LINGKAR
Journal of Environmental Engineering
E-ISSN: 2986-8807, P-ISSN: 2746-2498
https://journal.ar-raniry.ac.id/index.php/lingkar/index

Published by
Dept. of Environmental Engineering
UIN Ar-raniry Banda Aceh, Indonesia

Performance Evaluation of Sewage Treatment Plant Using Biochip Media in MBBR Technology : Case Study "X Garment, Central Java

Afifah Yusrina [1], Rachmad Ardhianto [2*], Khumaidah Darojat, K[3], Arief Rahman[4]
[1,2,3] Institut Teknologi PLN, Jakarta, Indonesia, 11750
[4] UIN Ar-Raniry, Banda Aceh, Indonesia, 23111

**Corresponding Email: rachmad@itpln.ac.id*
DOI: 10.22373/ljee.v5i2.5583

Abstract

"X" garment industry's Sewage Treatment Plant (STP) was built to treat domestic wastewater with an inflow capacity of 500 m^3/day. The main principle of the STP technology is an attached growth process with Moving Bed Biofilm Reactor (MBBR) technology using biochip media. Wastewater treated at the STP must meet the water quality standards of Ministry of Environment and Forestry Regulation 68 of 2016 before being discharged into water bodies. Therefore, this research aimed to evaluate the "X" garment industry's STP performance. Wastewater sampling was carried out at the inlet and outlet of STP. Water quality parameters analyzed included pH, BOD, COD, TSS, oil and grease, ammonia, and total coliforms. The removal efficiency value is obtained from the calculation of sampling results. The analysis showed that all treated water parameters met the water quality standards throughout the research period. Hence, the average removal efficiency value at the STP for each parameter was above 90%.

Keywords: electrocoagulation; tubular continuous reactor; electrode configuration; textile industry.

How to cite this article: *Yusina, Afifah. Ardhianto, Rachmad. Darojat, K. Rahman, Arief. 2024. "Performance Evaluation of Sewage Treatment Plant Using Biochip Media of MBBR Technology: Case Study X Garment, Central Java" Lingkar: Journal of Environmental Engineering 49 (4): 470–84. https://doi.org/10.22373/ljee.v3i2.2357*

1. Introduction

In Indonesia, home wastewater is the main source of wastewater generated by human activities (Widyarani et al., 2022). Domestic wastewater poses a threat to water bodies and aquatic life due to its mixture of organic and inorganic substances, as noted in a study by (Koul et al.,2022). Domestic wastewater must be treated before its release

Manuscript received 21 Aug 2023; revised 1 Sep 2024; accepted 13 Jan 2024

into waterways. Several treatment methods have been developed to handle domestic wastewater at Sewage Treatment Plants (STPs), encompassing physical, chemical, biological, physicochemical, and electrochemical processes (Koyuncu and Arıman, 2020). The STP is still based on fundamental principles of biological treatment, as stated by (Mažeikienė and Šarko, 2023).

In biological treatment, microorganisms such as microalgae, protozoa, fungi, and bacteria are harnessed for degrading various pollutants (Srivastava and Chattopadhyay, 2021). Two primary types of biological treatment processes exist, distinguished by oxygen: aerobic and anaerobic. In the aerobic process, wastewater is in an oxygen-rich condition due to the assistance of an air blower, which allows microorganisms to convert organic solids content into carbon dioxide, water, and nitrogen. In contrast, in the anaerobic process, anaerobic microorganisms that flourish in an oxygen-free environment convert organic solids into carbon dioxide, methane, and ammonia (Ranieri, Giuliano, and Ranieri 2021). The aerobic process in wastewater treatment has several advantages, including a less sensitive process, a low conditioning (start-up) period, and an efficient nutrient removal process. Meanwhile, the anaerobic process has numerous advantages, including magnificent organic compound removal capabilities, less sludge production, a low energy requirement, higher loading rates execution, less nutrient requirement, and large biogas production (Aziz et al., 2019). Apart from aerobic and anaerobic processes, there is also anoxic condition employed in biological treatment, where the absence of free oxygen in the wastewater allows microorganisms to utilize alternative compounds that contain bound oxygen, such as nitrate, as electron acceptors (Yorkor and Momoh, 2019).

The “X” garment industry, situated in Jepara, Jawa Tengah, has a STP with a capacity of 500 m^3/day to treat domestic wastewater. Its treatment process employs a variety of reaction tanks, which are used for aerobic, anaerobic, and anoxic treatments. The primary treatment process is based on the attached growth principle, with the aid of a Moving Bed Biofilm Reactor (MBBR). The MBBR system utilizes biochip-based media with an area of 3,000-5,500 m^2/m^3, which has a large surface area. This media enables wastewater treatment plant area minimization. The selection of biochip media is based on the superior process of using this media compared to using Kaldness MBBR media, as well as to saving the work area. The type of media employed is of no consequence; the MBBR system utilizing Kaldness and Biochip media can manage organic loads up to 3.2 kg COD/m^3, a condition where ammonium removal can be reduced to the maximum. In addition to the type of media used, the hydraulic retention time also determines the success of the process. MBBR media with Biochip produces superior ammonium efficiency to that of Kaldness (Bassin et al. 2016). Meanwhile, the wastewater quality standard that is used for the treatment is the Ministry of Environment and Forestry Regulation Number 68 of 2016. Some of the treated wastewater is discharged into the city drains, while the remainder is reused for watering plants.

It is of paramount importance to conduct regular assessments of the STP performance to ascertain that the effluent produced meets the quality standard before being discharged into the water body. This study is designed to demonstrate that the STP can treat domestic wastewater at industry "X" in an efficient manner, thereby meeting the quality standard. This study may serve as a reference for the design of

Manuscript received 21 Aug 2023; revised 1 Sep 2024; accepted 13 Jan 2024

similar STPs for the treatment of domestic wastewater in other industries. This study also examined the suitability of biochip media as a carrier medium in MBBR technology applications.

2. Methodology

2.1 Field Study

Domestic wastewater treated at "X" garment industry's STP comes from employee mess and toilets, office, and canteen. The domestic wastewater treatment flow diagram can be seen in Figure 1. Before being discharged to the STP, domestic wastewater is pretreated first using a type of septic tank, named BIOTANK. The BIOTANK are placed in the operational building, canteen, and mess. After going through BIOTANK, the wastewater is pumped to the STP. In this application of STP with 500 m^3/day, a combination of processes is used (Figure 1), namely the equalization (143 m^3) (1), anaerobic process with honeycomb (60 m^3) (2), anoxic (60 m^3) (3), aerobic process with biochip MBBR media (60 m^3) and tube diffuser (4), sedimentation using clarifier for TSS separation (20 m^3) (5), post-treatment using manganese zeolite and carbon active (6), and disinfection using UV 254 (7). All the system-controlled use PLC controller for the practice operational.

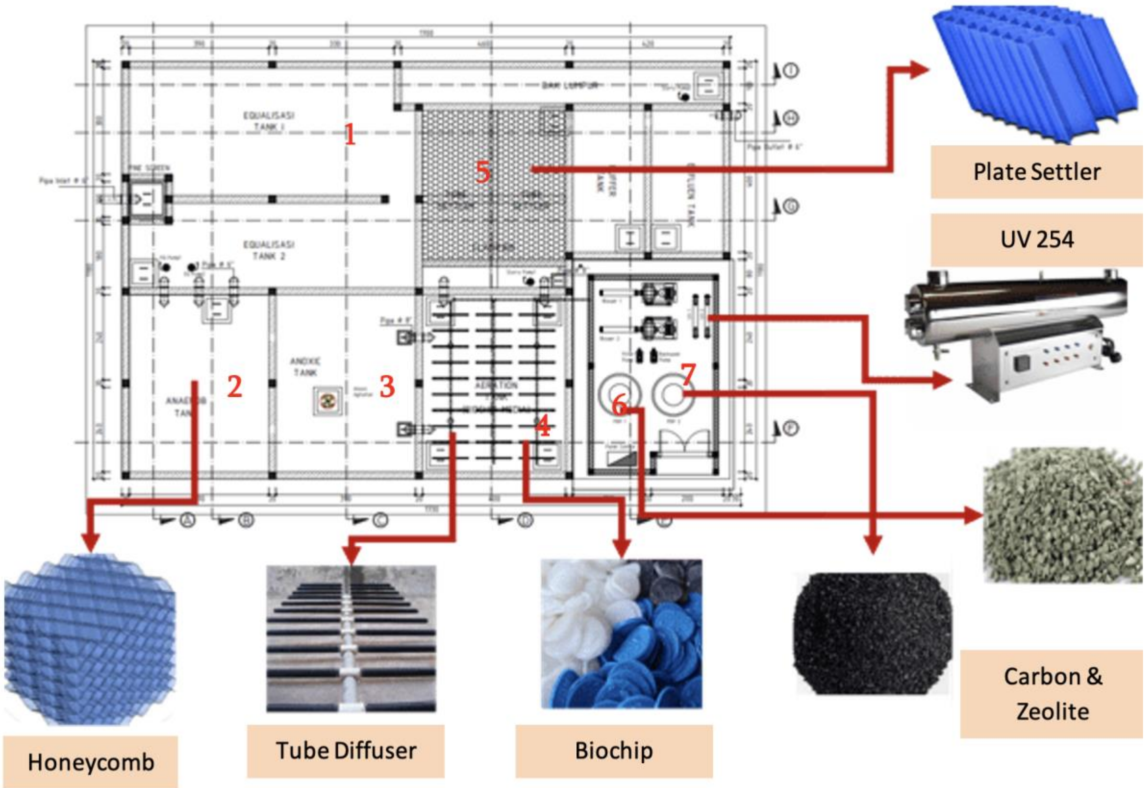

Figure. 1. Component system MBBR for domestic wastewater in "X" garment industry

2.2 Analytical Methods

For the STP performance evaluation, samples were collected at inlet level raw sewage from the preliminary stage and outlet level in the secondary treated water tank-outlet. The sampling technique that followed was called grab sampling. Samples were collected from July 2022 until June 2023. Standard procedures were followed as per the APHA and Indonesian National Standards (SNI) recommendations to test the quality of untreated and treated wastewater samples. Each water quality parameter was considered for testing. Water quality parameters were measured before and after wastewater treatment to understand the role and the impact of pollutants towards the treatment. Parameters (Table 1) were used to assess domestic wastewater quality based on water quality standards, namely pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), oil and grease, ammonia (NH_3-N), and total coliform (Widyarani et al., 2022).

Table 1. Standard method of water quality

No	Parameters	Method
1	pH	SNI 6989.11-2019
2	Biochemical oxygen demand (BOD)	APHA 5210 B-2017
3	Chemical oxygen demand (COD)	SNI 6989.2-2019
4	Total Suspended Solid (TSS)	SNI 6989.3-2019
5	Total Ammonia	SNI 06-6989.30:2005
6	Oil and Grease	SNI 6989.10-2011
7	Total Coliform	IKM-EI-SML-30

The average pollutant concentrations in wastewater influent sampling results can be seen in Table 2. Of the seven parameters, only pH meets the water quality standard. Meanwhile, the other parameters have concentration value that far exceed the standard. One of the causes of this is due to wastewater also comes from employee toilets. Based on (Widyarani et al,. 2022), one domestic wastewater type, named black water, has high organic and nitrogen content. High COD can also come from washing activities, while high oil and grease come from kitchen sinks. Pollutant concentrations in effluent were measured and compared with the standard. From the influent and effluent pollutant concentration values obtained, removal efficiency can be calculated to determine STP's ability to remove pollutants.

2.3 Analytical Methods

Data analysis was performed using the concentration value of domestic wastewater parameters. As for the pollutant removal efficiency, the value was calculated using the following equations:

$$R\ (\%) = \frac{C_t - C_0}{Co}\, x\ 100\% \qquad (1)$$

Manuscript received 21 Aug 2023; revised 1 Sep 2024; accepted 13 Jan 2024

Where R (%) is the pollutant removal efficiency, C_0 (mg/L) is the initial concentration in the feed of equalization, C_t (mg/L) is the concentration of parameters in the concentrated compartment (STP outlet).

3. *Result and Discussion*

3.1. Characteristic Domestic Wastewater

Over the course of one year with the MBBR unit operational, the average incoming wastewater values for specific characteristics were 191.38±36.64 mg/L, 426.70±76.80 mg/L, 300.20±64.50 mg/L, 33.38±5.66 mg/L, 44.50±8.91 mg/L, and 136,417.75±6,995.04 numbers/100 ml for the parameters including BOD, COD, TSS, oil and grease, Total Ammonia, and total coliform, as detailed in **Table 2**. Based the BOD/COD value falls into the biodegradable category where the value formed during the operation of the MBBR unit is 0.448.

Table 2. Domestic wastewater characteristic from "X" garment industry's STP inlet

Characteristic of wastewater	Value	Standard discharged*	Unit
pH	7,14±0,34	6-9	-
Biochemical Oxygen Demand (BOD)	191,38±36,64	30	mg/L
Chemical Oxygen Demand (COD)	426,70±76,80	100	mg/L
Total Suspended Solids (TSS)	300,20±64,50	30	mg/L
Oil and Grease	33,38±5,66	5	mg/L
Total Ammonia (NH_3-N)	44,50±8.91	10	mg/L
Total Coliform	136,417.75±6,995.04	3,000	number/100 mL

*Ministry of Environment and Forestry No P.68/MENLH 2016

3.2. Performance of Sewage Treatment Plant

Domestic wastewater discharge generated at "X" garment industry fluctuates over time. High wastewater discharge occurs in the morning and afternoon, while during the day, it is low. Hence, to ensure that the flow and load of wastewaters remain even and homogeneous during wastewater treatment at the STP, the wastewater is collected first in the equalization unit. Based on the organic load in the input of the system, the average BOD, COD, and ammonia load is 95.69 kg BOD/day, 213.25 kg COD/day, and 22.5 kg ammonia kg/day. The load is treated with a biological process by dividing the load into anaerobic, anoxic, and aerobic processes using the MBBR approach. In the process design, the planned efficiency in the anaerobic process is 30% with a honeycomb media volume of 40 m3. Then, for the anoxic process using calcareous

Manuscript received 21 Aug 2023; revised 1 Sep 2024; accepted 13 Jan 2024

media with a surface area of 800 m3/m3 with a target removal efficiency of ammonia parameters, it is planned that removal of 20% can be applied in this phase. Then, for the aerobic process with biochip media (2500-5000 m2/m3), a media of 3 m3 is used. With this composition, BOD, COD, and ammonia efficiencies of 93.16%, 90.76%, and 93.78% can be achieved at the outlet point after the post-treatment process between July 2022 and June 2023. In addition, TSS and oil and grease parameters were successfully reduced with efficiencies of 99.06% and 93.78%. The operational results of the STP for 1 year resulted in a processed average of 13.00 mg/L, 39.15 mg/L, and 2.85 mg/L. This difference can be influenced by filter process factors in the post-treatment. In general, it can be shown in Figure 2.

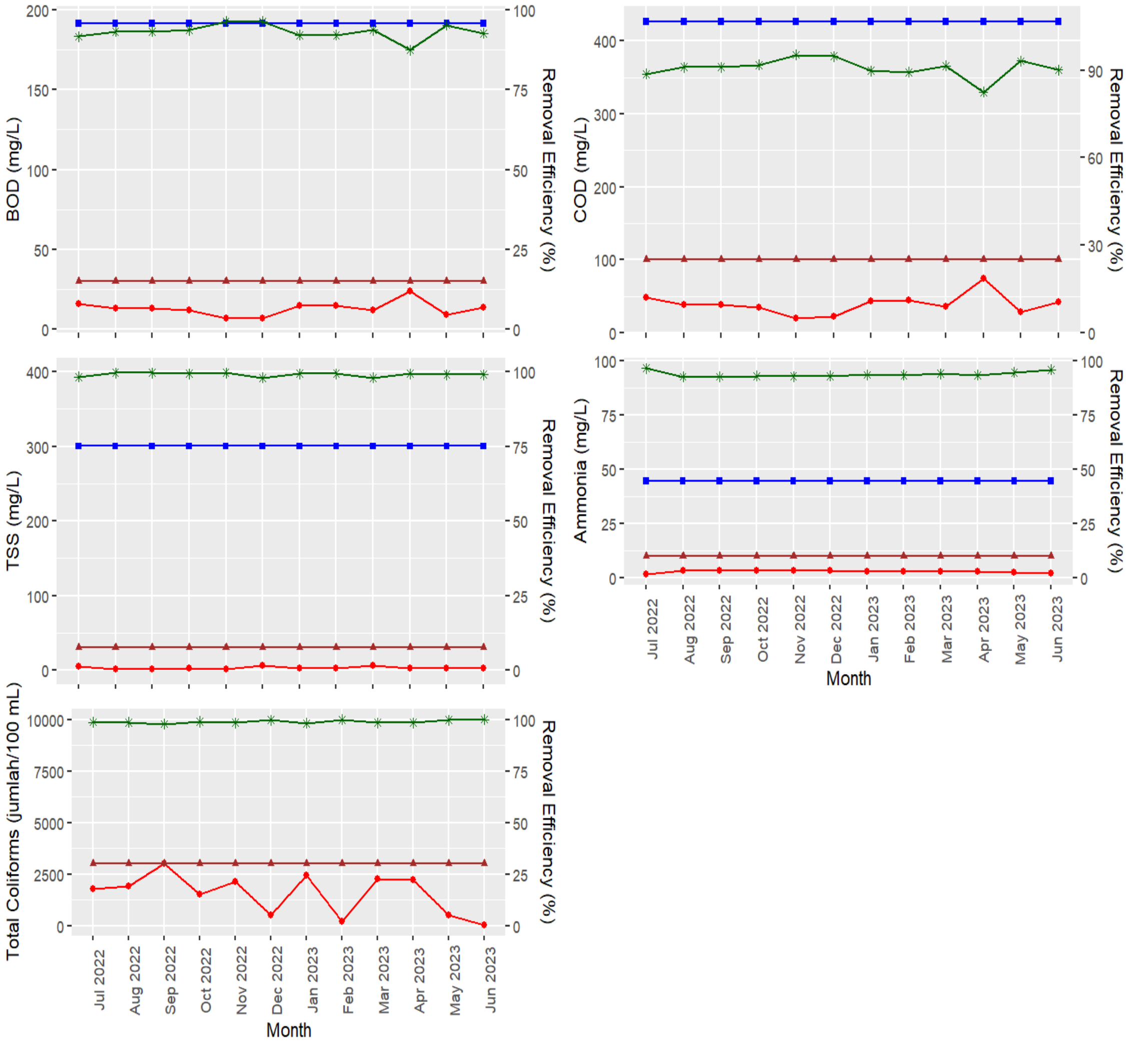

Figure 2. Performance sewage treatment plant in "X" garment industry

Based on Figure 2**,** illustrates the ability of the anaerobic-anoxic-MBBR process to degrade organic loads, particularly those associated with BOD, COD, and ammonia, which are dominant in this STP system. The process, when applied to the load planning calculation, results in a degradation of BOD, COD, and ammonia organic loads of 28.70 Kg BOD/day, 64.00 Kg COD/day, and 6.67 Kg ammonia/day, with a total volume of

Manuscript received 21 Aug 2023; revised 1 Sep 2024; accepted 13 Jan 2024

honeycomb media of 40%. The anaerobic tank has a capacity of 60 m³, and the load produced in the honeycomb media can be managed at a rate of 1.196 kg BOD/m³. day, 2.66 kg COD/m³.day and 0.278 kg COD/m³.day.

In contrast, the anoxic process is designed to have only 20% efficiency and can manage a load of 13.39 kg BOD/day, 28.86 kg COD/day, and 3.11 kg ammonia/day. The capacity of anoxic media with a surface area of 800 m2/m3 and a volume of 3 m3 can be calculated as follows: the resulting load capacity is 4,465 Kg BOD/m3.day, 9,956 Kg COD/m3.day and 1,038 Kg COD/m3.day. The aeration process, which employs biochip-based MBBR media, resulted in a loading and processing load of 42.86 kg BOD/day, 95.58 kg COD/day, and 9.968 kg ammonia/day. The biochip media employed in the planning process can manage loads of 14.28 kg BOD/m³. day, 31.86 kg COD/m³.day, and 3.32 kg COD/m³.day. Over a year, from July 2022 to June 2023, the results of the processing process were largely consistent with those predicted in the planning process. In the latter, a process efficiency of 30% in Anaerobic, 20% in Anoxic, and 80% in the MBBR process was assumed, resulting in an outlet BOD, COD, and ammonia concentration of 21.43 mg/L, 48.79 mg/L, and 4.98 mg/L. The aerobic, anoxic and MBBR processes yielded outlet BOD, COD, and ammonia concentrations of 21.43 mg/L, 48.79 mg/L, and 4.98 mg/L, respectively. The results obtained from the MBBR process using a Biochip were found to be significantly superior to those obtained from the Kaldness media process. When comparing the Anoxic process using 3 m3 of media (800 m2/m3) with the MBBR biochip (2500-5000 m^2/m^3), it was observed (Figure 3) that the two processes exhibited notable differences in terms of the attached growth and biofilm produced.

Figure 3. MBBR media for 1 year Sewage Treatment Plant Operations

Based on performance in Figure 2, Parameters of biological oxygen demand (BOD), chemical oxygen demand (COD), and ammonia, the parameters of total suspended solids (TSS), oil and grease, and total coliform also significantly contribute to the reduction process. The reduction process of TSS, oil, and grease, and total coliform resulted in 99.06%, 89.56%, and 98.87%, respectively. This process is by the findings of the study conducted by (Govindaraju et al., 2022). The TSS decomposition process is highly dependent on the biofilm formed in MBBR media, particularly Biochip media. In contrast, the total coliform process is processed using UV 254 nm, which has the potential to reduce the total coliform content in the output water. The results obtained from the domestic wastewater treatment process using the MBBR system demonstrate that the treatment process using MBBR is highly effective in reducing the efficiency of organic parameters (BOD, COD, etc.). Furthermore, the process provides efficiency on the use of land, as evidenced by the application of the MBBR in the STP system, which results in a residence time of 3 hours for the anaerobic process, 3 hours for the anoxic process, and 2 hours for the aerobic process (MBBR Biochip) with a water volume of 40 M3 from a tank volume of 60 m3. The findings demonstrate that the MBBR system is capable of effectively treating wastewater with a high level of efficiency, exceeding 90%. These results are generally consistent with those previously reported by (Barwal & Chaudhary, 2014).

4. Conclusion

"X" industry WWTP was evaluated in this study to see its ability to treat domestic wastewater. By combining aerobic, anaerobic, and anoxic processes, it can effectively reduce the concentration of BOD, COD, TSS, oil and grease, total ammonia, and total coliform parameters, so that the effluent meets water quality standard. Average removal efficiency for BOD, COD, TSS, total ammonia, and total coliform respectively are 93.16%; 90.76%; 99.06%; 93.78%; and 98.87%. Meanwhile, oil and grease parameter have removal efficiency value in the range of >85.02% - >92.81%. A biochip-based moving bed biofilm reactor technology utilised in domestic wastewater treatment is capable of handling high levels of organic matter and producing discharge quality that conforms to the stipulated discharge regulations.

5. Acknowledgments

The researcher would like to express his deepest gratitude to all those who have provided support and assistance during the preparation of the project/research. who have provided support and assistance during the preparation of this research.

REFERENCES

Aziz, Asad, Farrukh Basheer, Ashish Sengar, Irfanullah, Saif Ullah Khan, and Izharul Haq Farooqi. 2019. "Biological Wastewater Treatment (Anaerobic-Aerobic) Technologies for Safe Discharge of Treated Slaughterhouse and Meat Processing Wastewater." Science of the Total Environment. Elsevier B.V. https://doi.org/10.1016/j.scitotenv.2019.05.295.

Barwal, Anjali, and Rubina Chaudhary. 2014. “To Study the Performance of Biocarriers in Moving Bed Biofilm Reactor (MBBR) Technology and Kinetics of Biofilm for Retrofitting the Existing Aerobic Treatment Systems: A Review.” Reviews in Environmental Science and Bio/Technology 13 (September). https://doi.org/10.1007/s11157-014-9333-7.

Bassin, J. P., I. N. Dias, S. M.S. Cao, E. Senra, Y. Laranjeira, and M. Dezotti. 2016. “Effect of Increasing Organic Loading Rates on the Performance of Moving-Bed Biofilm Reactors Filled with Different Support Media: Assessing the Activity of Suspended and Attached Biomass Fractions.” Process Safety and Environmental Protection 100 (March):131–41. https://doi.org/10.1016/j.psep.2016.01.007.

R. A. Govindaraju, G. Parivallal, A. Nagalingam, and S. Devarajan, “Performance evaluation of 1 MLD MBBR type sewage treatment plant,” *Indian Journal of Microbiology Research*, vol. 9, no. 2, pp. 149–152, 2022, https://doi: 10.18231/j.ijmr.2022.027.

Koyuncu, Serdar, and Sema Arıman. 2020. “Domestic Wastewater Treatment by Real-Scale Electrocoagulation Process.” Water Science and Technology 81 (4): 656–67. https://doi.org/10.2166/wst.2020.128.

Mažeikienė, Aušra, and Julita Šarko. 2023. “Additional Treatment of Nitrogen and Phosphorus Using Natural Materials in Small-Scale Domestic Wastewater Treatment Unit.” Water (Switzerland) 15 (14). https://doi.org/10.3390/w15142607.

Ranieri, Ezio, Silvia Giuliano, and Ada Cristina Ranieri. 2021. “Energy Consumption in Anaerobic and Aerobic Based Wastewater Treatment Plants in Italy.” Water Practice and Technology 16 (3): 851–63. https://doi.org/10.2166/wpt.2021.045.

Srivastava, Nimmy, and Jayeeta Chattopadhyay. 2021. “Bacterial Community Structure, Composition and Their Role in Biological Wastewater Treatment Reactors Plants.” In Wastewater Treatment Reactors: Microbial Community Structure, 583–97. Elsevier. https://doi.org/10.1016/B978-0-12-823991-9.00020-4.

Widyarani, Diana Rahayuning Wulan, Umi Hamidah, Ahmad Komarulzaman, Raden Tina Rosmalina, and Neni Sintawardani. 2022. “Domestic Wastewater in Indonesia: Generation, Characteristics and Treatment.” Environmental Science and Pollution Research. Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/s11356-022-19057-6.

Yorkor, B, and Y O L Momoh. 2019. “A Review of Anoxic Wastewater Treatment: An Overlooked Aspect in Wastewater Treatment in Nigeria.” American Journal of Water Resources 7 (4): 136–45. https://doi.org/10.12691/ajwr-7-4-2.

Manuscript received 21 Aug 2023; revised 1 Sep 2024; accepted 13 Jan 2024