Assessment of Water and Wastewater Treatment Efficiency in Nigeria

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***Abstract*— Water and wastewater treatment are vital in safeguarding public health and environmental sustainability. In Nigeria, various factors influence water and wastewater treatment systems' efficacy, including infrastructure conditions, management practices, and regulatory compliance. This study assesses the efficiency of water and wastewater treatment in Nigeria through a comprehensive evaluation of key parameters such as infrastructure conditions, water quality, treatment efficacy, and management efficiency. Data collected from 35 engineers involved in the water and wastewater sector were analyzed using statistical methods to identify areas for improvement. The quantitative descriptive statistical analysis summarized and interpreted numerical data using central tendency and variability measures. Results indicate significant disparities in infrastructure conditions and management practices, highlighting the need for strategic investment and policy interventions. Recommendations for policymakers include prioritizing infrastructure upgrades and enhancing stakeholder engagement to align with global standards. Future research directions emphasize the importance of longitudinal studies to track the effectiveness of interventions and explore innovative technologies for sustainable water management. Overall, this study provides valuable insights into the current state of water and wastewater treatment in Nigeria and offers actionable recommendations for enhancing efficiency and sustainability in the sector.**

Keywords*— *Infrastructure, Management efficiency, Nigeria, Water treatment, Wastewater treatment, Water quality

I. Introduction

In the realm of water and wastewater treatment, the pursuit of efficiency is paramount for ensuring both human well-being and environmental integrity, especially in regions like Nigeria where the stakes are high due to prevalent pollution and resource management issues. Through a comprehensive review of the literature, it becomes evident that a multitude of scholarly inquiries have been dedicated to assessing and augmenting the efficacy of these critical treatment processes.

Firstly, researchers have delved into innovative approaches to optimize treatment methodologies, leveraging resources like banana stem juice to demonstrate the potential of natural solutions in enhancing water quality [1]. Similarly, Ref. [2] has explored bioremediation strategies tailored specifically to address the challenges posed by refinery wastewater, underlining the pivotal role of biotechnological interventions in combating industrial pollution.

Moreover, the discourse extends to the realm of infrastructure investment, as underscored by the insightful findings [3]. This research not only sheds light on the environmental justice hurdles intertwined with infrastructure development but also advocates for equitable resource allocation and robust governance frameworks to navigate these challenges effectively. Furthermore, advancements in adsorbent technology have emerged as promising avenues for mitigating pollution concerns, with graphene-based materials showcasing considerable potential in the removal of contaminants from wastewater [4].

In optimizing treatment performance, studies such as those conducted by Amuda et al. and Aniyikaiye et al. have provided valuable insights. Ref. [5] has meticulously evaluated the efficiency of coagulant/flocculant in industrial wastewater treatment, emphasizing the importance of fine-tuning treatment chemicals for maximal efficacy. Meanwhile, physico-chemical analyses of wastewater discharged from paint industries, offer critical insights into the composition and characteristics of industrial effluents [6].

The escalating concern surrounding emerging contaminants in water systems has spurred intensive research efforts. Ref. [7] has meticulously investigated the presence of pharmaceuticals and illicit drugs in aqueous environments, shedding light on evolving contamination threats. In parallel, Balogun and Ogwueleka have contributed to this discourse by meticulously assessing the microbial removal efficiency of a wastewater treatment plant, thereby providing crucial insights into the operational performance of municipal treatment facilities [8].

Furthermore, the pivotal role of water microbiology in safeguarding water quality and public health cannot be overstated [9]. Ref. [9] underscores the importance of microbiological considerations in treatment processes, emphasizing the need for robust monitoring and management strategies. Similarly, Ref. [10] has conducted extensive analyses to examine the presence of pharmaceuticals and personal care products (PPCPs) in freshwater environments, advocating for holistic approaches to contamination mitigation.

Continuing the narrative, Ref. [11] has provided a comprehensive review of electrocoagulation processes, offering nuanced insights into their fundamentals, emerging applications, and synergies with other treatment technologies. This study not only underscores the potential of electrocoagulation as an effective treatment method for various water contaminants but also highlights avenues for further technological innovation. Moreover, sustainability assessments of advanced wastewater treatment technologies serve as crucial frameworks for evaluating treatment methodologies through the lens of environmental, economic,

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and social considerations, thereby informing more holistic decision-making processes [12].

In tandem with these scholarly endeavors, physicochemical analyses of wells and streams in North Bank, Makurdi–Benue State, Nigeria have yielded invaluable insights into local water quality parameters and potential contamination sources [13]. Additionally, Ref. [14] has presented an expansive overview of electronic waste management approaches, emphasizing the imperative for sustainable practices in mitigating the environmental footprint of electronic waste disposal.

In the overarching pursuit of assessing and enhancing water and wastewater treatment efficiency, a wealth of scholarly investigations has illuminated various facets of this critical endeavor. Ref. [15] contributes significantly by delving into the global occurrence and emission of rotaviruses to surface waters, underscoring the profound implications of waterborne pathogens for public health and emphasizing the pivotal role of robust wastewater treatment in averting waterborne diseases. Concurrently, Ref. [16] enrich the discourse by scrutinizing the efficacy of bio-coagulants for turbid and wastewater treatment, elucidating the potential of harnessing nature-based solutions in the purification of water resources.

Advancing the dialogue on wastewater treatment methodologies, a research offers valuable insights into advanced sludge treatment techniques, with a specific focus on elucidating the role of extracellular polymeric substances in enhancing activated sludge dewatering efficiency [17]. Meanwhile, Ref. [18] delve into the intricate realm of microplastic pollution in wastewater treatment plants, meticulously investigating pathways, classifications, and removal efficiencies, thereby addressing emerging concerns regarding the pervasive presence of microplastics in aquatic ecosystems.

The applicability of electrochemical processes in industrial wastewater treatment is underscored by Ref. [19], who explore the removal of solids from palm oil mill effluent and paint wastewater using the electrocoagulation technique, thus highlighting the versatility of electrochemical approaches in addressing diverse wastewater challenges. Similarly, Ref. [20] advocates for the adoption of fortified soil-clay systems as decentralized, cost-effective solutions for domestic wastewater purification, aligning with the imperative of sustainable and environmentally friendly treatment practices.

In a broader public health context, Strunz et al. undertake a systematic review and meta-analysis to elucidate the intricate interplay between water, sanitation, hygiene, and soil-transmitted helminth infection, advocating for integrated approaches to mitigate disease burdens and enhance public health outcomes [21]. Furthermore, Ref. [22] delves into the pervasive presence of pharmaceuticals and personal care products in surface waters, emphasizing the urgent need for comprehensive monitoring and regulatory frameworks to address emerging contaminants effectively.

Addressing socio-economic dimensions, Ref. [23] provides valuable insights into the willingness to pay for water services in developing countries, shedding light on the complex interplay between socio-economic factors, water resource management, and infrastructure investment decisions. Finally, Ref. [24] offers a contextualized assessment of the treatment efficiency and economic viability of a poultry slaughterhouse wastewater treatment plant in Ibadan, Nigeria, reinforcing the imperative of sustainable wastewater management practices tailored to industrial sectors.

II. Methods

A. Data Collection

The data set includes ratings from 35 engineers on various aspects of water and wastewater treatment in Nigeria, rated from 1 to 5. Data was gathered through surveys, interviews, and reports from facilities across urban and rural areas. Key parameters assessed were Infrastructure Condition, Water Quality, Treatment Efficacy, Management Efficiency, Community Satisfaction, Compliance with Regulations, Equipment Reliability, Maintenance Frequency, Staff Training, Safety Standards, Innovation in Treatment Methods, Data Management, Response Time to Issues, Sustainability Practices, Stakeholder Engagement, and Risk Management.

B. Data Analysis

Statistical methods, including mean, median, mode, standard deviation, and range, were used to analyze the data. These statistics provided insights into the central tendencies and variability of the ratings for each parameter. The mean represents the average score, the median is the middle value, the mode is the most frequent score, the standard deviation is the variability, and the range is the difference between the highest and lowest scores. This analysis helped us understand the overall performance and variability of each parameter.

C. Sampling and Participants

Engineers were selected based on experience in the Nigerian water and wastewater sector, roles involving facility oversight, and geographic diversity. The criteria ensured a representative sample with diverse perspectives. Demographic information included years of experience, educational background, professional qualifications, and specific roles. This diverse sample provided a comprehensive view of the state of water and wastewater treatment efficiency in Nigeria.

III. Results and Discussion

Table 2 provides a comprehensive overview of key metrics about Nigeria's water and wastewater treatment efficiency, shedding light on various facets such as infrastructure conditions, management practices, and community satisfaction. Firstly, it reveals that infrastructure conditions received the lowest mean score of 2.57, indicating a pressing need for improvement to enhance the efficacy of treatment facilities across the country [25]. Conversely, water quality emerges as a standout performer with a high mean score of 3.71, signaling positive perceptions regarding the quality of water delivered by these facilities. Similarly, treatment efficacy garners a respectable mean score of 3.63, underscoring the perceived effectiveness of treatment processes in addressing water and wastewater issues.

However, the analysis also highlights areas where improvements are warranted. Management efficiency, for instance, receives a moderate mean score of 3.07, suggesting room for enhancement in administrative practices within these facilities. Community satisfaction, compliance with regulations, and equipment reliability all share this middling score of 3.07, indicating that there are aspects of operation and service delivery that may not fully meet stakeholder expectations. Furthermore, while maintenance frequency is perceived as average with a mean score of 3.00, there is a

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potential opportunity to optimize maintenance practices to ensure the sustained performance of treatment infrastructure.

On a positive note, staff training is viewed favorably, scoring moderately high with a mean of 3.21, indicating that training adequacy is generally perceived positively among respondents. Nonetheless, several areas, including safety standards, innovation in treatment methods, data management, response time to issues, sustainability practices, stakeholder engagement, and risk management, all receive an average mean score of 3.00. This suggests that while these aspects are considered satisfactory, there remains ample room for improvement and innovation to further enhance the efficiency and effectiveness of water and wastewater treatment operations nationwide.

In summary, while there are commendable aspects to Nigeria's water and wastewater treatment efforts, such as water quality and treatment efficacy, there are clear areas identified for improvement, particularly in infrastructure, management, and regulatory compliance. Addressing these areas comprehensively could lead to significant enhancements in service delivery, community satisfaction, and overall public health outcomes. Table 2 presents key metrics for evaluating water and wastewater treatment efficiency in Nigeria, including the mean, median, mode, standard deviation, and range of scores across various categories such as infrastructure condition, water quality, treatment efficacy, and more [26].

Interpretation of mean scores and standard deviations: Mean scores provide a snapshot of the overall perception of various aspects of water and wastewater management, while standard deviations indicate the degree of variability in respondents' opinions. Lower standard deviations suggest more consensus among respondents, while higher standard deviations imply greater diversity in opinions. In this dataset, the mean scores range from 2.57 to 3.71, with corresponding standard deviations ranging from 0.62 to 1.19. This suggests that while water quality received the highest mean score and relatively low standard deviation, indicating positive perceptions with little variability, infrastructure conditions received the lowest mean score with a higher standard deviation, suggesting less consensus and potentially more varied opinions among respondents.

Identification of high-performing and low-performing areas: Water quality emerged as the high-performing area with the highest mean score of 3.71, indicating positive perceptions among respondents. Conversely, the infrastructure condition received the lowest mean score of 2.57, indicating a need for improvement. Other areas such as treatment efficacy, management efficiency, and staff training scored moderately high, suggesting effectiveness but with room for enhancement. However, equipment reliability, community satisfaction, compliance with regulations, stakeholder engagement, and risk management all scored around the midpoint, indicating mixed perceptions and areas for improvement [27].

Figure 1 shows that Mean and Standard Deviation by Category display the average scores and variability for each category. The mean scores reveal the overall perception of different aspects of water and wastewater treatment, while the standard deviation indicates the consistency of these perceptions. Notably, "Infrastructure Condition" has the lowest mean score (2.57) coupled with a high standard deviation (1.19), suggesting a significant variability in responses and highlighting a critical area needing improvement. Conversely, "Water Quality" stands out with the highest mean score (3.71) and the lowest standard deviation (0.76), indicating positive and consistent perceptions about the quality of water, reflecting well on the efforts made in this area.

TABLE I. KEY METRICS FOR WATER AND WASTEWATER TREATMENT EFFICIENCY

Serial No.	Category	Mean	Median	Mode	SD	Range	Insight
1	Infrastructure Condition	2.57	3	4	1.19	3	Infrastructure may require improvement as it received the lowest mean score.
2	Water Quality	3.71	4	4	0.76	4	Water quality scored the highest mean, indicating positive perceptions.
3	Treatment Efficacy	3.63	4	4	0.62	2	Treatment efficacy scored relatively high, showing effectiveness.
4	Management Efficiency	3.07	3	3	0.76	2	Management efficiency has a moderate score with room for improvement.
5	Community Satisfaction	3.07	3	3	0.76	2	Community satisfaction shows average perception among respondents.
6	Compliance with Regulations	3.07	3	4	0.76	2	Compliance with regulations has room for improvement based on the mean score.
7	Equipment Reliability	3.14	3	4	0.76	2	Equipment reliability scored moderately, indicating some issues.
8	Maintenance Frequency	3.00	3	3	0.76	2	Maintenance frequency is perceived as average by respondents.
9	Staff Training	3.21	3	3	0.76	2	Staff training scored moderately high, showing adequacy in training.
10	Safety Standards	3.00	3	3	0.76	2	Safety standards are perceived as average, with room for improvement.
11	Innovation in Treatment Methods	3.00	3	3	0.76	2	Innovation in treatment methods is perceived as average.
12	Data Management	3.00	3	3	0.76	2	Data management is seen as average with potential for enhancement.
13	Response Time to Issues	3.00	3	3	0.76	2	Response time to issues is perceived as average by respondents.
14	Sustainability Practices	3.00	3	3	0.76	2	Sustainability practices are perceived as average, with room for growth.
15	Stakeholder Engagement	3.07	3	4	0.76	2	Stakeholder engagement may require improvement based on the mean score.
16	Risk Management	3.00	3	4	0.76	2	Risk management has an average score, indicating moderate perception.

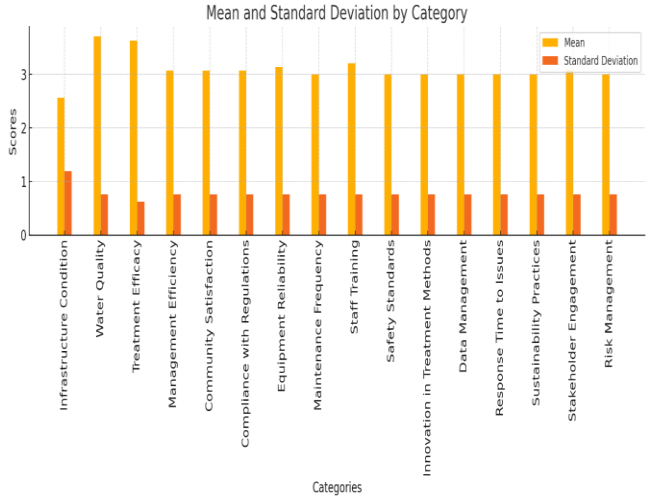


Fig. 1. Mean and standard deviation of results

Figure 2 shows that the Median by Category provides insight into the central tendency of scores, showing the middle value of responses. Most categories have a median score of 3, indicating that the typical respondent views these aspects as moderate. However, "Water Quality" and "Treatment Efficacy" have a higher median of 4, suggesting that a substantial number of respondents perceive these categories positively. This highlights the effectiveness and reliability of treatment processes and the quality of the treated water.

Figure 3 shows that Mode by Category illustrates the most frequently occurring scores, shedding light on the most common perceptions among respondents. The model for most categories is either 3 or 4, indicating that moderate to positive perceptions are prevalent. Interestingly, "Infrastructure Condition" has a mode of 4 despite having a lower mean score, indicating that while many respondents rated it positively, there is a significant portion that rated it lower, resulting in a lower overall average. This discrepancy points to a polarized perception of infrastructure conditions, suggesting that while improvements are recognized by some, others still see considerable room for enhancement.

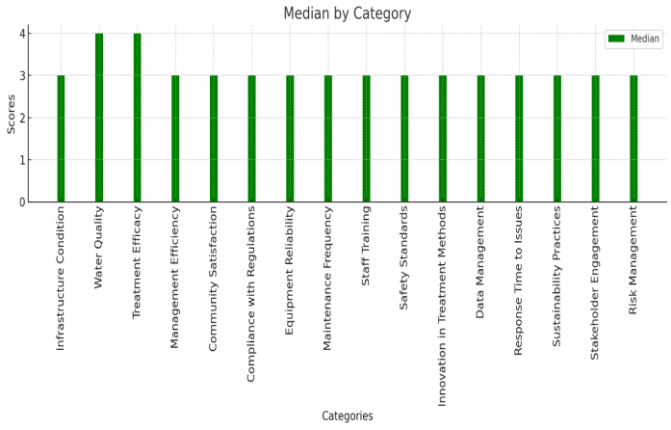


Fig. 2. Median by category

Fig. 3. Global standards for water and wastewater management emphasize not only the quality of water but also infrastructure reliability, regulatory compliance, stakeholder engagement, and sustainability practices. While water quality in this assessment aligns well with global standards, areas such as infrastructure condition, equipment reliability, and stakeholder engagement may lag. This indicates a need to align practices more closely with established global benchmarks to ensure comprehensive and sustainable water management. Nigerian practices appear to align well with global standards in terms of water quality and treatment efficacy, as indicated by relatively high mean scores. However, deviations from best practices are evident in areas such as infrastructure condition, equipment reliability, and stakeholder engagement, where perceptions are lower and improvements are needed to meet international benchmarks. Addressing these gaps will be crucial for ensuring that Nigerian water and wastewater management practices are in line with best practices worldwide.

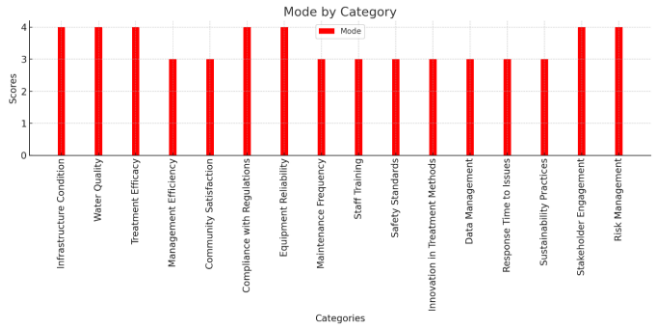


Fig. 4. Mode by Category

Policymakers should prioritize investment in improving infrastructure conditions and equipment reliability to address the low mean scores in these areas. Additionally, efforts should be made to enhance stakeholder engagement and compliance with regulations to align with global standards and ensure transparency and accountability in water management practices. Furthermore, initiatives to promote innovation in treatment methods and sustainability practices can help elevate overall performance and resilience in the face of future challenges [28]. Water and wastewater management entities should focus on implementing regular maintenance schedules to improve infrastructure reliability and equipment performance. Training programs should be enhanced to ensure staff competency and effectiveness in managing water treatment facilities [29]. Moreover, fostering partnerships with stakeholders, including communities and regulatory agencies, can enhance communication and collaboration, leading to more effective management practices. Lastly, adopting innovative technologies and sustainable practices can enhance efficiency, resilience, and environmental stewardship in water and wastewater management operations [30].

IV. Conclusion

The assessment of water and wastewater management practices highlighted key areas of performance and improvement. Water quality was identified as a high-performing area, while infrastructure conditions scored the lowest, indicating an urgent need for upgrades. Treatment efficacy, management efficiency, and staff training received moderate to high scores but still have room for enhancement. Additionally, equipment reliability, stakeholder engagement, and compliance with regulations require focused attention to meet global standards. Strategic investment is needed to upgrade infrastructure, improve training programs, and strengthen regulatory compliance and stakeholder engagement. Future research should prioritize longitudinal studies to evaluate the effectiveness of these improvements over time, explore innovative technologies, and promote sustainable practices to advance water management and ensure reliable water resources for communities.

References

[1] Agunwamba, J. C., Aho, M. I., Iorwua, M. B., & Tiza, M. T. (2016). Response Surface Optimization of Treated Turbid water using Banana

 EISSN: 2961-872X ● PISSN: 2961-8924 ● DOI: 10.56741/esl.v3i03.642

stem juice. International Journal For Innovative Research In Multidisciplinary Field, 2(8), 183–192.

[2] Ajao, A. T., Yakubu, S. E., Umoh, V. J., & Ameh, J. B. (2013). Bioremediation of refinery wastewater using immobilised Burkholderia cepacia and Corynebacterium sp and their transconjugants. Journal of Xenobiotics, 3(1), 4. https://doi.org/10.4081/xeno.2013.e4

[3] Alexandra Dapolito Dunn. (2010). Investment in Water and Wastewater Infrastructure: An Environmental Justice Challenge, a Governance Solution.

[4] Ali, I., Basheer, A. A., Mbianda, X. Y., Burakov, A., Galunin, E., Burakova, I., Mkrtchyan, E., Tkachev, A., & Grachev, V. (2019). Graphene based adsorbents for remediation of noxious pollutants from wastewater. Environment International, 127, 160–180. https://doi.org/10.1016/j.envint.2019.03.029

[5] Amuda, O., AMOO, I., & AJAYI, O. (2006). Performance optimization of coagulant/flocculant in the treatment of wastewater from a beverage industry. Journal of Hazardous Materials, 129(1-3), 69–72. https://doi.org/10.1016/j.jhazmat.2005.07.078

[6] Aniyikaiye, T. E., Oluseyi, T., Odiyo, J. O., & Edokpayi, J. N. (2019). Physico-Chemical Analysis of Wastewater Discharge from Selected Paint Industries in Lagos, Nigeria. International Journal of Environmental Research and Public Health, 16(7), 1235. https://doi.org/10.3390/ijerph16071235

[7] Baker, D. R., & Kasprzyk-Hordern, B. (2013). Spatial and temporal occurrence of pharmaceuticals and illicit drugs in the aqueous environment and during wastewater treatment: New developments. Science of the Total Environment, 454-455, 442–456. https://doi.org/10.1016/j.scitotenv.2013.03.043

[8] Balogun, S., & Ogwueleka, T. C. (2021). Coliforms removal efficiency of Wupa wastewater treatment plant, Abuja, Nigeria. Energy Nexus, 4, 100024. https://doi.org/10.1016/j.nexus.2021.100024

[9] Cabral, J. P. S. (2010). Water Microbiology. Bacterial Pathogens and Water. International Journal of Environmental Research and Public Health, 7(10), 3657–3703. https://doi.org/10.3390/ijerph7103657

[10] Ebele, A. J., Abou-Elwafa Abdallah, M., & Harrad, S. (2017). Pharmaceuticals and personal care products (PPCPs) in the freshwater aquatic environment. Emerging Contaminants, 3(1), 1–16. https://doi.org/10.1016/j.emcon.2016.12.004

[11] Garcia-Segura, S., Eiband, M. M. S. G., de Melo, J. V., & Martínez-Huitle, C. A. (2017). Electrocoagulation and advanced electrocoagulation processes: A general review about the fundamentals, emerging applications and its association with other technologies. Journal of Electroanalytical Chemistry, 801, 267–299. https://doi.org/10.1016/j.jelechem.2017.07.047

[12] Høibye, L., Clauson-Kaas, J., Wenzel, H., Larsen, H. F., Jacobsen, B. N., & Dalgaard, O. (2008). Sustainability assessment of advanced wastewater treatment technologies. Water Science and Technology, 58(5), 963–968. https://doi.org/10.2166/wst.2008.450

[13] Iorwua, M. B., Onyebuchi, M. N., Tiza, M. T., & Iorwua, J. (2018). Physico-Chemical Analysis of Some Wells and Streams in North Bank, Makurdi – Benue State, Nigeria. International Journal for Research in Engineering Application & Management (IJREAM), 4(1).

[14] Kiddee, P., Naidu, R., & Wong, M. H. (2013). Electronic Waste Management Approaches: An Overview. Waste Management, 33(5), 1237–1250. https://doi.org/10.1016/j.wasman.2013.01.006

[15] Kiulia, N., Hofstra, N., Vermeulen, L., Obara, M., Medema, G., & Rose, J. (2015). Global Occurrence and Emission of Rotaviruses to Surface Waters. Pathogens, 4(2), 229–255. https://doi.org/10.3390/pathogens4020229

[16] Mogbo, O. N., Iorwua, M. B., Duweni, E. C., & Tiza, M. T. (2000). A Study on the Efficacy of Bio-Coagulants for Turbid and Wastewater Treatment. Journal Of Critical Reviews, 7(18), 1307–1315.

[17] Neyens, E. (2004). Advanced sludge treatment affects extracellular polymeric substances to improve activated sludge dewatering. Journal of Hazardous Materials, 106(2-3), 83–92. https://doi.org/10.1016/j.jhazmat.2003.11.014

[18] Ngo, P. L., Pramanik, B. K., Shah, K., & Roychand, R. (2019). Pathway, classification, and removal efficiency of microplastics in wastewater treatment plants. Environmental Pollution, 255, 113326. https://doi.org/10.1016/j.envpol.2019.113326

[19] Nwabanne, J. T., Oguegbu, O. O., & Agu, C. M. (2018). Removal of Solids from Palm Oil Mill Effluent and Paint Wastewater Using Electrocoagulation Technique. International Journal of Electrochemistry, 2018, 1–9. https://doi.org/10.1155/2018/4349639

[20] Oladoja, N. A., & Ademoroti, C. M. A. (2006). The use of fortified soil-clay as on-site system for domestic wastewater purification. Water Research, 40(3), 613–620. https://doi.org/10.1016/j.watres.2005.11.031

[21] Strunz, E. C., Addiss, D. G., Stocks, M. E., Ogden, S., Utzinger, J., & Freeman, M. C. (2014). Water, Sanitation, Hygiene, and Soil-Transmitted Helminth Infection: A Systematic Review and Meta-Analysis. PLoS Medicine, 11(3), e1001620. https://doi.org/10.1371/journal.pmed.1001620

[22] Tixier, C., Singer, H. P., Oellers, S., & Müller, S. R. (2003). Occurrence and Fate of Carbamazepine, Clofibric Acid, Diclofenac, Ibuprofen, Ketoprofen, and Naproxen in Surface Waters. Environmental Science & Technology, 37(6), 1061–1068. https://doi.org/10.1021/es025834r

[23] Whittington, D., Briscoe, J., Mu, X., & Barron, W. (1990). Estimating the Willingness to Pay for Water Services in Developing Countries: A Case Study of the Use of Contingent Valuation Surveys in Southern Haiti. Economic Development and Cultural Change, 38(2), 293–311. https://doi.org/10.1086/451794

[24] Yahaya Mijinyawa, & Nurudeen Samuel Lawal. (2008). Treatment efficiency and economic benefit of Zartech poultry slaughter house waste water treatment plant, Ibadan, Nigeria. 3(6), 219–223. https://doi.org/10.5897/sre.9000965

[25] Barceló, D., Žonja, B., & Ginebreda, A. (2020). Toxicity tests in wastewater and drinking water treatment processes: A complementary assessment tool to be on your radar. *Journal of Environmental Chemical Engineering*, *8*(5), 104262. https://doi.org/10.1016/j.jece.2020.104262

[26] Derisso, C. R., Pompei, C. M. E., Spadoto, M., da Silva Pinto, T., & Vieira, E. M. (2020). Occurrence of Parabens in Surface Water, Wastewater Treatment Plant in Southeast of Brazil and Assessment of Their Environmental Risk. *Water, Air, & Soil Pollution*, *231*(9). https://doi.org/10.1007/s11270-020-04835-0

[27] Lundie, S., Peters, G. M., & Beavis, P. C. (2004). Life Cycle Assessment for Sustainable Metropolitan Water Systems Planning. *Environmental Science & Technology*, *38*(13), 3465–3473. https://doi.org/10.1021/es034206m

[28] Mazhar, S., Ditta, A., Bulgariu, L., Ahmad, I., Ahmed, M., & Nadiri, A. A. (2019). Sequential treatment of paper and pulp industrial wastewater: Prediction of water quality parameters by Mamdani Fuzzy Logic model and phytotoxicity assessment. *Chemosphere*, *227*, 256–268. https://doi.org/10.1016/j.chemosphere.2019.04.022

[29] Morera, S., Corominas, Ll., Poch, M., Aldaya, M. M., & Comas, J. (2016). Water footprint assessment in wastewater treatment plants. *Journal of Cleaner Production*, *112*, 4741–4748. https://doi.org/10.1016/j.jclepro.2015.05.102

[30] Yotova, H., Lazarova, G., Kudłak, G., Zlateva, T., Mihaylova, V., Wieczerzak, Y., Venelinov, M., & Tsakovski, K. (2019). Assessment of the Bulgarian Wastewater Treatment Plants' Impact on the Receiving Water Bodies. *Molecules*, *24*(12), 2274. https://doi.org/10.3390/molecules24122274