ZIBELINE INTERNATIONAL™ PUBLISHING

ISSN: 2523-5664 (Print)
ISSN: 2523-5672 (Online)
CODEN: WCMABD

Water Conservation & Management (WCM)

DOI: http://doi.org/10.26480/wcm.03.2025.420.423

RESEARCH ARTICLE

THE EFFECT OF PAC ADDITION ON THE PH, CONDUCTIVITY, TOTAL SOLIDS, AND TURBIDITY IN WASTEWATER (LEACHATE) AT THE TERJUN SUBDISTRICT FINAL WASTE DISPOSAL SITE, MEDAN MARELAN, NORTH SUMATRA

Sirmas Munte[a], Denny Akbar Tanjung[b*], Khairani Fitri[b], Fahma Shufyani[b], Masyithah Suhaitamy[b], Ali Affan Silalahi[c], Putra Chandra[c], Saddam Husein[c]

[a]Faculty of Engineering, Universitas Medan Area, Medan-20223, Indonesia
[b]Faculty of Pharmacy and Health Sciences, Institut Kesehatan Helvetia, Medan, Indonesia
[c]Faculty of Health Science, Universitas Haji Sumatera Utara, Medan, Indonesia
**Corresponding Author Email: dennyakbartanjung@helvetia.ac.id*

Article History:

Received 14 March 2025
Revised 02 April 2025
Accepted 24 May 2025
Available online 18 June 2025

ABSTRACT

Leachate, a hazardous liquid waste from landfills (landfills), is characterized by low pH, high turbidity, and high concentrations of dissolved solids and ions. This study evaluated the effects of various doses of Poly Aluminum Chloride (PAC) coagulant on leachate quality parameters, including pH, conductivity, total solids, and turbidity. PAC was applied at doses ranging from 0 to 1.0 g per 100 mL of leachate. The optimal dose, 0.6 g/100 mL, increased pH from 5.2 to 6.6, reduced turbidity from 680 NTU to 90 NTU, and reduced total solids from 3,200 mg/L to 1,850 mg/L. However, conductivity increased from 1,250 µS/cm to 1,800 µS/cm, indicating higher concentrations of dissolved ions. These results indicate that PAC is effective in improving leachate quality, mainly by reducing turbidity and total solids, although careful dosage selection is required to reduce the potential for dissolved ion accumulation.

KEYWORDS

Conductivity, Leachate, pH, Total Solid, Turbidity

1. INTRODUCTION

Leachate is a liquid waste produced when rainwater infiltrates through layers of solid waste in landfills, dissolving various organic and inorganic substances along the way (Qasim and Chiang, 2017). This process results in a complex mixture with diverse physical, chemical, and biological characteristics, posing a significant risk to the environment if not properly managed. The composition of leachate is influenced by factors such as landfill age, waste composition, rainfall, ambient temperature, and the effectiveness of waste management practices (Teng et al., 2021).

Leachate is generally categorized based on the stage of waste decomposition. Young leachate, typically found in newer landfills, is acidic with a pH range of 4.5 to 6.5, contains high concentrations of biodegradable organic matter (BOD/COD ratio > 0.5), and is usually dark in color. In contrast, old leachate from older, stabilized waste is neutral to alkaline (pH 7 to 9), with lower concentrations of organic compounds and more chemically stable pollutants such as heavy metals (Mukhtar et al., 2016). Regardless of age, poorly managed leachate poses a threat to groundwater and surface water through infiltration and runoff, contributing to contamination with heavy metals, pathogenic organisms, and eutrophication-related nutrients (Khrisat, 2022; Wdowczyk et al., 2024; Khrisat, 2022; Wdowczyk et al., 2024).

To address these risks, various treatment methods have been developed, among which coagulation-flocculation using chemical coagulants has been widely applied. One effective coagulant is Poly Aluminum Chloride (PAC), which offers advantages over traditional coagulants like alum due to its higher stability in solution and its efficiency in removing suspended solids (Meregildo Collave et al., 2024). PAC works by neutralizing the charges on colloidal particles, allowing them to aggregate into larger flocs that settle out of solution. However, PAC hydrolysis produces H^+ ions, which can lower the pH of the treated water, often requiring pH adjustment to maintain the optimal coagulation range of pH 6 to 7 (Anouzla et al., 2022). Additionally, PAC treatment can increase electrical conductivity due to the release of aluminum and chloride ions into solution (Bouaouine et al., 2022). While it typically reduces total suspended solids (TSS) and turbidity through effective floc formation, it may lead to higher total dissolved solids (TDS) as a result of inorganic compounds introduced during the process (Olukowi et al., 2022). Proper dosage is therefore essential to avoid side effects such as the restabilization of particles or elevated ion concentrations, both of which can compromise treatment outcomes (Cheng et al., 2021).

Several studies have confirmed the effectiveness of PAC in reducing turbidity, total solids, and organic pollutants in leachate, though optimization of both pH and PAC dosage is critical to achieving consistent and efficient treatment (Zhang et al., 2023). In Indonesia, particularly at the Terjun Final Disposal Site (TPA) in Medan Marelan, North Sumatra, open dumping practices since 1993 have resulted in the generation of

Quick Response Code	Access this article online	
	Website: www.watconman.org	**DOI:** 10.26480/wcm.03.2025.420.423

Cite The Article: Sirmas Munte, Denny Akbar Tanjung, Khairani Fitri, Fahma Shufyani, Masyithah Suhaitamy, Ali Affan Silalahi, Putra Chandra, Saddam Husein (2025). The Effect Of Pac Addition On The Ph, Conductivity, Total Solids, And Turbidity In Wastewater (Leachate) At The Terjun Subdistrict Final Waste Disposal Site, Medan Marelan, North Sumatra. Water Conservation & Management, 9(3): 420-423.

untreated leachate, which has significantly affected nearby water sources. Addressing this environmental issue requires targeted treatment strategies based on the specific characteristics of the leachate.

This study is motivated by the urgent need to develop site-specific leachate treatment strategies in Indonesia, and it innovatively evaluates the optimal dosage of Poly Aluminum Chloride (PAC) for improving multiple leachate quality parameters—pH, conductivity, total solids, and turbidity—at a landfill using open dumping practices.

2. Methodology

The Terjun landfill spans an area of approximately 3,828 m^2 and has a processing capacity tailored to accommodate the volume of leachate generated. To manage the leachate effectively, the landfill is equipped with a comprehensive Leachate Treatment System that consists of several sequential treatment stages. Initially, a leachate collection channel equipped with a piping system gathers leachate from the landfill and directs it to the treatment unit. The first stage of treatment takes place in the anaerobic pond, where the organic content of the leachate is reduced. This is followed by an aerobic pond, where oxygen levels are increased to support biological decomposition processes. The final stage is the maturation pond, which functions to stabilize water quality before the treated leachate is discharged or reused. To ensure data accuracy, samples are collected from the aeration pond, and each test is conducted in triplicate.

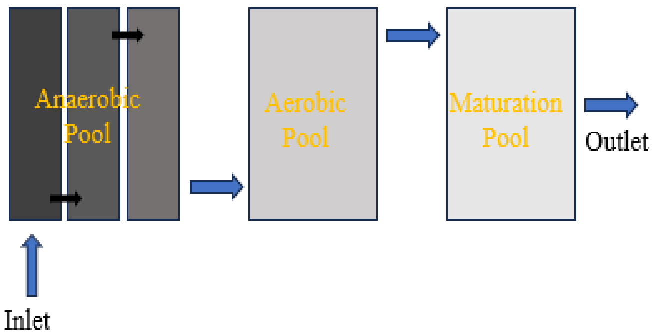

Figure 1: Leachate waste processing process

3. Results and Discussion

3.1 pH test

Poly Aluminum Chloride (PAC) is a widely used coagulant composed primarily of polymerized aluminum salts. When introduced into water, PAC undergoes hydrolysis, releasing aluminum ions (Al^{3+}) and, to a lesser extent, hydroxide ions (OH^-). One of the critical outcomes of this reaction is the production of hydrogen ions (H^+), which can lead to a decrease in pH (Ghafari et al., 2009; Ghafari et al., 2009). Consequently, the effectiveness of PAC in coagulation-flocculation processes is closely linked to pH conditions, with optimal performance typically occurring in the pH range of 6 to 7.

Figure 2 illustrates the changes in pH observed after the addition of varying PAC dosages to leachate. Initially, the untreated leachate has a pH of 5.2, indicating its acidic nature. This acidity is primarily due to the presence of degraded organic substances and metal compounds commonly found in landfill leachate. Upon the addition of 0.2 g of PAC per 100 mL of leachate, the pH increases to 5.8. This rise can be attributed to partial neutralization of H^+ ions by the OH^- ions released during PAC hydrolysis.

As the PAC dose increases to 0.4 g and 0.6 g, the pH continues to rise, reaching 6.3 and 6.6, respectively. These values fall within the optimal pH range for coagulation, suggesting that effective floc formation is occurring. At these doses, Al^{3+} ions from PAC actively destabilize negatively charged colloidal particles, enhancing aggregation and floc formation. The interaction between Al^{3+} and colloids also promotes further OH^- release, contributing to the continued increase in pH.

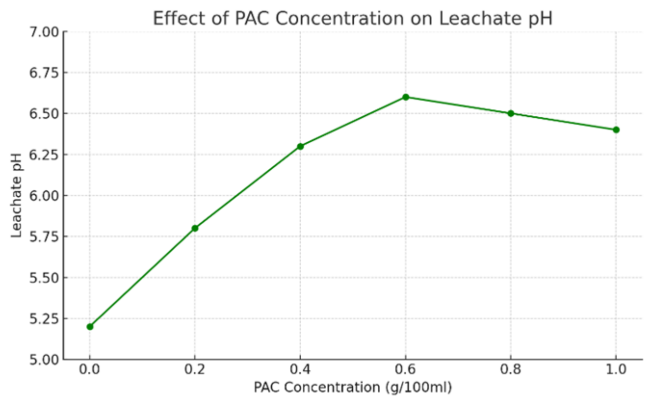

Figure 2: Effect of PAC concentration on leachate pH

Table 1: Effect of PAC Concentration on leachate pH

PAC Concentration (g/100ml)	pH
0 (control)	5,2
0,2	5,8
0,4	6,3
0,6	6,6
0,8	6,5
1,0	6,4

3.2 Conductivity test

The addition of Poly Aluminum Chloride (PAC) to leachate significantly affects its electrical conductivity due to the ionic nature of PAC. As a water-soluble coagulant, PAC dissociates into various ions, including aluminum (Al^{3+}), chloride (Cl^-), and hydrolyzed aluminum species. These ions contribute to an increase in the total dissolved solids (TDS), which in turn enhances the water's ability to conduct electricity (Shaheed et al., 2020).

As illustrated in Figure 3, electrical conductivity increases consistently with higher PAC dosages. In the untreated leachate, the baseline conductivity was 1,250 µS/cm. Upon the addition of 0.2 g of PAC per 100 mL of leachate, the conductivity rose to 1,380 µS/cm. This increase corresponds to the initial release of PAC-derived ions into the solution. With subsequent increases in PAC dosage—up to 1.0 g per 100 mL—the conductivity continued to rise, reaching a maximum of 1,800 µS/cm.

This upward trend clearly indicates that the concentration of dissolved ions grows proportionally with the PAC dose. As PAC hydrolyzes, it releases not only Al^{3+} and Cl^- ions but also forms a variety of intermediate ionic species that remain in solution. These additional ions contribute to the increased conductivity and reflect the cumulative effect of PAC dosing on the ionic strength of the leachate.

However, it is crucial to interpret this increase with caution. While conductivity serves as a useful indicator of the presence of dissolved ions, it does not directly reflect improvements in water quality. In fact, excessive conductivity may suggest an overaccumulation of salts or metal ions, which could pose environmental concerns if discharged untreated. Therefore, optimizing the PAC dosage is essential—not only to achieve effective coagulation and pollutant removal but also to avoid unintended consequences such as elevated residual ion concentrations (Shaheed et al., 2020).

In summary, the results confirm that PAC significantly increases leachate conductivity due to ion release. While this is a predictable outcome of PAC application, the findings emphasize the importance of balancing coagulant dosage to ensure both effective treatment and environmental safety.

Cite The Article: Sirmas Munte, Denny Akbar Tanjung, Khairani Fitri, Fahma Shufyani, Masyithah Suhaitamy, Ali Affan Silalahi, Putra Chandra, Saddam Husein (2025). The Effect Of Pac Addition On The Ph, Conductivity, Total Solids, And Turbidity In Wastewater (Leachate) At The Terjun Subdistrict Final Waste Disposal Site, Medan Marelan, North Sumatra. Water Conservation & Management, 9(3): 420-423.

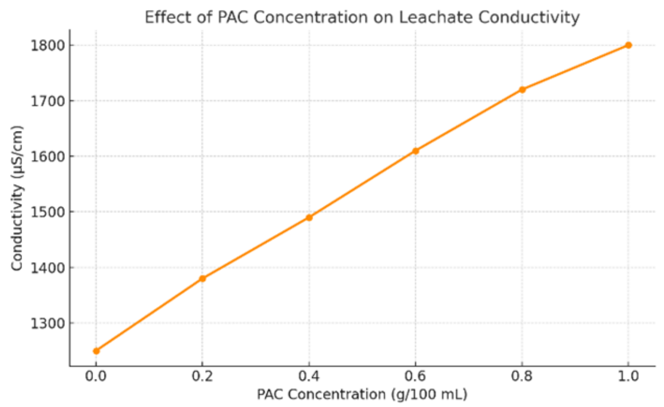

Figure 3: Effect of PAC concentration on leachate conductivity

Table 2: Effect of PAC Concentration on Leachate Conductivity	
PAC Concentration (g/100ml)	**Conductivity (µS/cm)**
0 (control)	1.250
0,2	1.380
0,4	1.490
0,6	1.610
0,8	1.720
1,0	1.800

3.3 Total Solid test

The addition of Poly Aluminum Chloride (PAC) to leachate had a notable impact on the concentration of total solids (TS), as shown in Figure 4. Total solids consist of both total suspended solids (TSS) and total dissolved solids (TDS), and their levels reflect the combined presence of particulate matter and soluble ions in the leachate. In the untreated leachate, the TS concentration was approximately 3,200 mg/L, indicating a high load of both organic and inorganic matter resulting from waste decomposition at the landfill site.

Upon the addition of 0.2 g PAC per 100 mL of leachate, the TS concentration decreased to 2,750 mg/L. This initial reduction can be attributed to the coagulation process, during which aluminum ions (Al^{3+}) from PAC neutralize the surface charge of colloidal particles. This destabilization facilitates the formation of flocs, which settle out of the solution, thereby reducing the TSS component.

As the PAC dose was increased to 0.4 g and 0.6 g, the TS values further decreased to 2,200 mg/L and 1,850 mg/L, respectively. These results suggest that this dosage range is optimal for the removal of suspended solids, as the formation and settling of flocs is most effective at these concentrations. The significant reduction in TS indicates efficient clarification and reflects the successful removal of particulate matter.

However, at higher PAC dosages (0.8 g and 1.0 g), the TS values slightly increased to 1,900 mg/L and 2,050 mg/L, respectively. This trend reversal is likely due to the excess PAC dissolving completely into the solution, contributing to an increase in the TDS component. When the dosage exceeds the optimal range, unreacted coagulant compounds-particularly aluminum and chloride ions—remain in the solution and increase the concentration of dissolved solids (Ahmad et al., 2006).

Therefore, while PAC is effective in reducing total solids through TSS removal, the overall TS concentration can rise again if overdosing occurs, primarily due to the increase in TDS. These findings highlight the importance of optimizing PAC dosage to balance effective removal of suspended particles while minimizing the residual dissolved ion content in the treated leachate.

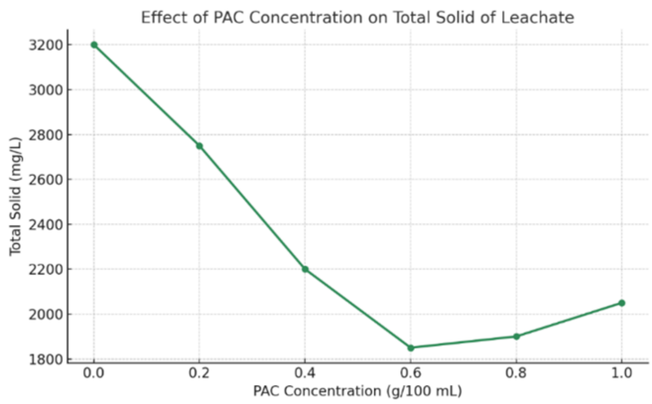

Figure 4: Effect of PAC Concentration on Total Solids of Leachate

Table 3: Effect of PAC Concentration on Total Leachate Solids	
Concentration PAC (g/100ml)	**TSS (mg/L)**
0 (control)	3200
0,2	2750
0,4	2200
0,6	1850
0,8	1900
1,0	2050

3.4 Turbidity test

The application of Poly Aluminum Chloride (PAC) was found to be highly effective in reducing the turbidity of leachate from the Terjun Village Landfill in Medan Marelan (Figure 5). Turbidity is a critical water quality parameter, reflecting the presence of suspended particles, colloids, and fine organic matter resulting from waste decomposition. In the untreated leachate, turbidity was initially measured at 680 NTU, indicating a high load of particulate impurities.

Upon the addition of 0.2 g of PAC per 100 mL of leachate, the turbidity decreased significantly to 420 NTU (Table 4). This reduction can be attributed to the initiation of the coagulation-flocculation process, where positively charged aluminum ions (Al^{3+}) neutralize the surface charges of negatively charged particles, allowing them to aggregate into flocs that settle more readily.

As the PAC dosage increased to 0.4 g and 0.6 g, turbidity continued to decline, reaching 210 NTU and 90 NTU, respectively. The lowest turbidity value of 90 NTU at 0.6 g represents the point of optimal coagulation efficiency. At this dosage, PAC successfully binds a large proportion of the suspended solids into dense flocs, leading to effective removal from the liquid phase (Darnoto and Astuti , 2009).

However, when the PAC dosage was increased beyond this optimum—to 0.8 g and 1.0 g—turbidity rose slightly to 100 NTU and 130 NTU, respectively. This reversal in trend is likely due to the destabilization of previously formed flocs. Overdosing PAC can introduce excess positive charge into the system, which may restabilize the colloids or produce fragile flocs that disintegrate easily under mild agitation. As a result, instead of being removed, smaller particles may remain suspended, increasing turbidity.

These findings align with previous studies indicating that while PAC is effective in reducing turbidity through charge neutralization and floc formation, its dosage must be carefully optimized. Excessive coagulant can hinder the treatment process by disrupting the stability of formed flocs and allowing fine particles to remain in suspension (Balbinoti et al., 2024).

The data suggest that a PAC dosage of 0.6 g/100 mL offers the most effective reduction in turbidity. Beyond this dosage, the benefits diminish due to potential re-dispersion effects. This underscores the importance of dosage optimization in coagulation-based treatment of landfill leachate to achieve maximum water clarity.

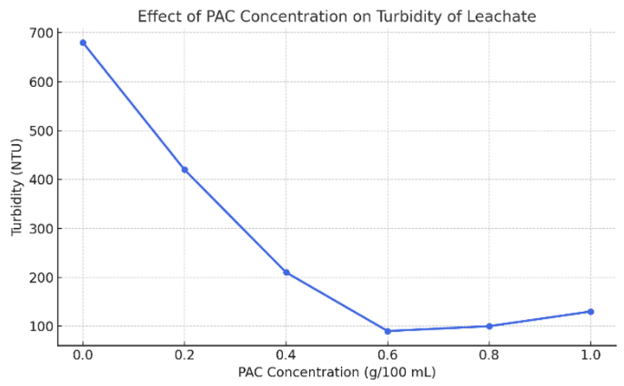

Figure 5: Effect of PAC Concentration on Total Solids of Leachate

Table 4: Effect of PAC Concentration on Total Leachate Solids

Concentration PAC g/100ml	Turbidity (NTU)
0 (control)	680
0,2	420
0,4	210
0,6	90
0,8	100
1,0	130

4. Conclusion

The application of Poly Aluminum Chloride (PAC) as a coagulant significantly improves the quality of leachate from the Terjun Village Landfill in Medan Marelan. At the optimal dose of 0.6 g/100 mL, PAC effectively increases pH from 5.2 to 6.6, reduces turbidity from 680 NTU to 90 NTU, and lowers total solids from 3,200 mg/L to 1,850 mg/L. However, this treatment also leads to a rise in electrical conductivity from 1,250 µS/cm to 1,800 µS/cm due to the increase in dissolved ions. These findings highlight that while PAC is efficient in stabilizing pH and removing suspended solids and turbidity, careful dosage control is essential to minimize the unintended consequence of elevated conductivity. This study underscores the importance of optimizing PAC dosage to achieve effective leachate treatment outcomes.

Acknowledgment

The authors express gratitude to the manager of the Terjun Sub-district Final Waste Disposal Site in Medan Marelan, North Sumatra, for permitting our research.

References

Ahmad, A. L., Sumathi, S., and Hameed, B. H., 2006. Coagulation of residue oil and suspended solid in palm oil mill effluent by chitosan, alum and PAC. Chemical Engineering Journal, 118(1–2), Pp. 99–105. https://doi.org/10.1016/j.cej.2006.02.001

Anouzla, A., Kastali, M., Azoulay, K., Bencheikh, I., Fattah, G., Mabrouki, J., Elhassani, C. E., Ouadil, B., El Moustaqim, K., Bakkouche, C., Moussadik, A., Mouhir, L., Digua, K., Souabi, S., Khaoulaf, R., El Hajjaji, S., Loukili, H., Saffaj, N., Azrour, M., and Abrouki, Y., 2022. Multi-response optimization of coagulation–flocculation process for stabilized landfill leachate treatment using a coagulant based on an industrial effluent. Desalination and Water Treatment, 254, Pp. 71–79. https://doi.org/10.5004/dwt.2022.28388

Balbinoti, J. R., Jorge, R. M. M., Junior, R. E. dos S., Balbinoti, T. C. V., Coral, L. A. de A., and de Jesus Bassetti, F., 2024. Treatment of low-turbidity water by coagulation combining Moringa oleifera Lam and polyaluminium chloride (PAC). Journal of Environmental Chemical Engineering, 12(1), Pp. 111624. https://doi.org/10.1016/j.jece.2023.111624

Bouaouine, O., Ihsanne, B., Delmon, C., Louvet, F., and Khalil, F., 2022. Optimization of coagulation–flocculation process conditions using the central composite design for pretreatment of Moroccan landfill leachate. Desalination and Water Treatment, 257, Pp. 150–157. https://doi.org/10.5004/dwt.2022.28588

Cheng, S. Y., Show, P.-L., Juan, J. C., Chang, J.-S., Lau, B. F., Lai, S. H., Ng, E. P., Yian, H. C., and Ling, T. C., 2021. Landfill leachate wastewater treatment to facilitate resource recovery by a coagulation-flocculation process via hydrogen bond. Chemosphere, 262, Pp. 127829. https://doi.org/10.1016/j.chemosphere.2020.127829

Darnoto S dan Astuti D., 2009. Pengaruh Penambahan Poly Aluminium Chloride (Pac)Terhadap Tingkat Kekeruhan, Warna, Dan TotalSuspended Solid (Tss) Pada Leachate (Air Lindi) Di TpasPutri Cempo Mojosongo Surakarta. Jurnal Kesehatan, 2(2), Pp. 179–184.

Ghafari, S., Aziz, H. A., Isa, M. H., and Zinatizadeh, A. A., 2009. Application of response surface methodology (RSM) to optimize coagulation–flocculation treatment of leachate using poly-aluminum chloride (PAC) and alum. Journal of Hazardous Materials, 163(2–3), Pp. 650–656. https://doi.org/10.1016/j.jhazmat.2008.07.090

Grathwohl, P., and Susset, B., 2009. Comparison of percolation to batch and sequential leaching tests: Theory and data. Waste Management, 29(10), Pp. 2681–2688. https://doi.org/10.1016/j.wasman.2009.05.016

Ifriani, N., 2020. Keefektifan Poly Aluminium Chloride (Pac) Dalam Menurunkan Kadar Biological Oxygen Demand (Bod) Limbah Cair Rumah Makan. Occupational Medicine, 53(4), Pp. 130.

Khrisat, H. T., 2022. Optimization of Integrated Solid Waste Management Improvement Scenarios for Salt City in Jordan Using Computer-Based Decision Support Tool. OALib, 09(06), Pp. 1–15. https://doi.org/10.4236/oalib.1108900

Meregildo Collave, C. X., Lázaro Bacilio, R. J., Guerrero Escobedo, A. E., Rodriguez Espinoza, R. F., Azabache Liza, Y. F., and Ipanaqué Roña, J. M., 2024. Turbidity and color removal from irrigation water, with coagulants and activated carbon, controlled by an Arduino system. Case Studies in Chemical and Environmental Engineering, 10, 100978. https://doi.org/10.1016/j.cscee.2024.100978

Mukhtar, S., Wafa, W., Halimzai, H., and Shams, A. K., 2016. Planning for the Solid Waste Management of Central Park in New Capital Development of Afghanistan. Journal of Environmental Protection, 07(06), 805–815. https://doi.org/10.4236/jep.2016.76073

Olukowi, O. M., Xie, Y., Zhou, Z., Adebayo, I. O., and Zhang, Y., 2022. Performance improvement and mechanism of composite PAC/PDMDAAC coagulant via enhanced coagulation coupled with rapid sand filtration in the treatment of micro-polluted surface water. Journal of Environmental Chemical Engineering, 10(5), Pp. 108450. https://doi.org/10.1016/j.jece.2022.108450

Qasim, S. R., and Chiang, W., 2017. Sanitary Landfill Leachate. Routledge. https://doi.org/10.1201/9780203740217

Shaheed, H., Mohamed, R., Al-Sahari, M., Mohd-Zind, N. S., Al-Gheethi, A., and Alomari, T., 2020. Coagulation and flocculation of printing ink effluent using polyaluminium chloride (PAC): optimization and phytotoxicity study. Desalination and Water Treatment, 208, Pp. 303–311. https://doi.org/10.5004/dwt.2020.26408

Teng, C., Zhou, K., Peng, C., and Chen, W., 2021. Characterization and treatment of landfill leachate: A review. Water Research, 203, 117525. https://doi.org/10.1016/j.watres.2021.117525

Wdowczyk, A., Szymańska–Pulikowska, A., and Gupta, A., 2024. Application of selected indicators to assess contamination of municipal landfill leachate and its impact on groundwater. Water Resources and Industry, 32, 100265. https://doi.org/10.1016/j.wri.2024.100265

Zhang, L., Liu, X., Zhang, M., Wang, T., Tang, H., and Jia, Y., 2023. The effect of pH/PAC on the coagulation of anionic surfactant wastewater generated in the cosmetic production. Journal of Environmental Chemical Engineering, 11(2), 109312. https://doi.org/10.1016/j.jece.2023.109312