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Composting Plant Leachate Treatment by Coagulation-Flocculation Process

[1]Afshin Maleki, [2]Mohammad Ali Zazouli, [3]Hassan Izanloo and [4]Reza Rezaee

[1]Faculty of Health, Kurdistan University of Medical Sciences, Sanandaj, Iran
[2]Faculty of Health, Mazandaran University of Medical Sciences, Sari, Iran
[3]Department of Environmental Health Engineering and Research Center for Environmental Pollutant, Qom University of Medical Sciences, Qom, Iran
[4]Faculty of Health, Kurdistan University of Medical Sciences, Sanandaj, Iran

Abstract: This experimental study was conducted to investigate the effect of treatment of composting plant leachate by a coagulation-flocculation process. The effects of different dosages of coagulant and different pH values on the coagulation processes were compared. Ferric chloride and aluminium sulphate (alum) were tested as conventional coagulants. The experimental results show that a 18% removal of COD and 90% removal of heavy metals can be attained at pH 6.5 (optimum for alum) with the addition of 1400 mg L^{-1} alum and a 28% removal of COD and 86% removal of heavy metals can be attained at pH 10 (optimum for ferric chloride) with the addition of 2000 mg L^{-1} ferric chloride. The comparison of these values with the Iranian guideline for effluent discharge shows that the concentration of heavy metals in leachate did not exceed the maximum values allowed.

Key word: Solid Waste · Leachate · Chemical treatment · Heavy metals

INTRODUCTION

The growing production of domestic and industrial wastes in the world causes serious disposal problems. Solid waste landfill sites are often defined as hazardous and heavily polluted wastewaters with considerable variations in both composition and volumetric flow [1]. Leachate is generated as a consequence of rainwater percolation through wastes, chemical biological processes in waste and the inherent water content of wastes themselves [2]. The discharge of landfill leachate can lead to serious environmental problems, since the leachate contains a large amount of organic matter (both biodegradable and non-biodegradable carbon), ammonia-nitrogen, heavy metals, chlorinated organic and inorganic salts [3, 4]. Although some of these pollutants can be degraded by microorganisms, the limitation of common biological processes (degradation is only a part of COD and limited removal of bio-refractory organic pollutants) has made it difficult to meet the correlative discharge standard [4]. Therefore, alternative technologies based on physical-chemical stages are required.

The specific composition of leachates determines its relative treatability. The treatment processes used for landfill leachates often involve a combination of appropriate techniques. They are designed as modular, multi-stage units, capable of coping with the changing leachate characteristics over the years. Several processes, drawn from wastewater and drinking water technology, have been applied for the treatment of landfill leachates, such as anaerobic and/or aerobic biological degradation, chemical oxidation, coagulation-precipitation, activated carbon adsorption, photo-oxidation and membrane processes [3, 5-7].

Coagulation/flocculation is an essential process in water and in industrial wastewater treatment. Several studies have been reported on the examination of coagulation–flocculation for the treatment of landfill leachates, aiming at performance optimization, i.e. selection of the most appropriate coagulant, determination of experimental conditions, assessment of pH effect and investigation of flocculant addition [8]. Coagulation and flocculation is a relatively simple technique that may be employed successfully in treating old landfill leachates [9]. Aluminum sulfate (alum), ferrous sulfate,

Corresponding Author: Dr. Mohammad Ali Zazouli, Department of Environmental Health Eng., Faculty of Health, Mazandaran University of Medical Sciences, Sari, Iran Tel: +981513543080-5

ferric chloride were commonly used as coagulants [4, 10]. Iron salts were proved to be more efficient than aluminum ones, resulting in sufficient chemical oxygen demand (COD) reductions (up to 56%), whereas the corresponding values in case of alum or lime addition were lower (39 or 18%), respectively [3].

Sanandaj is one of the most crowded cities in Iran. Everyday, municipality has to manage approximately 400 tons of solid waste generated from residential and commercial sources and a composting plant receive whole of them. Field data indicate that a large amount of leachate is produced every day which is collected and transferred by trucks to the nearest farmlands or unutilized. The aim of this study was the identification of Sanandaj composting plant leachate quality and the examination of coagulation/precipitation process efficiency for the treatment of fresh (raw) leachates, especially in terms of heavy metals removal. More specifically, the aim was the determination of most appropriate coagulant type and dose, the examination of pH effect on removal capacity and the identification of optimum experimental conditions for the efficient application of this process.

MATERIALS AND METHODS

Leachate samples were collected once every week for 6 months between December 2006 and June 2007 from the composting plant of Sanandaj (Iran), which has been in operation since 1982. The raw leachate samples were obtained directly from the area where fresh solid wastes were deposited. Samples were collected in 20-L plastic carboys, transported to the laboratory and stored at 4 °C. The following parameters were analyzed: pH, COD, TS, TVS, TFS, metals as cupper, zinc, cadmium, chromium and nickel. All analyses were carried out according to Standard Methods [11]. All chemicals used for the analytical determinations were of analytical grade. Coagulation/flocculation and precipitation studies were performed in a conventional jar-test apparatus, equipped with 6 beakers of 1 L volume. The experimental process consisted of three subsequent stages: the initial rapid mixing stage took place for 5 min at 100 rpm, the following slow mixing stage for 15 min at 60 rpm, while the final settling step lasted for another 30 min. After the settling period, the supernatant was withdrawn from the beaker and was used for chemical analysis. Chemicals reagents used as coagulants included $Al_2(SO_4)3.18H_2O$, $FeCl_3.6H_2O$. The influence of leachate pH [4-9] on Coagulation/flocculation performances was studied. Coagulation with ferric chloride and aluminum sulfate as coagulant were performed to optimize the treatment conditions with respect to coagulant dosage and to estimate the removal of COD, cupper, zinc, cadmium, chromium and nickel.

RESULTS AND DISSCUSSION

The characteristic values of main physico-chemical pollution parameters for the examined leachate sample are presented in Table 1. It is observed that this leachate presents a relatively low value of pH. It can be deduced that leachates corresponded to the acidic phase of decomposition. High concentration of COD was observed ranging from 25762 to 45500 mg L^{-1}. So, this leachate displayed high concentrations of contaminants. Beside, the average values of heavy metal concentrations in the leachate are given in Table 1. The comparison of these values with the guidelines from Iranian Environmental Protection Agency (for effluent discharge in the sewer) and EPA (according to water irradiation standards) show that, the concentration of heavy metals (Zn, Cu, Cd, Cr and Ni) in leachate exceed the maximum values allowed. Because of chemical coagulation/flocculation is a process, which is highly pH depended.

Therefore, in order to determine the optimal pH value and coagulant dosage a standard jar test technique was used. The best conditions for coagulation/flocculation tests were evaluated considering COD and heavy metals removal. The pH of initial samples was varied between 3 and 11 for each coagulant. Coagulation/flocculation process runs by the addition of 1400 mg L^{-1} alum and

Table 1: Characterization of composting plant leachate (unit in mg L^{-1} except pH)

Parameters	Mean	Range
pH	4.9	4.2- 5.5
COD	34650	22300-45000
TS	37600	26200-47600
TVS	21850	16000-25800
TFS	17750	11400-23400
Cd	0.23	0.07-0.34
Cr	1.13	0.26-1.8
Cu	1.35	0.32-2.25
Zn	5.9	1.2- 11
Ni	2.3	0.65-3.8

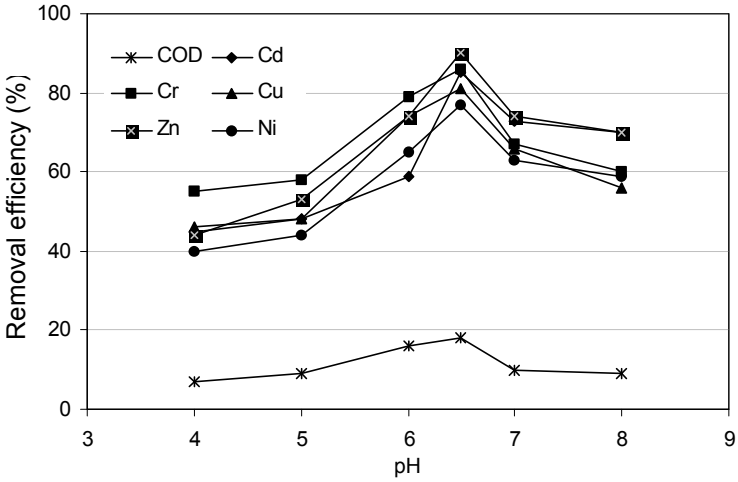

Fig. 1: Effect of pH values on the removal of COD and heavy metals using alum (coagulant dosage =1400 mg L^{-1})

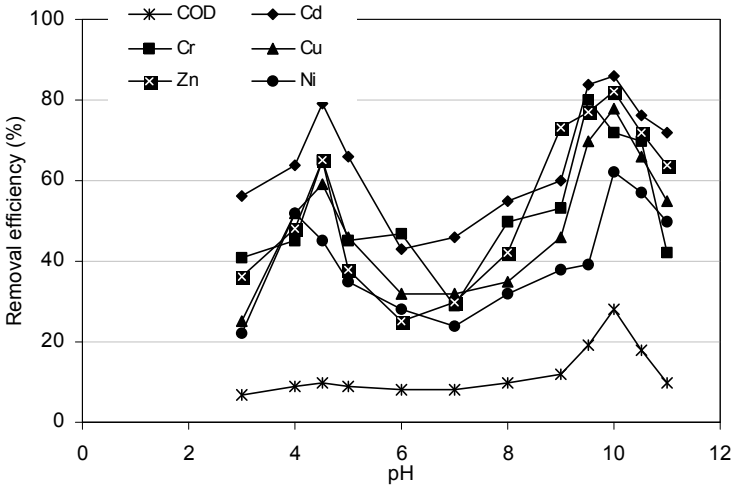

Fig. 2: Effect of pH values on the removal of COD and heavy metals using ferric chloride (coagulant dosage= 2000 mg L^{-1})

2000 mg L^{-1} ferric chloride in leachate samples separately, indicated a COD removal percentage varying from 7 to 18% for alum and from 7 to 28% for ferric chloride, the higher values were achieved at the pH value of 6.5 and 10 for alum and ferric chloride respectively. Tatsi *et al*. [3] and Silva *et al.* [9] indicated a COD removal capacity varying from 20 to 25% and 10 to 25%, respectively. Similar results were reported during the addition of alum and ferric chloride by Trebouet *et al.* [5] and Bila *et al.* [12]. COD and heavy metals removal results in various pH values are presented in Figs. 1 and 2, the data clearly shows that COD and heavy metals removal as a function of pH value. This result is in agreement with those obtained by Tatsi *et al.* [3] and Wang *et al.* [6].

The results also clearly indicate that the removal efficiency was increased with increasing pH up to optimum values (6 for alum and 10 for ferric chloride) and beyond which the removal efficiency is decreased. In general, chemical coagulation/flocculation is a process, which is highly pH dependant. The pH influences the nature of produced polymeric metal species that will be formed as soon as the metal coagulants are dissolved in water. The influence of pH on chemical coagulation/flocculation may be considered as a balance of two competitive forces: (1) between H and metal hydrolysis products for interaction with organic ligands and (2) between hydroxide ions and organic anions for interaction with metal hydrolysis products [13]. At low pH values, hydrogen ions out compete metal hydrolysis

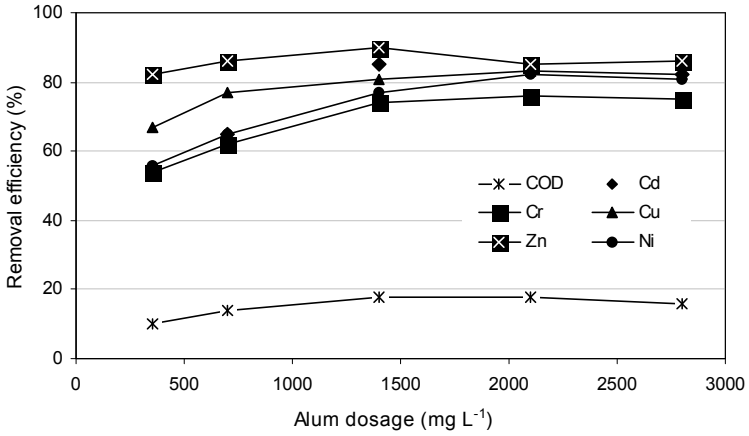

Fig. 3: Effect of alum dosage on the removal of COD and heavy metals in optimum pH value of 6.5

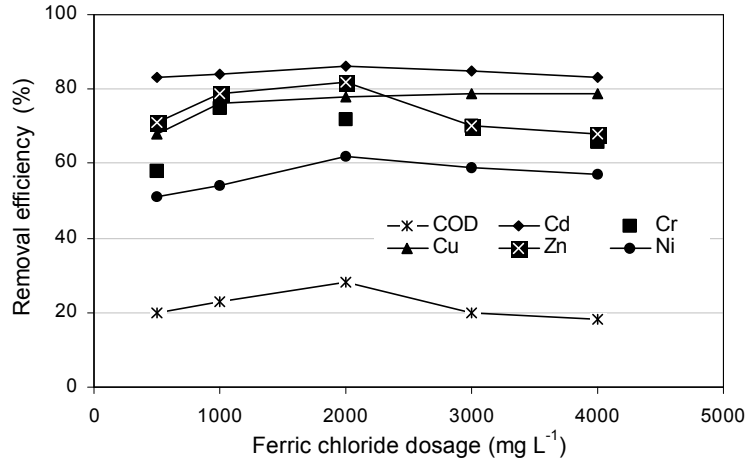

Fig. 4: Effect of ferric chloride dosage on the removal of COD and heavy metals in optimum pH value of 10

products for organic ligands, hence poor removal rates occur and some of the generated organic acids will not precipitate. At higher pH values, hydroxide ions compete with organic compounds for metal adsorption sites and the precipitation of metal-hydroxides occurs mainly by co-precipitation.

The amount of alum and ferric chloride on the efficiency of COD and heavy metals removal was also studied. Figs. 3 and 4 show the removal of COD and heavy metals by alum and ferric chloride at pH solution of 6 and 10 respectively. Coagulant dosage varied from 350 to 2800 mg $L^{-1}$and from 500 to 4000 mg L^{-1} for alum and ferric chloride, respectively.

As seen from results, the percentage removal of pollutants was increased with increasing coagulant dosage up to an optimum dosage and beyond which the removal percentage of pollutants decreased slowly. Similar findings are in agreement with those obtained by Tatsi *et al.* [3]. Results in COD reduction, when alum dosage were in the range of 0.8 – 1.5 g L^{-1}, whereas for higher dosage, further COD reduction was not observed. Wang *et al.* [6]. Observed that when the ferric chloride dosage was greater than 500 mgL^{-1}, the removal of COD increased slowly. Similar trend was reported by Rivas *et al.* [2]. The best yields of COD and heavy metals removal using alum and ferric chloride were obtained in dosage of 1400 and 2000 mg L^{-1}, respectively. This result is mainly due to the fact that the optimum coagulant dosage produced flocs have a good structure and consistency. But in the lower dose than optimum dose, the produced flocs are small and influence on settling velocity of the sludge.In the higher dose than optimum dose, in addition to small size of floc, restability of floc can be happened. The results shown the addition of alum and ferric chloride to leachate resulted in 18 and 28% reduction of COD values, respectively

and also, 77 to 90 and 62-86 % reduction of heavy metals values, respectively. Previously, lower heavy metals removal was observed by Silva *et al.* [9] during coagulation/flocculation process. Furthermore, comparing the results of coagulation experiments, it can be observed that ferric chloride was more efficient than alum for the removed of COD. Especially at pH values greater than 9, hydrous iron hydroxides are precipitating in greater degree than the corresponding alum flocs, resulting in more efficient removal of pollutants, than that obtained at lower pH values. Chain [14] indicated that humic-type substances constitute an important group of leachate organic matter. Therefore, alum can be depolymerised in the presence of natural organic matter [15, 16], thus resulting in the lowest of alum coagulants. However, heavy metals removal was low for ferric chloride, but for alum the reduction reached up to 90%. Anyhow the comparison of these values with the Iranian guideline for effluent discharge shows that the concentration of heavy metals in leachate did not exceed the maximum values allowed.

CONCLUSIONS

The application of coagulation/precipitation treatment for raw leachate (before composting process) collected from a composting plant was examined in this study. Leachate was characterized by low pH value and high concentration of pollutants; especially organic matter was in the range of 45000 mg L^{-1} COD. The addition of ferric chloride or alum coagulants to leachates resulted reduction of COD values; the optimum removal was found during the addition of 1.4 g L^{-1} alum and 2 g L^{-1} ferric chloride to the samples. In this case, the optimum COD removal value reached about 18% for an alum dosage of 1.4 g L^{-1}, when the pH value was adjusted at 10 and about 28% for a ferric chloride dosage of 2 g L^{-1}, when the pH value was adjusted at 10. The addition of high amount of coagulants was found to affect slightly the process efficiency. Nevertheless, almost high removal of heavy metals (90 % by using alum and 86% by using ferric chloride) was obtained in all cases and under these conditions the residual heavy metals concentration were below the limit value recommended by Iranian guidelines for effluent discharge.

Furthermore, comparing the results of coagulation experiments, it can be observed that ferric chloride was more efficient than alum for the removal of COD. Especially at pH values greater than 9, hydrous iron hydroxides are precipitating in greater degree than the corresponding alum flocs, resulting in more efficient removal of pollutants, than that obtained at lower pH values. It is concluded that the advantages of the proposed physico-chemical method for the treatment of leachates are mainly simplicity, low cost, good removal efficiencies and easy onsite implementation. This method could be used for pre- or post-leachate treatment in combination with biological treatment process.

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