Xi'an Shiyou Daxue Xuebao (Ziran Kexue Ban)/
Journal of Xi'an Shiyou University, Natural Sciences Edition
ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 68 Issue 08 | 2025
DOI: 10.5281/zenodo.16900308

COMPARISON AND PHYSICO-CHEMICAL CHARACTERIZATION OF WASTEWATER FROM Quaid-e-Azam INDUSTRIAL ESTATE, LAHORE PAKISTAN

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Abstract

This investigation undertook a comprehensive physicochemical characterization of wastewater effluents originating from the Quaid-e-Azam Industrial Estate, Lahore, using random sampling method. A broad spectrum of water quality indicators was systematically analysed in accordance with standardized analytical protocols prescribed by international environmental quality assurance guidelines. These parameters included total dissolved solids (TDS), total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), electrical conductivity (EC), total Kjeldahl nitrogen (TKN), total hardness (calcium and magnesium), turbidity, sulfate concentrations, and trace heavy metals including cadmium, chromium, copper, lead, nickel, silver, and iron. Quantitative results revealed alarming exceedances from permissible thresholds as delineated by the World Health Organization (WHO) and Pakistan's National Environmental Quality Standards (NEQS). Specifically, the concentration ranges exceeding threshold levels were: BOD (142.12–247.52 mg/L), COD (209–364 mg/L), turbidity (110.43–260 NTU), TSS (1143–1305 mg/L), TKN (40–350 mg/L), EC (17.82–2534 µS/cm), and Cadmium (0.43–0.83 mg/L). Additionally, the levels of Calcium and Magnesium hardness also transcended regulatory limits, indicating substantial ionic contamination and water hardness. Statistical correlation analysis underscored significant positive associations between several parameters, indicating possible co-emission or similar origin sources like: BOD-COD (r = 0.94), TSS-SO_4^{-2} (r = 0.91), TDS-EC (r = 0.85), Ca hardness- SO_4^{-2} (r = 0.82), TKN-Cd (r = 0.93), TKN-Ni (r = 0.84), Cr-Ag (r = 0.76), and Ni-Cr (r = 0.78). These interrelationships suggest complex pollutant interactions and potential synergistic impacts on aquatic ecosystems. This research contributes substantively to the existing body of knowledge regarding anthropogenic impacts on urban water bodies in Lahore and serves as a foundation for evidence-based policy formulation and environmental remediation strategies.

Keywords: Wastewater Effluents, Physicochemical Characterization**,** Water Quality Parameters**,** Heavy Metal Contaminationn, Industrial Pollution.

INTRODUCTION

Industrialization plays a pivotal role in economic growth, but it often comes at a significant environmental cost—particularly in the form of industrial wastewater. In developing countries like Pakistan, where environmental regulations are inconsistently enforced,

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untreated or poorly treated industrial effluents are a growing threat. This is especially evident in major industrial zones like Lahore, where rapid urban and industrial expansion has placed enormous pressure on the region's natural water resources.

Lahore, the second-largest city in Pakistan, houses a wide variety of industries including textiles, chemicals, pharmaceuticals, and food processing. These sectors contribute extensively to the local economy but also generate large volumes of wastewater. This wastewater frequently contains harmful substances such as heavy metals, hydrocarbons, persistent organic pollutants (POPs), and other toxic chemicals (Al-Mudhaf *et al* 2009). Without adequate treatment, these contaminants are discharged into water bodies or used for irrigation, leading to severe consequences for water quality, soil fertility, food safety, and public health (Haydar *et al*., 2016).

The intensity of the situation is enhanced by health issues such as hepatitis, cancer, skin diseases, and gastrointestinal disorders among populations exposed to contaminated water (Borges *et al*., 2010). Studies have indicated that around 800 to 1000 hectares of land in Lahore are irrigated with untreated effluent, directly impacting both agricultural output and human well-being. The bioaccumulation and biomagnification of pollutants like POPs further aggravate the problem, as these chemicals persist in the environment and accumulate in the food chain, leading to long-term ecological and health hazards.

Despite the known dangers, Lahore lacks a centralized wastewater treatment infrastructure for many of its industrial estates, including the Quaid-e-Azam Industrial Estate (QIE). As a result, individual factories either discharge wastewater directly into the environment or rely on makeshift, ineffective treatment systems. The QIE, home to a diverse mix of industries, exemplifies this issue, where wastewater laden with hazardous substances continues to flow unchecked into surrounding ecosystems (Al- Mudhaf *et al.*, 2009).

The issue of industrial pollution is not confined to Lahore alone—it affects nearly all major cities in Pakistan including Karachi, Faisalabad, Sheikhupura, Multan, and Islamabad. However, Lahore's dense population and the diversity of industries amplify the risks. The textile industry, one of the dominant sectors, is particularly water- and chemical-intensive, using up to 400 liters of water per kilogram of fabric. Without effective wastewater treatment, the effluent from such industries contributes significantly to environmental degradation and poses risks to both surface and groundwater sources.

While general awareness exists regarding the environmental impact of industrial wastewater, there is a significant lack of localized, data-driven research focused on specific industrial estates like the QIE. Most existing studies provide a broad overview of the national or regional picture, leaving a critical gap in understanding the specific composition, volume, and ecological impact of effluents from QIE. Moreover, policy and regulatory frameworks often lack the empirical foundation needed to devise targeted and effective mitigation strategies. This study aims to fill that gap by providing a detailed physico-chemical analysis of wastewater samples from the Quaid-e-Azam Industrial

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Estate. Through this localized approach, the research seeks to inform future policies, improve regulatory oversight, and propose sustainable solutions for industrial wastewater management in Lahore. By addressing both the scientific and policy dimensions of the problem, the study aspires to support environmentally responsible industrial growth and safeguard public health.

MATERIAL AND METHODS

Plan of work

This research work was conducted in the chemistry laboratory of the Faculty of Science and Technology at University of Central Punjab (UCP), Lahore. This Study was completed between March, 2024 and May, 2025.

Study Design

It is a descriptive and cross- sectional study.

Sample Preparation

For the characterization of industrial effluents, five samples were collected from an unlined industrial drain (ID) that received combined wastewater discharges from various industries (Figure 1). The samples were taken at two-hour intervals using plastic bottles that had been cleaned with 1M nitric acid (HNO_3). Immediately after collection, the bottles were placed in an icebox to preserve the samples and were transported to the laboratory. In the laboratory, the wastewater from each bottle was divided into five smaller bottles and was stored in a refrigerator at 4°C for further analysis (Almeida *et al*., 2000). These composite samples were collected from the drain providing combined waste water from textile, paper, pharmaceutical, fertilizer and construction industries.

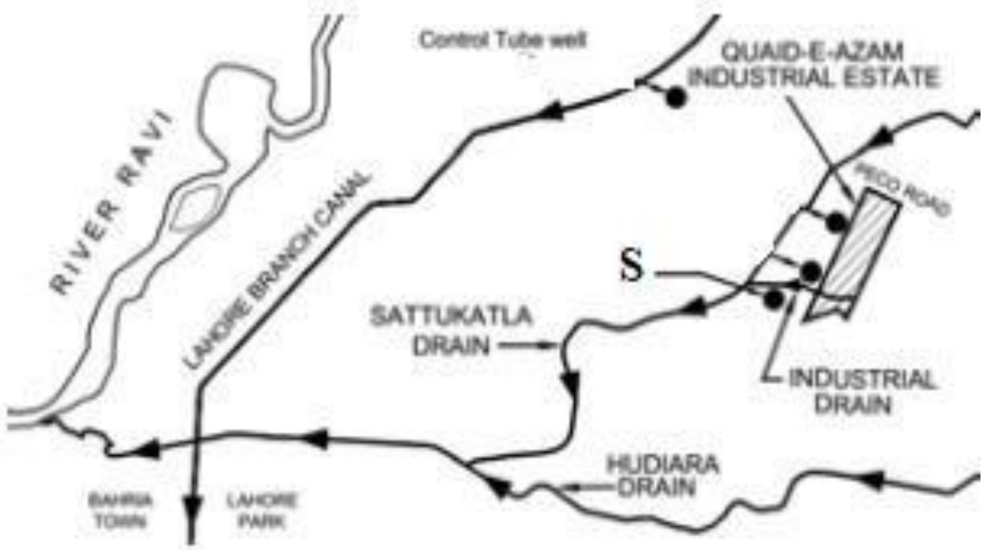

Figure 1: Location map of Quaid-e-Azam Industrial Estate

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Determination of Biochemical Oxygen Demond

The procedure involved preparing an oxygen- and nutrient-rich dilution media with a controlled pH (8–9) and aerating it. BOD bottles were filled with different concentrations of wastewater and sealed to avoid air bubbles. Initial DO levels were measured using a titration method involving $MnSO_4$, alkali azide iodide, sulfuric acid, starch, and sodium thiosulfate. After incubating the samples for seven days, final DO levels were measured, and BOD was calculated based on DO depletion (Nomngongo *et al*.,2012).

Determination of Chemical Oxygen Demond

To measure COD, a 50 mL water sample was treated with silver to remove chlorides and refluxed for two hours with a sulfuric acid–potassium dichromate oxidizing mixture. After cooling and dilution, ferroin indicator was added, and the solution was titrated with ferrous ammonium sulfate (FAS) to a red-brown endpoint, alongside a reagent blank for accuracy. COD was calculated using a standard formula. For total solids, a 50 mL sample was evaporated in a pre-weighed china dish, oven-dried, cooled in a desiccator, and reweighed to determine solid contents (Wang *et al*., 2021).

Estimation of Total Dissolved Solids

A 100 mL sample was filtered using pre-weighed Whatman filter paper, and 50 mL of the filtrate was used to measure total dissolved solids (TDS). The filtrate residue was dried in an oven at 103°C, cooled in a desiccator, and reweighed. TDS was calculated using the weight difference and sample volume (Rusydi *et al*., 2018).

Estimation of Total Suspended Solids

To measure Total Suspended Solids (TSS), a pre-dried and weighed Whatman No. 41 filter paper was used to filter 50–100 mL of the industrial water sample. The suspended solids collected were washed with distilled water, then dried in an oven at 103–105°C until a constant weight was reached. After cooling in a desiccator, the filter paper was reweighed, and TSS was calculated from the difference in weight and sample volume (Khan *et al*., 2021).

Determination of Total Kjeldahl Nitrogen

To determine Total Kjeldahl Nitrogen (TKN), 40 mL of sewage water was digested with concentrated sulfuric acid and a $CuSO_4$–K_2SO_4 catalyst, then diluted and heated to convert organic nitrogen into ammonium sulfate. The sample was made basic with a hydroxide-thiosulfate mixture and distilled, collecting ammonia in boric acid with indicators. The resulting solution was titrated with 0.02 N sulfuric acid, and TKN was calculated using a standard formula based on titrant volume (Hicks *et al.,* 2022).

Determination of Turbidity

To prepare turbidity standards, hydrazine sulfate and hexamethylenetetramine solutions were made and combined to form a 4000 NTU stock solution, which was diluted using the $N_1V_1 = N_2V_2$ formula to prepare lower NTU standards like 200 NTU. A digital turbidity

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meter was calibrated using 0 NTU and 400 NTU reference solutions. Wastewater sample turbidity was then measured, with values recorded based on light scattering intensity using a standard formula (Henze *et al.,*2007).

Determination of Hardness & Sulphate ions

To estimate water hardness, 50 mL of the sample was titrated with 0.01M EDTA using ammonia buffer and Eriochrome Black T for total hardness, and NaOH buffer with Eriochrome Blue Black R for calcium hardness. Magnesium hardness was calculated by subtracting calcium hardness from total hardness. For sulfate estimation, standard and unknown samples were reacted with barium chloride to form turbidity, which was measured using a turbidity meter. A calibration curve was used to determine sulfate concentration based on turbidity values (Vanrolleghem et al., 2003).

Determination of pH & Electrical Conductivity

A 100 mL sample was settled at room temperature for electrical conductivity assessment. The conductivity meter was calibrated with potassium chloride (KCl) solutions. Both the sample and probe were cleaned with deionized water to avoid contamination. The probe was fully submerged without touching the container sides, and conductivity was measured. Temperature corrections were applied, and results were normalized to 25°C, reported in µS/cm (Singare et al., 2010).

The pH meter (Hanna, H12211) was calibrated using a standard buffer solution. Before each measurement, the electrode was rinsed with distilled water. The electrode was immersed in the sample, and the pH reading was recorded once stabilized. (Vanrolleghem et al., 2003).

Heavy Metals Estimation

To measure heavy metals, 100 mL of the sample was acidified with concentrated nitric acid (HNO_3), filtered through pre-weighed fiber filter paper, and digested with HNO_3 and, if needed, perchloric acid ($HClO_4$).

The mixture was heated to reduce the volume to ~25 mL, then diluted to 50 mL with deionized water after cooling. A spectrophotometer was calibrated using reference metal solutions, and absorbance was measured at the specific wavelength for each target metal. Heavy metal concentrations were determined using a calibration curve and reported in mg/L (Sasamal *et al.,* 2007).

RESULTS & DISCUSSION

This study produced a number of noticeable results, especially in relation to industrial effluents that were found to be above the allowable limits established by regulatory organizations such as the World Health Organization (WHO) and the National Environmental Quality Standards (NEQS).

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Results of the findings are shown in table 1 which depicted that the thermal pollution was not a significant problem in the study area, as evidenced by the combined effluent's average temperature of 27°C to 29°C & far below then the NEQS limit of 40°C. The effluent's pH ranged from 7.45 to 8.78, which was within the recommended NEQS range, indicating that aquatic life was not seriously endangered by the wastewater's acidity or alkalinity (Sasamal *et al.,*2007).

The NEQS limit of 80 mg/L was greatly compromised in case of BOD, which ranged from 142.12 to 247.52 mg/L. Excessive organic matter in the water is indicated by high BOD levels, which can lower oxygen levels in aquatic systems (Kumar *et al*.,2019). Similarly, the Chemical Oxygen Demand (COD) exceeded the NEQS criterion of 150 mg/L and ranged from 209 to 364 mg/L, underscoring the effect of industrial effluents on water quality.

The study's turbidity levels ranged from 110.43 to 260 NTU, which is higher than the WHO recommended threshold of 5 NTU. Reduced light penetration in water bodies due to elevated turbidity can impact aquatic life and photosynthesis (Khan *et al*., 2021). The Total Kjeldahl Nitrogen (TKN) readings were above the 10 mg/L IFC guideline limit and ranged from 40 to 350 mg/L (*Fig.2*). Nutrient contamination is a result of high TKN concentrations, which are associated with nitrogen-rich organic molecules (Singh *et al*., 2020).

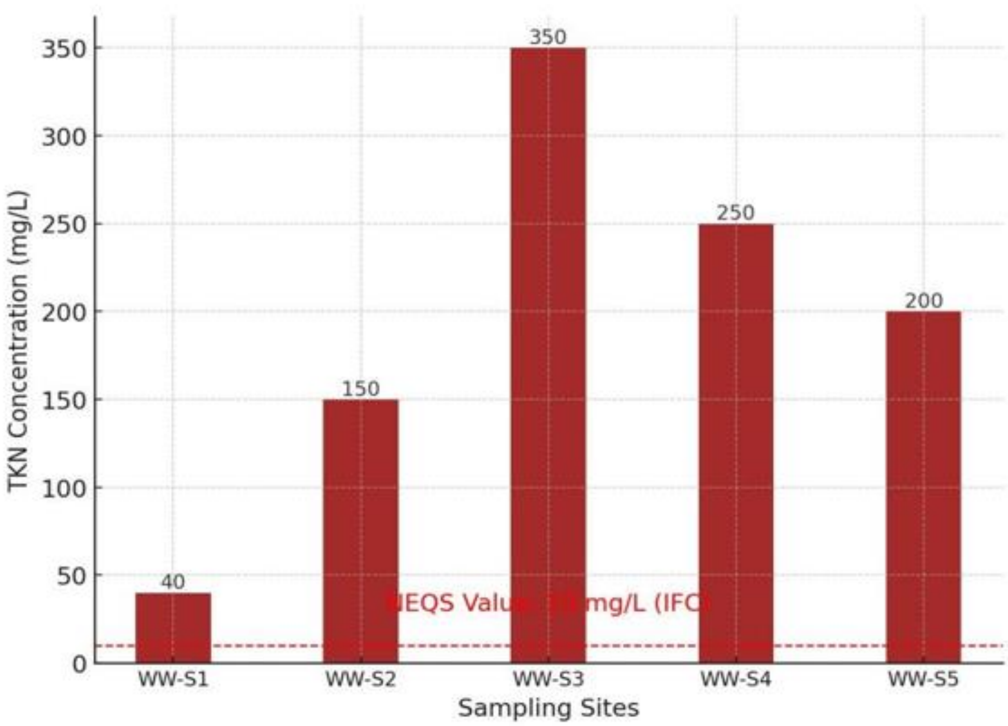

Figure 2: TKN of industrial wastewater samples

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Table 1: Physico-chemical characteristics of water at different sampling sites

Sampling Sites	Temperature (°C)	pH	Biochemical Oxygen Demand (mg/L)	Chemical Oxygen demand (mg/L)	Electrical Conductivity (µS/cm)	Total Dissolved Solids (mg/L)	Total Suspended Solids (mg/L)	Sulphates (mg/L)	Turbidity (NTU)
WW-S1	28±1.01	7.45±0.01	142.12±1.06	209±1.12	2067±0.82	1377±0.82	1223±0.81	88.14±1.07	110.43±1.22
WW-S2	29±1.03	8.20±0.02	247.52±1.27	364±1.00	2534±0.82	1688±0.72	1305±0.47	243.16±1.08	260±1.00
WW-S3	28±1.04	8.78±0.01	159.12±1.06	234±1.02	2433±1.25	1621±0.32	1258±0.81	156.53±1.27	156.85±1.44
WW-S4	28±1.01	8.0AA8±0.02	243.54±1.28	354±1.05	2474±0.82	1829±0.81	1143±1.70	90.60±1.31	159±1.00
WW-S5	27±1.11	7.49±0.03	1271±0.81	324±1.06	17.82±0.08	1186±0.52	1271±0.81	239.16±1.08	163±1.00

Both calcium (76–108.5 mg/L) and magnesium (107–122 mg/L) hardness levels were higher than the WHO- recommended limits of 75 mg/L and 50 mg/L, respectively (*Fig.*3&4), which are harmful to aquatic life and human health (Ghosh *et al.*, 2022)

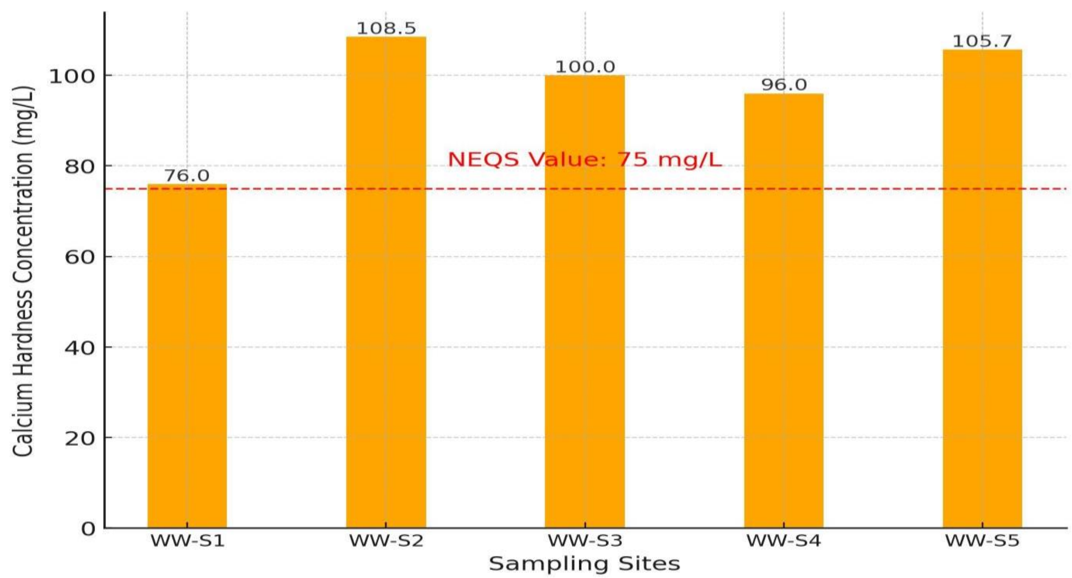

Figure 3: Ca-Hardness of wastewater samples

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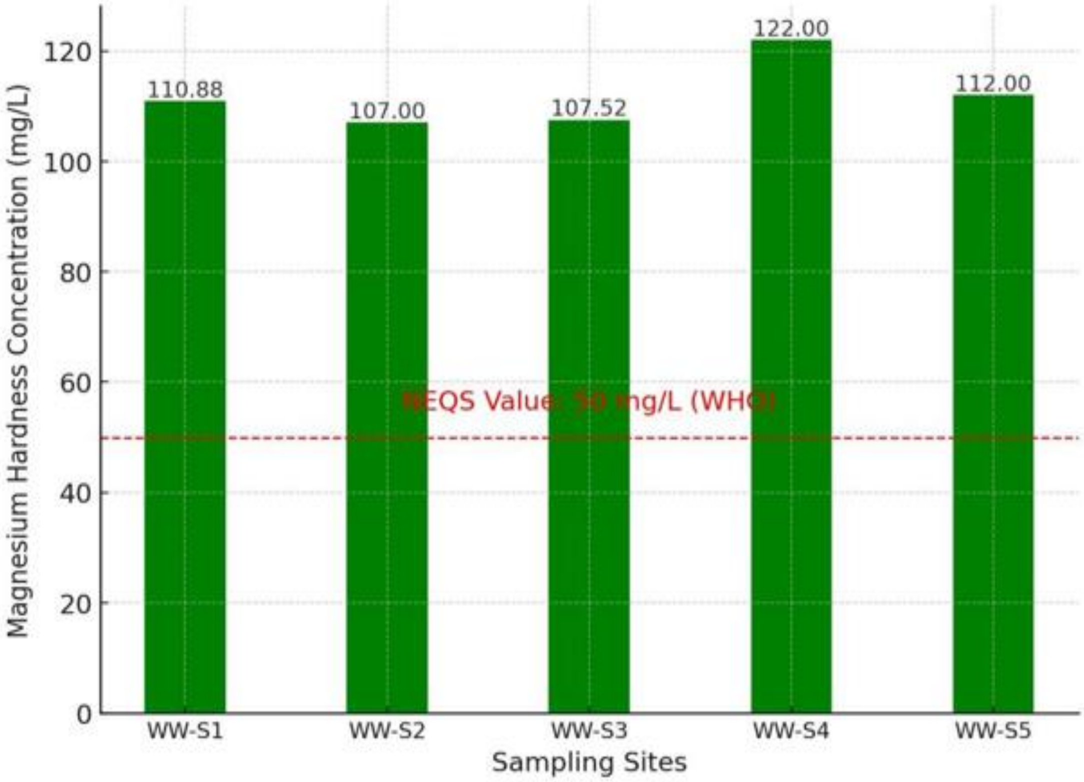

Figure 4: Mg-Hardness of industrial wastewater samples

Electrical conductivity (EC) values ranged from 17.82 to 2534 µS/cm (Table 1), which is significantly higher than the 400 µS/cm WHO acceptable limit. Elevated EC values frequently signify the existence of dissolved salts and ions from industrial processes, an issue also mentioned by Gupta *et al*., in 2017.

Total Dissolved Solids (TDS) was not a significant problem in the study region, as evidenced by the fact that it fluctuated between 1186 and 1829 mg/L, staying far below than the NEQS limit of 3500 mg/L.

The NEQS standard of 150 mg/L was very low for Total Suspended Solids (TSS) which ranged from 1143 to 1305 mg/L in waste water samples. This could affect the water quality and clog the gills of aquatic organisms (Mollah *et al*., 2017).

Concentrations of sulphate ranged from 88.14 to 243.16 mg/L, all under the NEQS limits (Gupta *et al.,*2017), however, the amount of a heavy metal i.e Cadmium (Cd) varied. Cd concentration in the waste water samples ranged between 0.43 to 0.83 mg/L (*Fig.*5): excessive than the NEQS limit of 0.1 mg/L.

The elevated Cd concentration likely resulted from industrial discharges, especially from electroplating, battery manufacturing, or pigment industries. Inadequate wastewater treatment or illegal dumping could further contribute to the excess levels.

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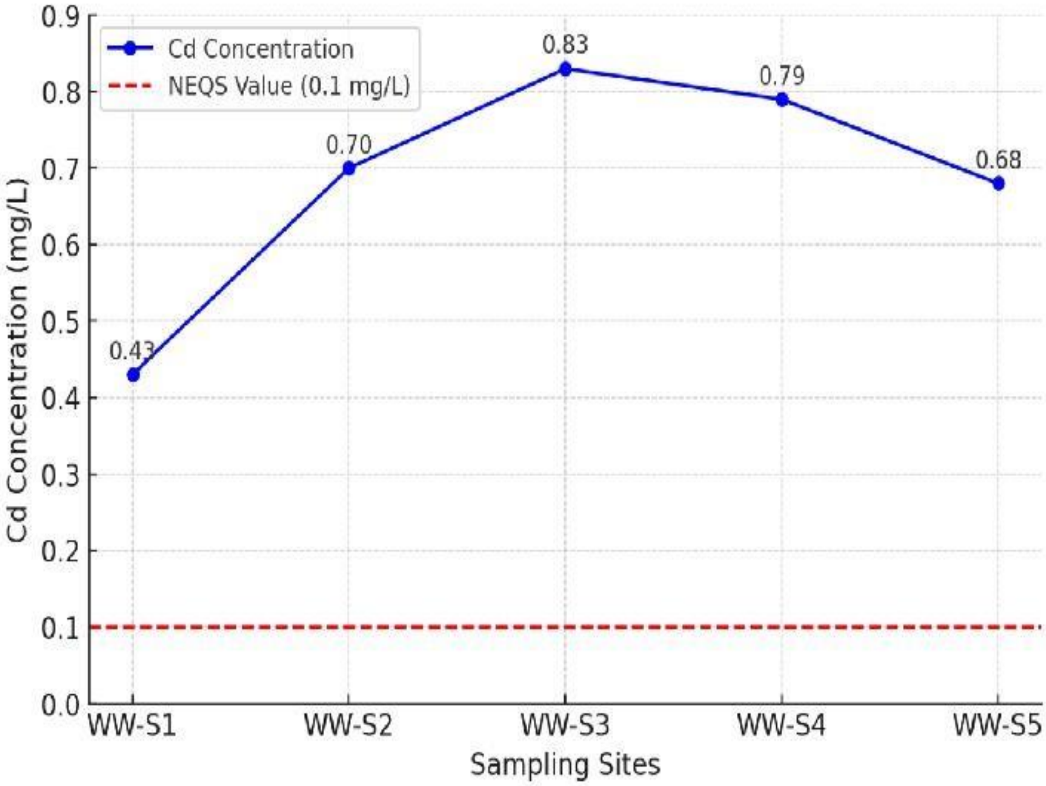

Figure 5: Cd concentration in the waste water samples

While remaining were within the NEQS limit (1 mg/L), This implies that there was not a substantial immediate risk to aquatic ecosystems or human health due to the comparatively low level of heavy metals contamination in the effluent. The results of the correlation analysis provided valuable insights into the interrelationships between various water quality parameters of industrial wastewater.

A very strong positive correlation (r=0.94926) was observed between BOD and COD (*Fig.*6), suggesting that higher biochemical oxygen demand (BOD) is associated with higher chemical oxygen demand (COD), indicating that industrial effluents in this study contain a significant proportion of organic matter which consumes oxygen during microbial decomposition (Rahman *et al.,* 2018). Total Suspended Solids (TSS) showed a very strong positive correlation with Magnesium (Mg) (r=0.90963), which indicates that higher TSS concentrations are closely associated with higher levels of Magnesium (Khan *et al*., 2021).

Additionally, TSS also exhibited a very strong positive correlation with Sulphate (r=0.9177) (*Fig.*7), suggesting that suspended solids in industrial wastewater often serve as carriers for sulfate ions (Gupta *et al*.,2017). TDS had a very strong positive relation with Electrical Conductivity (r=0.856296) (*Fig.*8), indicating that higher concentrations of dissolved ions in wastewater contribute to its electrical conductivity (Rahman *et al.,* 2018).

It suggests that dissolved salts and ions, such as sodium, chloride, and sulfates, significantly increase conductivity. These ions often originate from industrial effluents, detergents, and urban runoff.

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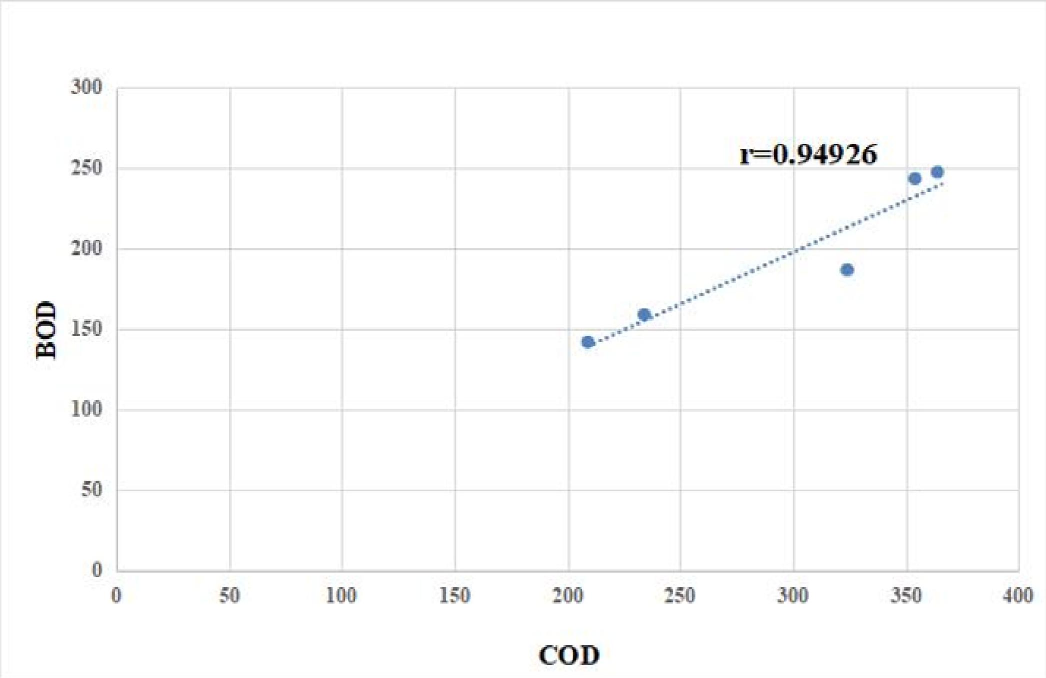

Figure 6: Correlation between BOD & COD

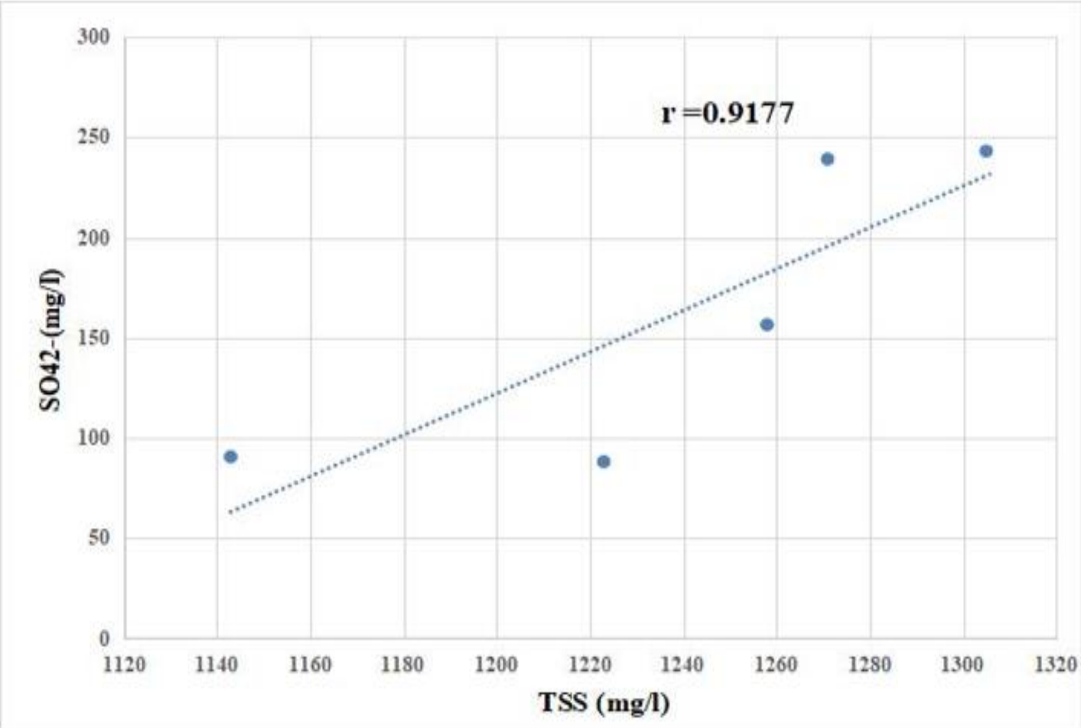

Figure 7: Correlation between TSS (mg/l) & SO_4^{2-} (mg/l)

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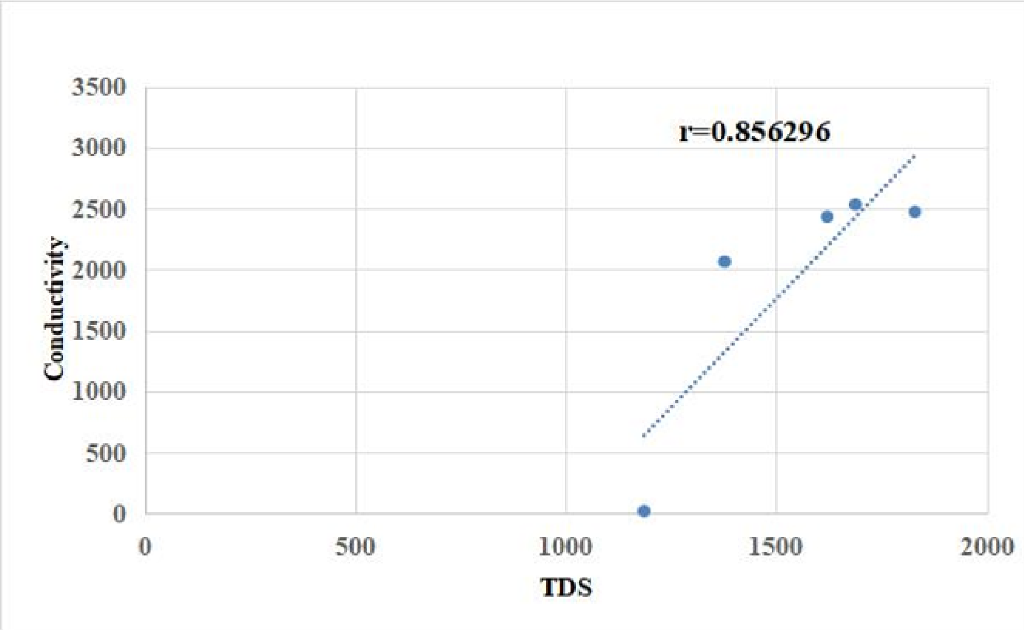

Figure 8: Correlation between Conductivity & TDS

TSS also showed a very strong positive correlation with Iron (r=0.85049), indicating that iron particles are frequently present in suspended solids.

A very strong negative correlation was found between COD and Chromium (Cr) (r=-0.81831), indicating that higher concentrations of Chromium are associated with lower COD values, possibly due to Chromium inhibiting the biodegradability of organic matter (Sharma *et al.*,2018). Calcium hardness and Sulphates also exhibited a very strong positive correlation (r=0.822435) (*Fig.*9), implying that high levels of calcium salts often coincide with elevated sulphate concentrations (Ghosh *et al.*,2022).

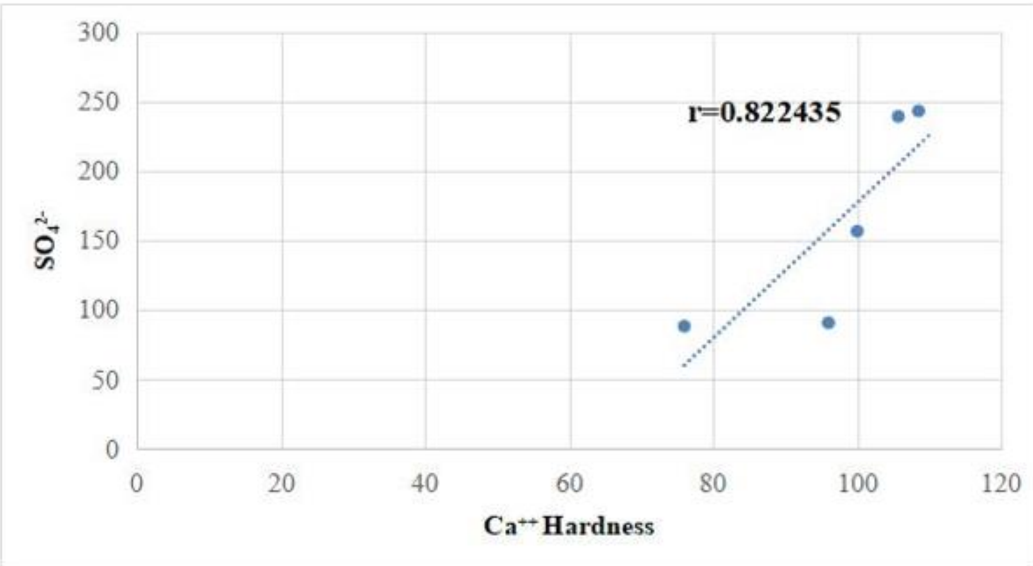

Figure 9: Correlation between Ca^{++} Hardness (mg/l) & $SO4^{2-}$

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TKN showed a very strong positive relationship with Cd (r=0.933033) and Ni (r=0.848081) (*Fig.*10), suggesting that these heavy metals are often present in nitrogenous industrial effluents (Singh *et al*.,2020). Nickel had a strong positive correlation with Chromium (r=0.780372) (*Fig.*11), indicating that these two metals often co-occur in wastewater from electroplating and metal finishing industries (Kumar *et al*., 2019). Chromium also exhibited a strong positive correlation with Ag (0.763138) (*Fig.*11), suggesting that Chromium and Silver may be co-released from industrial processes, particularly in electroplating industries (Ahmed *et al*.,2021).

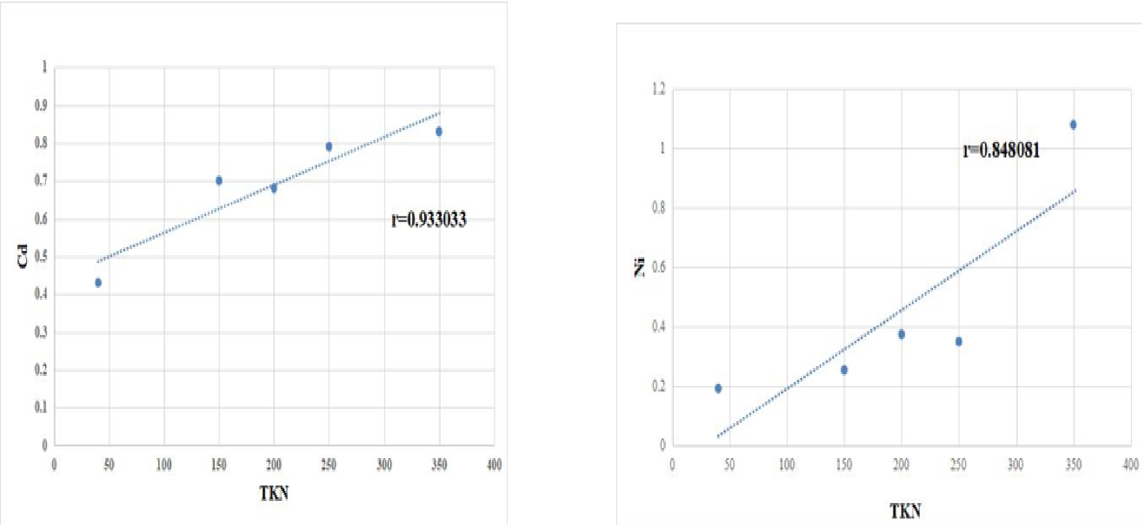

Figure 10: Correlation between TKN-Cd & TKN-Ni

Copper (Cu) showed a strong positive correlation with Silver (Ag) (0.80157), indicating that both metals are commonly found together in wastewater discharges from industries such as electroplating (Sharma *et al.*, 2018).

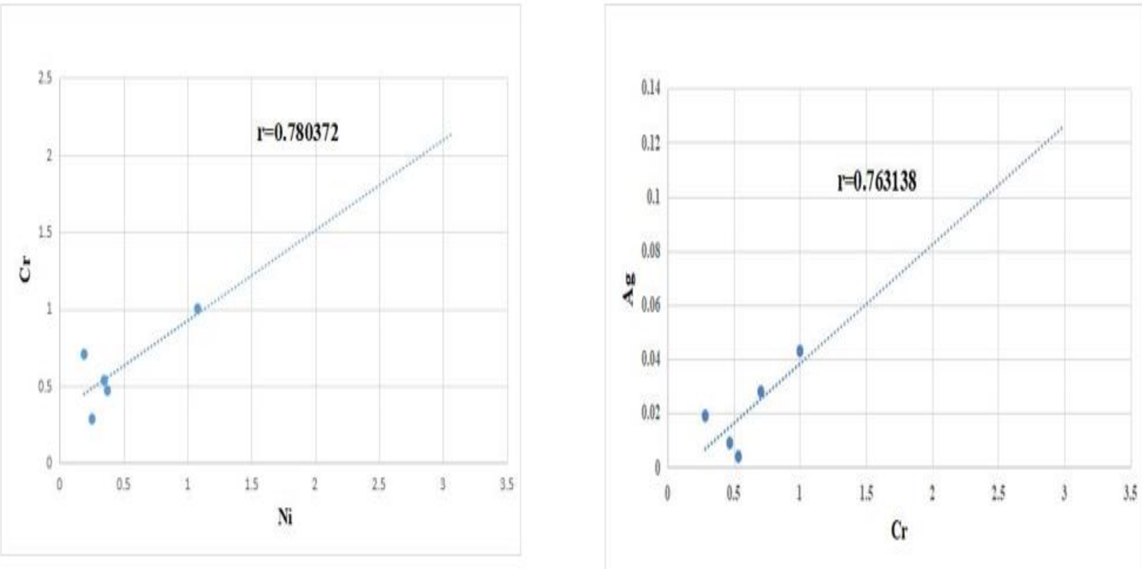

Figure 11: Correlation between Chromium-Nickel & Chromium Silver

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CONCLUSION AND FUTURE DIRECTIONS

This study evaluated the water quality of wastewater from Quaid-e-Azam Industrial Estate, Lahore, and revealed concerning pollution levels, particularly in parameters such as BOD, COD, TSS, turbidity, TKN, hardness, EC, and Cadmium, all of which surpassed regulatory thresholds. These elevated pollutant levels pose threats to aquatic ecosystems and oxygen levels. However, metals such as silver, iron, chromium, nickel, copper, and lead were found within acceptable limits. The study also revealed significant correlations between various pollutants, including the connection between BOD and COD, TSS and other contaminants like magnesium, sulfate, and iron, and TKN with Cadmium and Nickel. These findings highlight the intricate relationships between pollutants and emphasize the need for focused wastewater management strategies. Future research should aim to pinpoint the specific industrial sources contributing to pollutants like BOD, COD, TSS, and heavy metals through detailed effluent analysis. The study suggests investigating advanced wastewater treatment methods to lower pollutant concentrations. Implementing long-term monitoring programs is vital to track seasonal variations, ensure compliance with environmental standards, and evaluate the effectiveness of treatment methods. Strengthening regulatory measures, promoting sustainable practices in industries, and investing in wastewater treatment infrastructure are crucial steps in reducing long-term environmental impacts. Collaboration between industry, government, and environmental groups will be essential for achieving effective, sustainable wastewater management.

References

1) Ahmed, N., Malik, A., & Shahid, M. (2021). Heavy metal contamination in industrial wastewater: A review of environmental implications and risk assessment. *Environmental Science and Pollution Research,* 28(9), 11234-11256.

2) Almeida, M. C., Butler, D., & Friedler, E. (2000). At source domestic wastewater quality. *Urban Water*, 6(8) (49–55).

3) Al-Mudhaf, H. F., Alsharifi, F. A., & Abu-Shady, A. S. (2009). A survey of organic contaminants in household and bottled drinking waters in Kuwait. *Science of the Total Environment,* 407(5), 1658-1668.

4) Borges, G., Nock, M. K., Abad, J. M. H., Hwang, I., Sampson, N. A., Alonso, J., ... & Kessler, R.C. (2010). Twelve-month prevalence of and risk factors for suicide attempts in the World Health Organization World Mental Health Surveys. *The Journal of Clinical Psychiatry,* 71(12), 1777- 1789.

5) Ghosh, P., Roy, R., & Hossain, K. M. (2022). Impact of industrial discharges on water hardness: A study of water quality parameters in urban areas. *Journal of Water and Climate Change, 13*(4), 1538-1550.

6) Ghosh, R., Banerjee, A., & Bhattacharya, P. (2022). Hardness and Heavy Metal Contamination in Industrial Areas. *Environmental Research Letters*, 39(2), 121-129.

7) Gupta, V., Sharma, N., & Kumar, M. (2017). *Electrical Conductivity as an Indicator of Pollution in Chemical Manufacturing Wastewater. Journal of Water Quality*, 55(4), 215-223.

8) Haydar, S., Hussain, G., & Haider, H. (2016). Wastewater characterization of selected industries in Quaid-e-Azam Industrial Estate: Treatment options and impact on groundwater quality. *Proceedings of the Pakistan Academy of Sciences: B. Life and Environmental Sciences, 53(2),* 93–102.

ISSN: 1673-064X
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9) Henze, M., Harremoes, P., la Cour Jansen, J., & Arvin, E. (2002). *Wastewater treatment: Biological and chemical processes* (3rd ed.). Springer-Verlag.

10) Hicks, T. D., Kuns, C. M., Raman, C., & Bates, Z. T. (2022). *Simplified method for the determination of total Kjeldahl nitrogen in wastewater*. *Environments, 9*(5), 55. https://doi.org/10.3390/environments9050055

11) Hina, S., Zahid, M., Baloch, I. H., & Pasha, T. S. (2011). Environmental impacts of Quaid-e- Azam industrial estate on neighboring residential area in Lahore, Pakistan. *Journal of Water Resource and Protection*, *3*(3), 182-185.

12) Kumar, S., Patel, R., & Mehra, S. (2019). Biochemical Oxygen Demand in Industrial Effluents. *Environmental Pollution Research*, 42(4), 265-273.

13) Kumar, R., Mehta, P., & Mishra, R. (2019). Nickel Contamination in Wastewater from Electroplating Industries. *Environmental Toxicology Journal*, 62(8), 431-439.

14) Khan, S., Zhang, L., & Ali, R. (2021). Turbidity and total suspended solids in wastewater from textile and chemical industries: A case study from South Asia. *Environmental Pollution, 268(1)*, 115582-115592.

15) Li, S., Zhou, Y., & Wang, L. (2021). Electrochemical analysis of wastewater pollution from chemical industries: Implications for water quality monitoring. *Environmental Science and Pollution Research, 28*(5), 5142-5152.

16) Mollah, M. Y. A., & Rahman, M. M. (2017). Assessment of total suspended solids and turbidity in industrial wastewater in Bangladesh: A case study of the leather industry. *Environmental Monitoring and Assessment, 189*(5), 248-260.

17) Nomngongo, P. N., Ngila, J. C., Msagati, T. A., Gumbi, B. P., & Iwuoha, E. I. (2012). Determination of selected persistent organic pollutants in wastewater from landfill leachates, using an amperometric biosensor. *Physics and Chemistry of the Earth, 50*(1), 252–261.

18) Rahman, S. M., Alam, A. S., & Hossain, M. M. (2018). Biochemical oxygen demand and chemical oxygen demand correlation in industrial effluents: A study on wastewater from textile and food processing industries. *Journal of Environmental Chemical Engineering, 6*(4), 4261- 4267.

19) Rusydi, A. F. (2018). Correlation between conductivity and total dissolved solid in various type of water: *A review*. *IOP Conference Series: Earth and Environmental Science, 118*(1), 012019. https://doi.org/10.1088/1755-1315/118/1/012019

20) Sasamal, S.K., Rao, K.H., and Suryavansi, U.M., 2007, Sewage and industrial pollution in and around Thane Creek, Mumbai using high resolution IRS data., International Journal of Remote Sensing, 28(19), 4391-4395.

21) Sharma, A., Gupta, P., & Sharma, R. (2018). Effect of Chromium on Biodegradability of Organic Pollutants in Wastewater. *Environmental Engineering Science,* 35(11), 1425-1432.

22) Sharma, S., Sharma, R., & Gupta, S. K. (2018). Chemical interactions between heavy metals and organic pollutants in industrial wastewater. *Journal of Hazardous Materials, 342(1)*, 389.

23) Singh, P., Kumar, A., & Kaur, S. (2020). Nitrogen Compounds in Industrial Effluents and their Impact on Eutrophication. *Journal of Environmental Science*, 67(8), 2317- 2325.

24) Vanrolleghem, P. A., Insel, G., Petersen, B., Sin, G., De Pauw, D., Nopens, I., Dovermann, H., Weijers, S., & Gernaey, K. (2003). A comprehensive model calibration procedure for activated sludge models. *Proceedings of the Water Environment Federation*, 2003(9), 210–237.