH level and using lime and soda [2]. The aim of the present study was to compare the efficacy rates of cadmium removal with the coagulants like poly aluminum chloride and lime using chemical precipitation method.

Materials & Methods

In this experimental study, the raw studied samples were collected from the landfill

located in Kahrizak, Iran, in May 2014 and were sent to a Laboratory at Health Faculty of Kashan University of Medical Sciences.

In order to avoid any changes in the quality of the leachate, 1.5ml of nitric acid was added to every liter of the sample. Then, the pH level and the concentration of cadmium were measured. 50ml of the sample was isolated and filtered through Watson filter No. 40. The filtered sample was digested in accordance with the wastewater guidelines [19].

Chemical precipitation experiments were fulfilled using common jar test with six 1 liter beakers. At first, the amount of 200ml of the sample was applied into the containers of the jar test device. Secondly, using soda and sulfuric acid in the quantities of 7, 9 and 11, the pH levels were adjusted. Thirdly, 1000, 1500 and 2000mg/l of lime or 100, 150 and 200mg/l of poly aluminum chloride were added to the samples. At last, the pH levels were measured at the reaction time periods of 20, 40 and 60min. After precipitating, 50ml of the supernatant from the containers was extracted and filtered out for the chemical analysis. Then, 5ml of concentrated nitric acid was added to 50ml of the sample and it was placed on the heater at 90-95°C to reduce the sample volume. After reducing the volume, 5ml of nitric acid was re-added. After fully transparent, the sample was taken from the heater and again 2ml of nitric acid was added and it was passed through a filter. After the sample's temperature was reduced, the quantity of cadmium was determined by ICP device, 2100 DV model (Optima; USA). The elimination rates of cadmium at 1000, 1500 and 2000mg/l concentrations of lime; at 100, 150 200mg/l concentrations of poly aluminum chloride; at 7, 9, 11 pH levels; and during 20, 40 and 60min of the reaction time were studied.

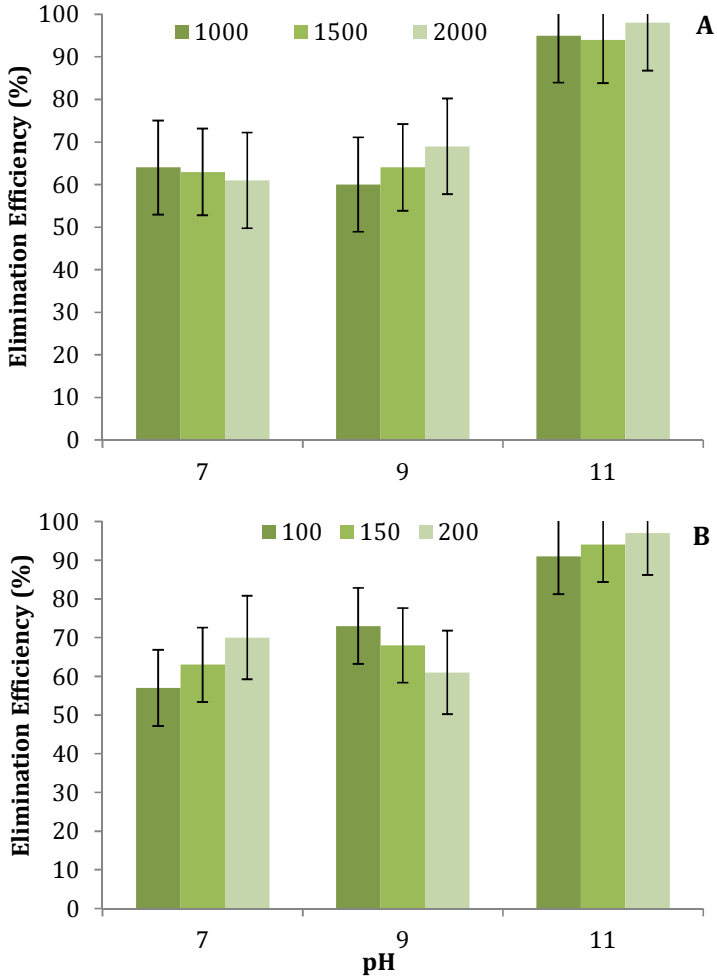

Figure 1) The effects of pH levels on the efficacy rates of cadmium elimination at various lime (A) and poly aluminum chloride (B) concentrations

Data were analyzed in SPSS 16 software using ANOVA and repeated measurement tests. ANOVA is used to determine the relation of studied variables in removing Cadmium and also LSD test is used for one by one comparison of these variables in different pH. Independent T test was used for testing the relation of the type of coagulant in removing Cadmium from leachate with chemical precipitation process. At the end, repeated measurement test was used to examine the effect of type of coagulant, time of reaction, and pH on Cadmium removal rate.

Findings

The maximum elimination rate of cadmium in both lime and poly aluminum chloride were seen at pH=11 (Figures 1A and 1B), at the 2000mg/l concentration of lime (97%) and 200mg/l concentration of poly aluminum chloride (30%). Coagulants concentration of lime (p=0.619) and simultaneous effect of coagulant concentration of lime and pH (p=0.667) had not significant effects on the removal of cadmium. Poly aluminum chloride coagulant concentration (p=0.849) as well as its simultaneous effect (p=0.171) had no significant effects on removal of cadmium.

The elimination rates of cadmium at pH=11, at various reaction time periods and at different concentrations of lime and poly aluminum chloride were measured (Figures 2A and 2B). The maximum rates of cadmium removal occurred at minute 40 in 2000mg/l concentration of lime (99.4%) and 200mg/l concentration of poly aluminum chloride (98%). Simultaneous effect of coagulant concentration of lime and time (p=0.984) and poly aluminum chloride and time (p=0.985) had not significant effects on the removal of Cadmium.

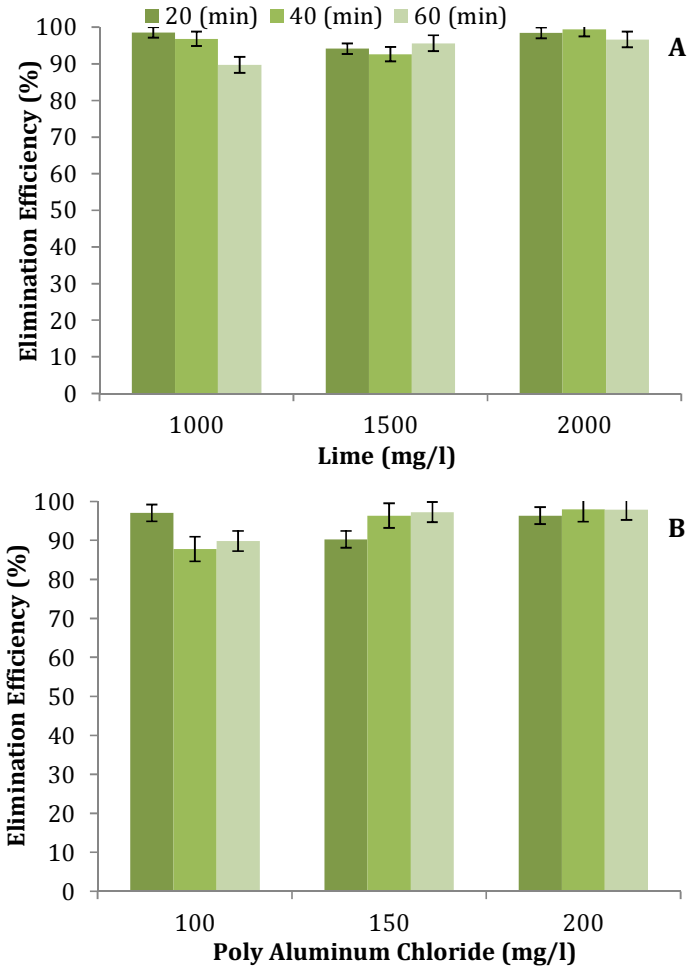

Figure 2) The effects of lime (A) and poly aluminum chloride (B) concentrations on cadmium elimination rate at pH=11 in various reaction time periods

Discussion

The current study elaborated the removal of cadmium from the leachate obtained from Kahrizak, Iran, landfill through chemical precipitation method using lime and poly aluminum chloride coagulants. The initial concentration of cadmium and the initial pH level in the raw leachate were 0.35mg/l and 7.8, respectively. According to the national standards of outlet sewage, cadmium concentrations should be less than 0.01mg/l [19]. Otherwise, the leachate must be treated thoroughly prior to discharge to the environment like absorbing wells or before using for agricultural purpose. In other words, raw leachate should not be used by any means.

Laboratory studies conducted in this research showed that both coagulants were able to remove cadmium and increasing coagulants concentrations increase the elimination rates. The best flocculation type was formed at the 2000mg/l concentration of lime (99.4%) and 200mg/l concentration of poly aluminum chloride (98%) at pH=11 after 40 minutes of the process. Sardar & Takdastan have also shown that increasing in lime concentration cause the elimination rate to be increased [20].

Considering the findings, the remained concentration of cadmium would be removed using the coagulants. The elimination rate was less than 0.01mg/l which was consistent with the national guidelines for outlet sewage regarding cadmium [19]. Moreover, increased pH levels from 7 to 9 and then to 11 and also creating insoluble metallic hydroxides caused the elimination rate to be increased so that the maximum rate was seen at pH=11. This finding is compatible with Parvaresh *et al.* [3]. The current study is incompatible with Mahvi *et al.* that have shown the maximum rate of elimination to be obtained at pH=7 using poly aluminum chloride [17]. Cadmium is a sort of metals precipitating at high pH levels in the form of hydroxide and it had the least solubility at pH level equal to 11-11.5.

Furthermore, our results showed that increased reaction time caused the elimination rate to be increased, but it did not increase the rate after 40 minutes and have decreased the elimination rate up to the minute 60. Noor Ainee *et al.* have shown that the efficacy rates for eliminating chemical oxygen demand, ammoniacal nitrogen and color were high by different concentrations of PAC at 30 minutes [21].

Being more inexpensive and easily available than poly aluminum chloride, lime is considered as an appropriate coagulant. Given the high efficacy rate at pH=11, it is recommended that further studies be conducted in this regard.

Conclusion

Both lime and poly aluminum chloride have the best cadmium removal rate from leachate at pH=11 after 40 minutes of precipitation process.

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Ethical Permission: The Ethics Committee of Kashan University of Medical Sciences approved the study.

Conflicts of Interests: The authors certify that there is no conflict of interests in this manuscript.

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