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Polymeric Flocculation as a Sustainable Solution for Heavy Metal Removal from Leachate in Barka Landfill, Oman

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Abstract

Purpose: This study investigates the effectiveness of polymeric flocculation in removing heavy metals from leachate through filtration, sedimentation, and precipitation, aiming to separate and eliminate particulate matter. to separate and remove particulate matter.

Method: This study investigated the use of alum and chitosan to remove heavy metals from leachate. The addition of a polymeric flocculant, chitosan, promoted the formation of stable flocs, which effectively removed heavy metals. Chitosan, a natural biopolymer, was found to be a promising alternative to synthetic polymers.

Main Findings: The experimental results demonstrated that alum outperformed chitosan in terms of removing heavy metals. Under optimal conditions, an alum dosage of 6 mg/l at a pH of 6.23 resulted in copper and magnesium removal efficiencies of 84% and 92%, respectively. In contrast, the optimal chitosan dosage was 8 mg/l at a pH of 7.5, with copper and magnesium removal efficiencies of 43.1% and 91.8%, respectively.

Implications: Leachate treatment reduces heavy metals and organic compounds, controls odors, and generates foam indicating the presence of gases like carbon dioxide and methane. These gases can be harnessed for clean energy production and green hydrogen development. harnessed for clean energy production and green hydrogen development.

Novelty: This study is the first to scientifically analyze leachate treatment at the Barka landfill. Chitosan, a natural polymer, effectively removes suspended matter and heavy metals, reducing their concentrations. removes suspended matter and heavy metals, reducing their concentrations.

INTRODUCTION

Leachate refers to the liquid that passes through a landfill, containing a significant amount of organic and inorganic substances, as well as suspended solids. The Barka landfill, a sanitary landfill adhering to proper engineering principles, serves as a method for the safe disposal of solid waste without causing environmental hazards or contamination. Leachate generated from the Barka landfill is collected in designated ponds to prevent any leakage into the surface or groundwater. Leachate is characterized by high levels of chemical oxygen demand (COD), pH, biochemical oxygen demand (BOD), total dissolved solids (TDS), nitrogen, ammonia, heavy metals, a brownish color, and a strong odor due to acetic and anoxic conditions and the presence of hydrogen sulfide (H_2S). The presence of heavy metals in leachate, primarily resulting from industrial waste, poses a significant concern, particularly in the case of the Barka landfill.

Leachate generation from municipal solid waste is a common environmental issue in many countries. Sanitary landfills, such as the Barka landfill in the Sultanate of Oman, provide a method for waste disposal that follows appropriate engineering principles. The Barka landfill, operational since July 2015, has a lifespan of four years and receives approximately 1300 tons of municipal solid waste per day. Leachate is formed when precipitation infiltrates the landfill through soil pores, along with moisture present in the waste during its degradation.

Various factors contribute to leachate generation, including rainfall, groundwater infiltration, water produced from deposited waste due to constant pressure, and evaporation from the site. Leachate is characterized by high values of COD, pH, BOD, TDS, nitrogen, ammonia, heavy metals, a brownish color, and a strong odor due to the presence of ammonia and H_2S. The specific characteristics of leachate vary depending on its composition, volume, and the amount of biodegradable matter present.

The presence of foam on the surface of leachate is a consequence of its composition and can impede evaporation. The foam layer is often thick and heavy. The composition and quantity of leachate generated depend on factors such as solid waste composition, compaction degree, waste age, waste's absorptive capacity, precipitation levels, landfill engineering and operational factors, hydrogeological conditions, and biological activities, as well as seasonal weather variations.

In young landfill leachate, the concentration of heavy metals, inorganic ions, and volatile acids is high due to the acid fermentation phase, which occurs at low pH during anaerobic degradation. As leachate matures and stabilizes, the pH becomes neutral, and heavy metal concentrations decrease.

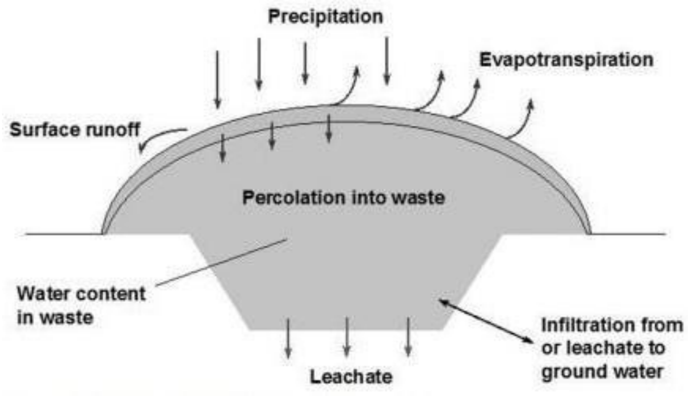

Fig 1: Leachate generation (Morling, 2007)

The presence of heavy metals in leachate is a significant issue for landfills as it poses environmental risks to surface and groundwater, as well as human health, while also increasing the cost of treatment. Heavy metals are dense, non-biodegradable, and toxic at low concentrations. Examples of heavy metals include mercury, zinc, copper, lead, and cadmium.

Copper (Cu) is a metal with relatively high toxicity potential, although it is an essential element for biological purposes. The heavy metals found in leachate originate from industrial waste. The Barka landfill receives 14 different types of waste, including complex materials, glass, and wood. The mobility and solubility of metals within the landfill are influenced by factors such as pH, the presence of complex organic and inorganic substances, and redox conditions. Removing heavy metals from leachate reduces negative environmental impacts and provides a cost-effective and efficient solution.

Various methods, such as chemical precipitation, coagulation-flocculation processes, and membrane filtration, are employed for the treatment of leachate and removal of heavy metals. Coagulation-flocculation processes, utilizing different coagulants like alum and chitosan, have proven to be effective in removing heavy metals from leachate. The study conducted at the Barka landfill will be the first of its kind, comparing leachate characteristics, treatment methods, and different coagulants used for heavy metal removal.

Collecting leachate samples from the Barka landfill at once is crucial due to the high concentration of heavy metals. Analyzing multiple leachate samples collected at different times is challenging, as leachate properties change over time. Therefore, it is necessary to store leachate samples in a cold environment to maintain their properties. Finding a suitable polymeric coagulant for heavy metal removal is a complex task.

The main objective of this study is to analyze leachate samples to determine the concentration of heavy metals and identify a suitable polymeric coagulant that can enhance the removal efficiency of heavy metals from leachate.

LITERATURE REVIEW

Following literatures were reviewed during this study. Main results and objective is summarized here.

Raghab et al. (2013)

Investigated the use of coagulation-flocculation with alum as a coagulant and Perlite or Bentonite as an accelerator to improve treatment efficiency. Perlite yielded higher removal rates for turbidity, conductivity, BOD, and COD compared to Bentonite. The optimal dosage of alum was determined to be 90 mg/L.

Jurczyk and Koc-Jurczyk (2007)

Examined the removal of heavy metals from landfill leachate using different treatment methods. Chemical and biological treatments were found to be effective in reducing heavy metal concentrations but did not achieve complete removal.

Dikshit and Shabiimam (2011)

Studied the removal of COD and turbidity from leachate using coagulation-flocculation with alum, calcium hydroxide, and lime. Calcium hydroxide exhibited better removal efficiency than alum. The optimal pH for COD removal using calcium hydroxide was 8, with a coagulant dosage of 25 g/L.

Azim et al. (2011)

Characterized leachate from a landfill and assessed its potential impact on surface and groundwater. Biological treatment through sedimentation and aeration was found to improve leachate quality. Continuous monitoring was recommended to prevent contamination.

Samadi et al. (2010)

Investigated the effectiveness of coagulation-flocculation on leachate from a landfill. Ferrous sulfate was identified as the most efficient coagulant for COD removal at a pH of 12 and a dosage of 1500 mg/L.

Angadi et al. (2015)

Used alum and polyelectrolyte to remove heavy metals from leachate through coagulation.The combination of alum (1 g/L) and polyelectrolyte (0.3 g/L) at pH 7 achieved the highest removal rates for chromium (77.3%), cadmium (92.4%), and nickel (80.1%).

GAO and Song (2013)

Explored the use of oyster shells as an adsorbent for heavy metal removal from leachate. Equilibrium was reached at pH 8, with the adsorption capacity increasing with metal concentration and decreasing with adsorbent mass.

Bakraouy et al. (2015)

Applied coagulation-flocculation with ferric chloride as a coagulant and cationic polymer as a flocculent to treat leachate. The optimal pH for removal of turbidity, phenol, and surfactant was 8.4.

Rui, Daud, and Abdul Latif (2012)

Evaluated the use of various coagulants and polymers in coagulation-flocculation for leachate treatment. Synthetic polymers were found to be effective in removing suspended solids, COD, color, and ammonium nitrogen.

Ab Jalil, Abdul Aziz, and Kamarudzaman (2011)

Studied the removal of iron and manganese from leachate using horizontal and vertical subsurface flow constructed wetlands. Both systems achieved high removal efficiencies, with vertical flow being slightly more effective.

Matilainen et al. (2010)

Investigated the removal of natural organic matter from drinking water using coagulation-flocculation. Ferric salts were found to be more efficient than aluminum sulfate in removing organic matter.

Wang (2011)

Examined the effectiveness of mercaptoacetyl chitosan as a flocculent for heavy metal removal. the flocculent exhibited high efficiency in removing heavy metals and turbidity.

Amuda et al. (2006)

This study examined the effectiveness of polymer addition to coagulation-flocculation for removing heavy metals from industrial wastewater. The results showed that the optimal removal efficiency was achieved using 300 mg/L of ferric chloride and 65 mg/L of polymer.

Ghafari et al. (2009)

Optimized coagulation-flocculation treatment of leachate using poly-aluminum chloride and alum. Poly-aluminum chloride was found to be more effective than alum at a pH of 7.5 and a dosage of 2 g/L. showed that mercaptoacetyl chitosan was an effective flocculent for removing heavy metals and turbidity.

METHODOLOGY

Sample Collection: Samples of leachate were collected from the leachate pond at the Barka landfill site in the Sultanate of Oman. The landfill site was opened in July 2015. The collected samples were stored at a temperature of 42°C. The composition of leachate varies depending on factors such as the type of waste present during that period and other influencing factors. Typically, leachate samples from young leachate, which is in the acid fermentation phase, exhibit high concentrations of heavy metals, chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), organic compounds, and inorganic compounds.

Chemicals for Flocculation: Chitosan and alum were used as flocculants in the study. Chitosan is a biopolymer derived from the deacetylation of chitin, which is found in crustaceans and the exoskeleton of shellfish (Babel, Kurniawan 2003). Chitosan is an ideal natural polymer known for its exceptional characteristics such as biocompatibility, non-toxicity, and hydrophilicity. It possesses hydroxyl and amino groups that enable it to effectively remove heavy metals. However, chitosan's performance is highly influenced by the pH value (Ngah, 2011). Alum, also known as aluminum potassium sulfate ($KAl(SO_4)_2.12H_2O$), is a solid powder at room temperature and a hygroscopic material that easily dissolves in water. It is commonly used for water purification and acts as a coagulant in the coagulation-flocculation process.

Parameters Tested for Study: The following parameters were measured to study the removal process: COD, TSS, TDS, total organic carbon (TOC), turbidity (NTU), conductivity (mS/cm), pH, copper (Cu) removal, and magnesium (Mg) removal.

The pH value of each sample was determined using a digital pH meter, and turbidity was measured using a turbid meter.

COD was analyzed using a COD analyzer. The test involved taking a COD vial, adding 2 ml of distilled water as a blank, and adding 2 ml of the sample to another vial. The vials were then heated in a digester block for 2 hours, followed by a cooling period and subsequent measurement.

TSS represents the amount of total suspended solids and was determined by drying the filter paper with the residue in an oven for one day. The weight of the dried filter paper was recorded, and TSS was calculated using the equation W2-W1/V, where W1 is the weight of the filter paper after drying, W2 is the weight of the empty filter paper, and V is the volume (ml).

For instance, sample 1 of 2g dosage of alum, W1 was 0.149 g, W2= 0.653g and V= 30ml

TSS (mg/l) = (0.653*1000) - (0.514*1000) / (30*10^{-3}) = 4633.33 mg/l

TDS, which refers to the total dissolved solids in water, was measured using an Eutech instrument.

Heavy metal testing was conducted using an Atomic Absorption Spectrophotometer (AAS), and the same procedures were repeated for treated leachate using chitosan.

Analytical Method: Coagulation-flocculation is a widely used and effective treatment process in wastewater treatment plants. It is a simple treatment method that involves the addition of chemical coagulants, such as alum, and polymers as coagulants. Coagulation-flocculation is suitable for treating fresh leachate to remove heavy metals, suspended solids, dissolved solids, COD, BOD, and organic compounds from leachate. Flocculation is a process where destabilized particles come together during low-speed mixing, leading to the formation of larger floc particles that settle slowly (Prakash, 2008). These particles can be separated through flotation, sedimentation, or filtration. Flocculants act as an extensive solution and do not significantly affect the pH value of the medium.

Experimental Setup:

Stage 1: Analysis of parameters such as pH, TSS, TDS, COD, TOC, turbidity, and conductivity of the leachate sample before treatment.

Stage 2: Application of coagulation-flocculation treatment to the leachate using calculated amounts of alum and chitosan.

The initial treatment involved adding different doses of alum to 5 glass conical flasks, each containing 100 ml of landfill leachate, at room temperature. The dosages ranged from 2,4,6,8 and 10 mg/l. The samples were then transferred to a water bath shaker for 1 hour, with a rapid mixing speed of 75 rpm. The pH value of the samples was adjusted to the desired level by adding HCl or NaOH. This mixing step was crucial for achieving effective coagulation and ensuring proper mixing of the leachate with alum. During the rapid mixing, foam was produced after a few minutes, as shown in Figure 4.

After 1 hour of rapid mixing, the samples were allowed to settle for 30 minutes. During this settling period, the floc particles formed by the coagulation process settled at the bottom of the conical flasks, leaving clear supernatant above. After the settling period, samples were taken from the supernatant for analysis.

A subsequent filtration process was conducted to further purify the treated leachate. Filtration is an essential technique employed in water purification to separate solid particles from a liquid medium. In this particular study, filtration was particularly valuable in removing and isolating foam from the treated leachate. Additionally, filtration facilitated the collection of solid particles that had precipitated in the filter paper, which was subsequently used to calculate the total suspended solids (TSS) content.

The filtration process was conducted using gravity as the driving force. Due to the high viscosity of the leachate, the filtration process required an extended duration of one week to achieve optimal separation and purification.

RESULT & DISCUSSION

An analysis was conducted to determine the characteristics of landfill leachate collected from the Barka landfill site at a specific time. The pH value of the leachate was measured to be 6.9, indicating that the leachate was in its early stage and undergoing acid fermentation. This suggests that the leachate exhibited a high concentration of heavy metals (Jurczyk & Koc-Jurczyk, 2007). Table 1 provides an overview of the characteristics of the young landfill leachate prior to any treatment. Similar characteristics have been observed in various young landfill sites, where pH values ranged from 5 to 8, indicating the presence of high concentrations of organic and inorganic substances (Calli et al., 2005).

Table 1: Characteristics of leachate from Barka landfill before treatment

Parameter	Measured Values
pH	6.9
Turbidity (NTU)	51.9
Conductivity (mS/cm)	117.9
TOC (mg/l)	4752
COD (mg/l)	20162
TDS (mg/l)	62500
TSS (mg/l)	118000
Color (mg/l)	Dark brown
Odor	Strong smell
Cu (mg/l)	3.959
Mg (mg/l)	12.893

In order to evaluate the efficiency of Alum and chitosan as a coagulant were added different dosage of coagulants in leachate samples. The dosages were 2 mg/l, 4 mg/l,6 mg/l, 8 mg/l and 10 mg/l.

A: Effect of Alum dosages on Leachate

Effect of Alum dosage on COD removal

Table 2: The impact of dosages of alum on properties

Dosage (mg/l)	COD	TSS	TDS	TOC removal	Turbidity (NTU)	Conductivity (mS/cm)	pH	Cu removal	Mg removal
2	1417	4633	38100	1187.1	19.5	0.75	7.66	2.9	4.931
4	1320	8001	37809	1094.4	22.4	1.070	7.49	3.2	5.620
6	706.1	4000	38274	1274	6.15	1.666	6.23	0.632	1.032
8	1298	4766.67	38395	1375	15.6	1.57	4.71	2.5	4.545
10	954	7533.3	38516	1384	35.8	1.43	6.54	0.835	2.046

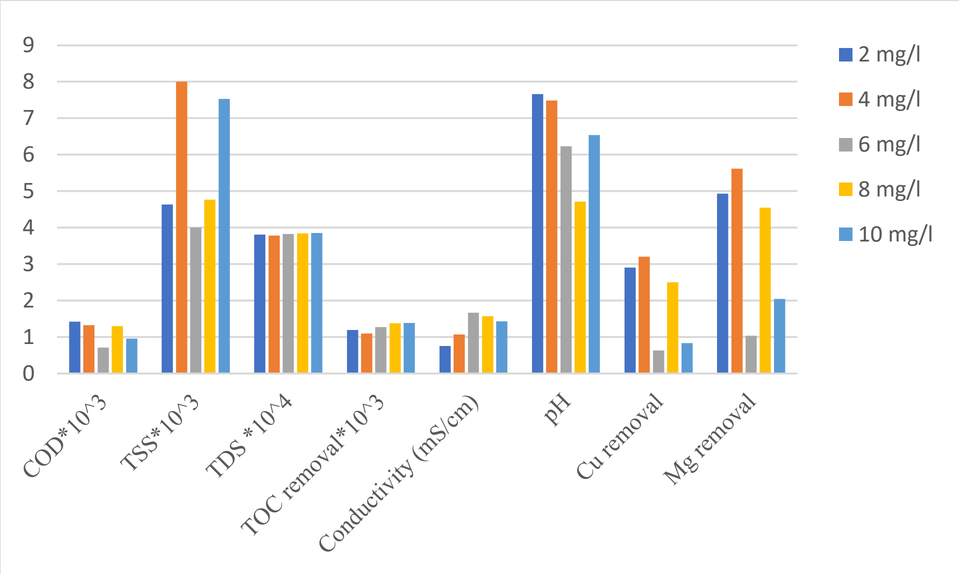

Figure 2: Showing effect of dosage of alum on parameters

Table 2 presents the impact of varying alum dosages on COD readings. Generally, COD values decreased after alum addition compared to the initial untreated value. As shown in Figure 2, the COD reading initially declined gradually with increasing alum dosage. The lowest point was reached at a dosage of 6 mg/L, where the COD decreased to 760.1 mg/L. This indicates that the optimal alum dosage for COD removal was 6 mg/L at a pH of 6.23. Figure 2 shows that the most significant COD reductions occurred at alum dosages of 6 mg/L, 10 mg/L, 8 mg/L, 4 mg/L, and 2 mg/L, respectively. The efficiency of COD removal is influenced by pH. According to Ahmad et al. (2008), decreasing the pH from alkaline to near or neutral levels enhances COD removal. This is because the neutralization process destabilizes particles, causing colloidal particles in flocs to enter a destabilization phase, resulting in a decrease in COD. Furthermore, the reduction in COD value suggests an increase in methane gas emissions, as carbonaceous matter is converted into carbon dioxide and methane during anaerobic processes (Timur & Oezturk, 1999).

Effect of Alum Dosage on TSS Reduction

Table 2 presents the impact of varying alum dosages on TSS values. As shown in Figure 2, TSS decreased after alum addition compared to the initial untreated value. In general, TSS removal increased with increasing alum dosages. From the graph, it can be observed that the TSS value increased at a dosage of 4 mg/L. This suggests that this dosage was not sufficient to destabilize the suspended solid particles. The highest reduction in TSS was obtained at a dosage of 6 mg/L at pH 6.23, with a decrease to 4000 mg/L. This indicates that 6 mg/L is the optimal alum dosage for maximum TSS removal. pH plays a crucial role in TSS removal. Lower pH values provide more favorable conditions for efficient removal. Similar results were reported by Samadi (2010).

Effect of Alum Dosage on TDS Reduction

Table 2 also shows the effect of varying alum dosages on TDS values. The initial TDS concentration was 62500 mg/L, and after alum addition, the effluent TDS concentrations were 381100 mg/L, 37809 mg/L, 38274 mg/L, 38274 mg/L, 38395 mg/L, and 38516 mg/L, respectively. This indicates that TDS decreased after alum addition. The lowest TDS value was obtained at an alum dosage of 4 mg/L, suggesting that this dosage was optimal for maximum TDS removal. The reduction in TDS was 24691 mg/L. Saleh et al. (2014) reported a similar reduction in TDS of 68314 mg/L.

Effect of Alum Dosage on Turbidity and Conductivity Reduction

As mentioned earlier, the leachate had a high turbidity value of 51.9 NTU. Chemical treatment with alum was effective in reducing turbidity, with the optimal dosage being 6 mg/L (Figure 2). At this dosage, turbidity was reduced from 51.9 to 6.15

NTU, a decrease of 44.85 NTU. This reduction in turbidity is attributed to the sedimentation of particles after their ions were equalized. Similar results were obtained by Raghab et al. (2013), who reported an 82% removal of turbidity.

Alum dosage also significantly affected conductivity. Figure 2 shows that conductivity decreased drastically at an alum dosage of 2 mg/L, from 117.9 to 0.75 mS/cm. This reduction can be attributed to the adsorption of salts on the surface of the alum. Raghab et al. (2013) reported similar findings.

Effect of Alum Dosage on pH Values

pH is a critical parameter for achieving maximum COD and TSS removal. Figure 2 shows that pH decreased with increasing alum dosages. The lowest pH value was obtained at an alum dosage of 8 mg/L, decreasing from 6.9 to 4.71. The addition of inorganic coagulants like alum results in an optimal pH value at which metal hydroxide precipitates. This reduction in pH is a consequence of the addition of metal coagulants (Ahmad et al., 2008). Guida et al. (2007) reported higher removal of COD and TSS at a pH of 5, with efficiencies of 70% and 90%, respectively. The pH values for different alum dosages are given in Table 2.

Effect of Alum Dosage on TOC

TOC is reduced through the conversion of organic matter into methane and carbon dioxide. Table 2 shows that TOC decreased after alum addition.

Effect of Alum Dosage on Heavy Metal Removal

A coagulation-flocculation study was conducted to investigate the removal of heavy metals (copper and magnesium) using different alum dosages. As shown in Figure 2, alum dosages ranged from 2 mg/L to 10 mg/L at pH 6.23. The removal of heavy metals followed a specific sequence, with the highest removal occurring at an alum dosage of 6 mg/L.

At this dosage, the reduction in copper and magnesium concentrations was 0.632 mg/L and 1.032 mg/L, respectively, corresponding to removal efficiencies of 84% for copper and 92% for magnesium.

B: Effect of Chitosan Dosages on Leachate

Chitosan is used to remove and reduce dissolved particles, organic and inorganic matter, and suspended solids (Figure 6.8). Both TSS and TDS decreased after chitosan addition.

The optimal dosage for maximum TSS removal was 8 mg/L of chitosan. At this dosage, TSS was reduced from 62500 mg/L to 3769 mg/L. This reduction is attributed to the stability of chitosan in the sample. This reduction is attributed to the stability of chitosan in the sample.

Effect of Chitosan Dosages on pH Removal

pH is a crucial variable affecting the performance and effectiveness of chitosan. Chitosan is more stable at lower pH values due to the protonation of the amino group in the polymeric chain (Meraz et al., 2016). The pH values for different chitosan dosages are recorded in Table 3. Figure 3 shows the relationship between chitosan dosages and pH. The optimal pH value was obtained at a dosage of 8 mg/L, with a pH of 7.5. However, this pH range indicates poor solubility and is not ideal for turbidity reduction (Yang et al., 2011).

Table 3: Value of parameters removal with different dosage of Chitosan.

Dosage (mg/l)	TSS removal	TDS removal	pH	Turbidity (NTU)	Conductivity (mS/cm)	Cu	Mg
2	14840	54.24	8.01	394	12.67	3.158	1.112
4	8060	48.88	7.66	365	6.02	2.342	1.076
6	8120	50.29	7.6	344	5.33	2.612	1.103
8	6610	37.69	7.5	218	1.140	2.250	1.058

Effect of Chitosan Dosages on Turbidity Reduction

Turbidity reduction is influenced by pH. Figure 3 shows the relationship between chitosan dosages and turbidity removal. Turbidity removal increased with increasing chitosan dosages. However, the reduction was less effective at pH 7.5. This is because the charge neutralization and pH value were higher than the acidic range (>6), resulting in poor chitosan sterilization (Meraz et al., 2016).

Effect of Chitosan Dosages on Conductivity Reduction

As shown in Figure 3, conductivity decreased significantly at a chitosan dosage of 8 mg/L, indicating that this was the optimal condition for maximum conductivity reduction. The conductivity value decreased from the initial untreated value after chitosan addition, from 117.9 to 1.140. Conductivity reduction decreased with increasing chitosan dosages.

Effect of Chitosan Dosages on Heavy Metals Removal

The effect of chitosan dosages on heavy metals removal is given in Table 4. Chitosan was effective in removing copper and magnesium. The highest removal of both metals occurred at a dosage of 8 mg/L. Figure 3 shows the reduction of heavy metals using different chitosan dosages. The reduction increased with increasing chitosan concentration. However, heavy metal removal decreased with increasing dosages.

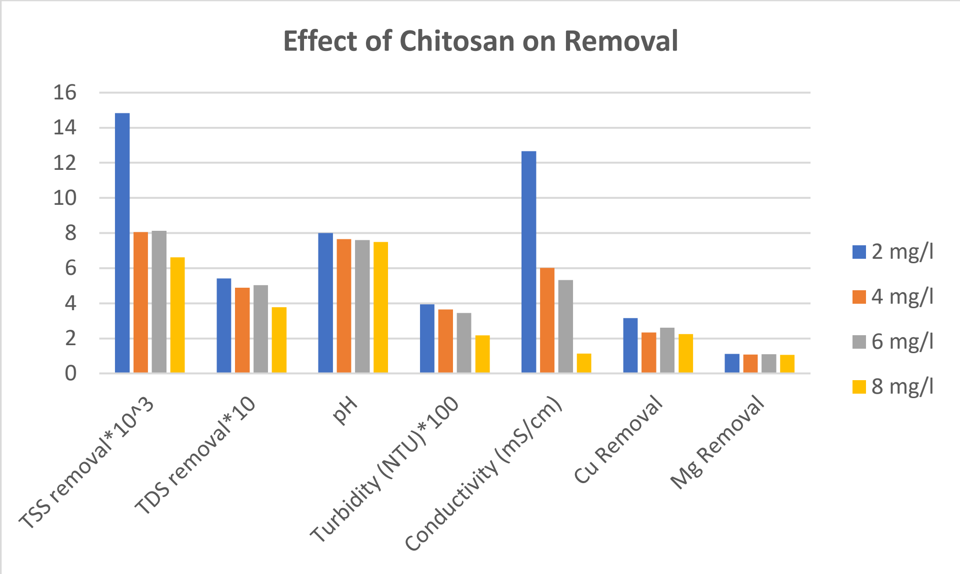

Figure 3: Effect of Chitosan on Removal

Table 3 shows that the reduction of copper and magnesium at a dosage of 8 mg/L was 2.250 and 1.058, respectively. The removal efficiencies for copper were 20%, 34%, 40.8%, and 43.2% for dosages of 2, 4, 6, and 8 mg/L, respectively. The removal efficiencies for magnesium were 91.4%, 91.44%, 91.6%, and 91.8% for the same dosages. Chitosan was more effective in removing magnesium than copper.

Challenge of Foam Production

Foam production was a significant challenge during the experimental work. Foam was generated when chemical coagulant (alum) was added to the leachate. Initially, the foam production rate was slow, but it gradually increased with high speed after the leachate was placed in a shaker. Foaming was caused by gases formed during treatment, such as methane and carbon dioxide. The foam was removed by filtration. Foaming can be reduced by stabilizing and neutralizing acidic waste before disposal. By increasing the pH to a range between 6.5 and 8.5, the leachate becomes stabilized, reducing foaming.

Chemical reaction: Alum + leachate → foam + (gases emission)

Fig 4: Foam production

CONCLUSIONS

Heavy metals are present in leachate due to solid waste from municipalities. Young leachate has a higher concentration of heavy metals, which decreases during the stabilization and maturation phases. Experimental results indicate that the coagulation-flocculation process effectively removes high concentrations of heavy metals, TSS, and TDS. Chemical coagulant (alum) and polymeric flocculent (chitosan) improve removal efficiency. During the coagulation-flocculation process, the removal efficiency of copper and magnesium using alum was 84% and 92%, respectively. Chitosan effectively removed copper and magnesium, with removal efficiencies of 43.2% and 91.8%, respectively.

The optimal removal dosage of alum was 6 mg/L, while that of chitosan was 8 mg/L. pH plays a crucial role in TSS and

COD removal. The removal efficiency of COD and TSS at pH 6.23 and an alum dosage of 6 mg/L was 96.5% and 96.6%, respectively. Chitosan was more effective in removing Mg than alum.

RECOMMENDATIONS & FUTURE WORK

Due to the hazardous nature of leachate and its high concentration of heavy metals, organic, and inorganic substances, caution should be exercised when handling leachate. Personal protective equipment (PPE) should be worn during experimental work. Flocculent polymer (chitosan) is sensitive to pH. During experimental work, the pH should be adjusted to less than 7 to achieve high solubility in the solution.

Future work should focus on combining chitosan with alum to treat leachate and studying its effectiveness in reducing heavy metals. Additionally, exploring new natural coagulants to reduce the cost of chemical coagulants is recommended. Investigating the main reason for foam production and finding a suitable solution for Barka landfill is also important. Furthermore, extracting methane gas from treated leachate and generating electricity should be explored.

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