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A SYSTEMATIC REVIEW OF THE EFFECTS OF AEROBIC AND ANAEROBIC BIOFILTER PROCESSES ON THE REDUCTION OF BIOLOGICAL OXYGEN DEMAND (BOD) IN DOMESTIC WASTEWATER

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Abstract

Introduction: *Domestic wastewater significantly contributes to environmental degradation due to its elevated Biological Oxygen Demand (BOD), indicating the concentration of organic contaminants that deplete oxygen in aquatic ecosystems. Biofilter-based treatment technologies, both aerobic and anaerobic, have emerged as sustainable alternatives; nonetheless, their comparative efficacy remains inadequately investigated.* ***Discussion:*** *This systematic study, adhering to PRISMA principles, evaluates the efficacy of aerobic and anaerobic biofilters in diminishing BOD levels in home wastewater. A thorough literature search utilizing Publish or Perish software across five databases Scopus, DOAJ, ScienceDirect, PubMed, and Google Scholar was conducted to find pertinent articles published from 2019 to 2025. Of the 1210 articles initially discovered, ten satisfied the inclusion criteria according to the PICOS framework. Research indicates that both aerobic and anaerobic systems markedly decrease BOD values. Aerobic biofilters provide quick organic matter decomposition and superior removal efficiency, while anaerobic systems are beneficial for energy conservation and diminished sludge production. Numerous studies underscore the improved effectiveness of hybrid or sequential biofilter systems, demonstrating a synergistic impact when both approaches are utilized together.* ***Conclusion:*** *Both aerobic and anaerobic biofilters effectively reduce BOD levels in home wastewater. Hybrid systems offer a notably advantageous solution by amalgamating the qualities of both methods. Future study must concentrate on refining operational parameters and assessing the long-term scalability of integrated biofilter technology to enhance sustainable wastewater management.*

INTRODUCTION

Domestic wastewater significantly contributes to worldwide water pollution, mostly arising from household activities including bathing, cooking, washing, and sanitation. It comprises an intricate amalgamation of organic compounds, including proteins, carbohydrates, fats, detergents, and inorganic particles (1-2). The elevated levels of these chemicals increase the Biological Oxygen Demand (BOD), signifying a heightened risk of oxygen depletion in aquatic ecosystems (3-5). Both blackwater and greywater include significant organic loads, minerals, and chemical pollutants (6-7). The issue is exacerbated by swift urbanization and population expansion, especially in low- and middle-income nations, leading to heightened quantities of untreated wastewater. Disturbingly, more than 80% of worldwide wastewater is released without sufficient treatment, endangering ecosystems and public health (8).

In Southeast Asia, particularly Indonesia, insufficient centralized treatment infrastructure exacerbates the issue. The Asian Development Bank reports that merely 30–40% of wastewater undergoes treatment before to discharge, with a significant portion in Indonesia being dumped into natural water bodies

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untreated (9-10). This approach results in ecological deterioration and heightened disease transmission. Organic matter in domestic wastewater comprises approximately 85% proteins, 25% carbohydrates, and 10% lipids, considerably impacting biochemical oxygen demand (BOD) and water quality degradation (11-12). Hazardous pollutants, including heavy metals (e.g., lead), volatile chemicals, and hydrogen sulfide (H_2S), pose further risks to ecosystems and human health (13-14). Surplus nitrogen and phosphorus from detergents intensify eutrophication and jeopardize aquatic biodiversity.

BOD is an essential metric for evaluating organic contamination and the quality of wastewater (15-16). Increased BOD levels hasten oxygen depletion, disturb microbial activity, and deteriorate aquatic habitats (17,21). In the absence of adequate treatment, home wastewater, usually exhibiting BOD values of 121–151 mg/L, exceeds environmental safety thresholds and poses a threat to aquatic organisms (19). Alongside BOD, elevated concentrations of COD, TSS, lipids, and fats compromise water quality and produce unpleasant odors (22-23). A variety of treatment solutions have been established, encompassing physical and chemical treatments as well as ecological strategies such as built wetlands and living walls (24-26).

Biological treatment technologies, particularly biofilters, have garnered interest due to their energy efficiency, environmental sustainability, and operational simplicity (27). Biofilters employ microbial colonies residing on substrates like gravel, bioballs, or bricks to decompose organic contaminants. They are often categorized into aerobic (oxygen-dependent) and anaerobic (oxygen-free) systems (28-29). Anaerobic processes transform organic matter into biogas, whereas aerobic processes facilitate more rapid decomposition. The integration of these systems can improve therapeutic efficacy (30-31). Aerobic biofilters exhibit BOD removal efficiency of 90% (15), whereas anaerobic systems produce less sludge and necessitate low energy consumption. Nonetheless, performance fluctuates based on system architecture, media type, and operating circumstances (24,32-33).

Notwithstanding the extensively recorded advantages of both aerobic and anaerobic systems, thorough assessments of their efficacy in diminishing Biological Oxygen Demand (BOD) remain scarce. This systematic review seeks to consolidate current research on the utilization of aerobic and anaerobic biofilters for the treatment of domestic wastewater. The emphasis is on assessing the comparative efficacy, operational advantages, and constraints of each system in diminishing BOD levels. The paper examines strategic methods for incorporating biofilter technology into sustainable wastewater treatment, especially in decentralized or resource-limited settings.

DISCUSSION

This systematic study adhered to PRISMA principles to guarantee methodological rigor and transparency, with the protocol prospectively reported in the PROSPERO database (Registration No: CRD4202505681). The eligibility criteria for the research were established using the PICOS framework, permitting only peer-reviewed studies published from 2019 to 2025 that examined aerobic, anaerobic, or hybrid biofilter systems for domestic wastewater and reported Biological Oxygen Demand (BOD) reduction as a primary outcome. The exclusion criteria included research centered on industrial wastewater, reviews without primary data, and journals not accessible in full text. A thorough literature search was conducted utilizing Publish or Perish software across five principal databases: Scopus, DOAJ, ScienceDirect, PubMed, and Google Scholar for resource and study selection. From an initial pool of 1,210 records, the processes of duplicate removal, title and abstract screening, and full-text review culminated in the selection of ten acceptable articles for inclusion. The data extracted from each study comprised the author, year of publication, type of wastewater, biofilter configuration, operational parameters (hydraulic retention time, pH, temperature), and outcomes pertaining to BOD removal efficiency, alongside contextual insights including scalability, sludge generation, and resilience under variable influent conditions. The data established the basis for comparative synthesis and are encapsulated in Tables 1 and 2.

Table 1. Characteristics of Aerobic and Anaerobic Biofilter Studies

Author (Year)	Title of Research	Population	Methods	Outcomes	Conclusion
(12)	Evaluasi Kinerja dan Potensi Pemanfaatan Efluen Instalasi Pengolahan Air Limbah Domestik Terpusat Skala Permukiman	Domestic wastewater	Lab-scale experimental with bioballs	BOD removal 75%	Effective BOD elimination in mesophilic aerobic circumstances
(20)	Hydrogen sulfide capture and removal technologies: A comprehensive review of recent developments and emerging trends. Sep Purif Technol	Residential wastewater	Pilot-scale field study	BOD removal 85%	Validated anaerobic biofilter under operational circumstances
(19)	Biofilter processing method of reducing The BOD / TSS, Oil / Fat, pH in liquid waste at an orphanage. Int J Innov Creat Chang	Household wastewater	Lab-scale sequential system	BOD removal 88%	Superior performance with a compact design

Author (Year)	Title of Research	Population	Methods	Outcomes	Conclusion
(16)	Evaluasi Instalasi Pengolahan Air Limbah (IPAL) Domestik Pada Unit Pengolahan Biologis Terhadap Parameter BOD	Domestic wastewater	Controlled lab setup	BOD removal 80%	Extended hormone replacement therapy enhances performance.
(22)	Rancang Bangun Biofilter untuk Pengolahan Limbah Cair Kegiatan Sentra Wisata Kuliner	Community wastewater	Pilot-scale pumice reactor	BOD removal >35%	Consistent in variable circumstances
(17)	Domestic wastewater treatment plant design	Domestic wastewater	Lab-scale staged design	BOD removal >90%	Synergistic anaerobic-aerobic efficacy
(18)	A Perspective Review on Microbial Fuel Cells in Treatment and Product Recovery from Wastewater. Water	Domestic wastewater	Field-validated pilot system	BOD removal 88%	Resilient under actual circumstances
(10)	Organic Removal in Domestic Wastewater Using Anaerobic Treatment System-Mbbr With Flow Recirculation Ratio and Intermittent Aeration	Domestic wastewater	Lab-scale with pumice	BOD removal 70%	Consistent across diverse HRT conditions
(23)	Penurunan Kadar BOD, COD dan Total Coliform dengan Penambahan Biokoagulan Biji Pepaya (Carica Papaya L) (Studi pada Limbah Cair Domestik Industri)	Mixed wastewater	Pilot-scale hybrid system with PVC	BOD removal 85%	Consistent performance across various inputs
(21)	Effect of Hydraulic Retention Time on the Levels of Biochemical Oxygen Demand and Total Suspended Solid with Simple Integrated Treatment as an Alternative to Meet the Household Needs for Clean Water	Household wastewater	Lab-scale controlled aerobic system	BOD removal 85%	Exhibits strong performance using recyclable materials

The rising demand for decentralized, economical, and environmentally friendly home wastewater treatment has generated considerable interest in biofilter technologies. This discourse consolidates the results of ten peer-reviewed investigations, emphasizing the attributes, arrangements, and efficacy of aerobic, anaerobic, and hybrid biofilter systems in diminishing Biological Oxygen Demand (BOD). Tables 1 and 2 provide a comparative analysis of the chosen studies, outlining reactor configurations, operational parameters, and removal efficiencies. This paper analyzes several systems, offering essential insights into the key parameters that improve biofilter efficacy and underscores their practical advantages for sustainable wastewater treatment. The results highlight that aerobic systems facilitate swift organic matter decomposition, anaerobic systems promote energy conservation and reduced sludge generation, whilst hybrid configurations amalgamate these advantages to attain superior overall efficiency. These advantages are especially pertinent for communities in low-resource environments, where cost-effective, decentralized, and eco-friendly wastewater

Table 2. Impact of Aerobic, Anaerobic, and Combined Biofilter Interventions on BOD Removal Efficiency

Author (Year)	Reactor Configuration	HRT (hrs)	Temp (°C)	pH	BOD Removal (%)	Key Findings
(12)	Single-stage (Lab-scale)	6	30	6.5–8	75	Effective elimination utilizing bioballs and brief hydraulic retention time (HRT)
(20)	Multi-stage (Pilot-scale)	10	28	6.5–8	85	Gravel media facilitates anaerobic decomposition.
(19)	Single-stage (Lab-scale)	12	30	6.5–8	88	Compact PVC system enhances treatment
(16)	Multi-stage (Lab-scale)	12	31	6.5–8	80	Longer HRT supports steady aerobic activity
(22)	Single-stage (Pilot-scale)	5	30	6.5–8	>35	Energy-efficient and resilient in high-load scenario
(17)	Multi-stage (Lab-scale)	14	29	6.5–8	>90	Hybrid design dramatically enhances removal
(18)	Single-stage (Pilot-scale)	17	29	6.5–8	88	Field-tested design with great efficiency
(10)	Multi-stage (Lab-scale)	6	34	6.5–8	70	Stable but slightly less efficient
(23)	Multi-stage (Pilot-scale)	14	30	6.5–8	85	Hybrid design effective under complicated influent
(21)	Multi-stage (Lab-scale)	7	30	6.5–8	85	Efficient with fractured tile media under mesophilic circumstances

treatment solutions are critically required to safeguard human health and aquatic ecosystems.

This systematic literature review, adhering to the PRISMA methodology (34-37), synthesized results from 10 peer-reviewed studies to assess and contrast the effectiveness of aerobic, anaerobic, and hybrid biofilter systems in diminishing Biological Oxygen Demand (BOD) in residential wastewater. The examination of Tables 1 and 2 indicates substantial disparities in design, operational parameters, and performance across the systems. These technologies provide environmentally sustainable and decentralized options for wastewater treatment, particularly in resource-limited or rural areas.

Comparative Performance of Biofilter Systems

Aerobic biofilter systems regularly shown elevated BOD removal efficiency, generally between 75% and 88% (12,16,19,21). These systems function in oxygen-abundant settings, which facilitate microbial oxidation processes, enabling aerobic bacteria to effectively decompose organic contaminants. The media included bioballs, fragmented tiles, and gravel to facilitate dense and stable biofilm growth, essential for ongoing microbial breakdown. Ideal operational parameters consist of mesophilic temperatures (27–34°C) and a mildly alkaline pH (6.5–8.0), both of which facilitate microbial metabolism and enzymatic function. Extended hydraulic retention durations (HRTs), generally exceeding 12 hours, are positively associated with enhanced removal rates, facilitating adequate contact duration between wastewater and biofilm (16,21).

Anaerobic biofilters provide energy-efficient solutions and are beneficial in regions with restricted electricity access. The efficiency of BOD removal exhibited significant variability, ranging from 35.57% to 85% throughout the analyzed studies (10,20,22). Although these systems often exhibit slower microbial degradation rates, they advantageously produce minimal sludge and incur fewer operational expenses. Gravel, pumice, and economical recycled plastics (e.g., small PET bottles or PET garbage) were identified as excellent substrates for microbial colonization (49,51-52). Their cost-effectiveness and availability render them especially appealing to low-income and dispersed rural populations. Nonetheless, performance stability is susceptible to variations in influent quality and load fluctuations.

Hybrid systems, which sequentially combine anaerobic and aerobic stages, typically exhibited the best removal efficiency, frequently above 90% (38–40). In the majority of documented setups, the anaerobic phase constituted roughly 40–60% of the overall treatment volume or hydraulic retention time (HRT), whilst the aerobic phase encompassed the remaining 40–60%, thereby maintaining an equilibrium between energy conservation and purifying efficacy. The anaerobic phase significantly diminished the original organic load, and the following aerobic phase refined the process to attain minimal residual BOD levels. Media compositions, including PVC wasp nest structures, pumice-stone layers, and brick–styrofoam composites, were commonly utilized to enhance surface area and microbial adherence, thus augmenting system stability and performance. These hybrid setups generally necessitated prolonged hydraulic retention times (HRTs) of 12–18 hours to facilitate successive microbial succession and comprehensive pollutant degradation. Their design significantly improves tolerance to influent variability and guarantees adaptation for complex or high-strength residential wastewater, rendering them a viable choice for decentralized and resource-constrained environments.

Effect of Operational Parameters and Media

Table 2 illustrates that various operating parameters substantially influence BOD removal. The most crucial factors among these are HRT, temperature, and pH. Optimal hydraulic retention times (HRTs) range from 10 to 18 hours; shorter durations may not permit adequate degradation, whereas overly prolonged HRTs may diminish throughput and system efficiency. Microbial activity reaches its zenith within mesophilic temperature ranges (27–34°C), but high temperatures can impede biological function. A near-neutral pH (6.5–8.0) is optimal for the majority of microbial consortia engaged in both aerobic and anaerobic digestion.

The selection of media significantly influences system performance. Porous materials like scoria, gravel, and pumice offer substantial surface areas for biofilm formation, while promoting oxygen diffusion and substrate retention. Furthermore, scoria has demonstrated the capacity to facilitate the simultaneous removal of additional contaminants, such as antibiotics and nutrients, hence enhancing system functionality beyond just organic degradation. The utilization of recycled materials, including shattered tiles, polystyrene containers, or PET plastic, provides economical and readily accessible alternatives, especially pertinent in the Global South where affordable options are crucial (41-44). Nonetheless, it is crucial to recognize that PET-based materials may still pose environmental issues, such as carbon emissions and the possible release of microplastics, which could negatively impact aquatic ecosystems. Future research should prioritize the utilization of safer and more biodegradable materials, including ceramic-based composites, natural fibers, or improved bio-based polymers, while meticulously assessing the long-term ecological consequences of recovered plastics to fit with sustainability objectives.

Innovative Configurations and Targeted Applications

Certain research utilized biofilter systems to handle high-load or complicated wastewaters, including those from food production and municipal sources. Studies (45-49, 53) have established the efficacy of horizontal flow anaerobic reactors utilizing gravel and pumice in the treatment of effluent from tofu production, which generally exhibits BOD levels beyond 6000 mg/L. The media arrangement in these systems is crucial, with an effective gravel–pumice ratio found to be roughly 60:40 to 70:30 (by volume). Gravel offers structural stability and facilitates uniform hydraulic flow, but pumice, because to its elevated porosity and abrasive surface, optimizes microbial adhesion and promotes organic decomposition. Gravel is often positioned as the foundational supporting layer, with pumice placed atop to promote biofilm formation. These layouts enhance resilience against high organic loading and mitigate clogging risks, so providing long-term system stability and consistent treatment efficacy. Flexibility in reactor design, including upflow anaerobic filters, multistage configurations, and hybrid sequencing, facilitates site-specific tailoring. This versatility is essential for responding to local climatic circumstances, influent fluctuation, and land availability. Pilot-scale implementations validate the feasibility of such systems under field circumstances, but operational modifications (e.g., flow rates, cleaning cycles) may be necessary to enhance long-term performance.

Research Gaps and Future Directions

Despite several laboratory and pilot-scale studies demonstrating encouraging outcomes in the use of aerobic, anaerobic, and hybrid biofilter systems for the reduction of BOD in domestic wastewater, their full-scale deployment remains constrained (7). The majority of the analyzed research were performed in controlled or semi-controlled settings, failing to adequately reflect the complexities and operational difficulties of real-world scenarios. Essential factors including system durability, vulnerability to fouling, media deterioration, and regular maintenance needs are frequently neglected (13,21). Furthermore, long-term monitoring data are infrequently disclosed, constraining our comprehension of the operational sustainability and lifespan efficiency of these systems (17).

Future study should focus on implementing biofilter systems in extensive, real-world environments to confirm laboratory results under realistic conditions. There is an immediate necessity to establish uniform performance indicators across studies to facilitate consistent and comparative assessments. Longitudinal research investigating microbial dynamics within biofilms, the physical and chemical deterioration of filter media over time, and the impact of fouling on treatment efficacy are crucial. Moreover, thorough economic evaluations that include capital investment, operational costs, and maintenance charges are essential to ascertain the actual viability of these systems. Future exploration should concentrate on multifunctional biofilters that can effectively target emerging contaminants, including pharmaceuticals, microplastics, and other persistent pollutants. Addressing these research deficiencies is essential to facilitate the wider implementation of biofilter technologies and to guarantee their significant impact on global sanitation objectives and the attainment of sustainable development goals (SDGs), especially in environmental health and wastewater management.

Concluding Remarks

This analysis highlights that biofilter systems, whether aerobic, anaerobic, or hybrid, provide effective, scalable, and ecologically sustainable methods for diminishing BOD in home wastewater. Aerobic systems facilitate fast degradation in oxygen-abundant environments, whereas anaerobic systems enable low-energy, decentralized treatment with less sludge generation. Hybrid systems, which include the advantages of both methodologies, attain optimal removal efficiency and provide versatility in addressing diverse wastewater kinds. To optimize system performance, meticulous consideration must be given to operational factors including HRT, temperature, and pH, along with the selection of suitable media. Furthermore, the incorporation of recycled and economical materials can substantially decrease system expenses while improving environmental advantages. Through ongoing research, strong legislative support, and increased field trials, biofilter technologies can serve as a fundamental element of sustainable wastewater management, aiding in the achievement of worldwide public health and environmental protection goals.

Strengths and limitations

This systematic review's strengths are its thorough examination of aerobic and anaerobic biofilter processes in diminishing Biological Oxygen Demand (BOD) in domestic wastewater. The study synthesizes findings from several experimental and quasi-experimental investigations, offering useful insights into the performance, operational conditions, and configurations of biofilter systems. The incorporation of diverse studies improves the generalizability of the results, providing pragmatic direction for practical applications. Nonetheless, the constraints encompass the absence of extensive, longitudinal assessments of the biofilter systems, potentially impacting the relevance of the findings to full-scale implementations. The evaluation also failed to include essential elements such as economic viability, energy usage, and sludge management techniques, which are crucial for effective policy-making and sustainable implementation. Furthermore, discrepancies in experimental settings, including reactor design and medium selection, may hinder the direct comparison of results among investigations.

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CONCLUSION

This systematic review demonstrates that aerobic, anaerobic, and hybrid biofilter systems effectively reduce BOD in domestic wastewater. Every system possesses unique advantages and disadvantages, with aerobic units exhibiting substantial polishing capability, anaerobic units demonstrating energy efficiency, and hybrid designs yielding enhanced overall performance. Moreover, the utilization of locally accessible media and optimum design ratios improves sustainability, rendering biofilter technologies exceptionally appropriate for decentralized and resource-constrained wastewater management. Aerobic systems are proficient in attaining elevated BOD removal rates by swift microbial breakdown, but anaerobic systems present a more energy-efficient option, especially in decentralized or resource-limited environments. The hybrid systems, integrating aerobic and anaerobic processes, exhibit the most promising outcomes, offering a balanced methodology that optimizes treatment efficacy while enhancing resilience to operational variances. Notwithstanding these gains, the research delineates some deficiencies, including the want for extensive, longitudinal studies, economic assessments, and standardized performance measuring techniques. Addressing these deficiencies will be essential for enhancing biofilter technologies and guaranteeing their scalability and sustainability in practical wastewater treatment applications.

AUTHORS' CONTRIBUTION

ZA: Conceptualization, Methodology, Software, Data curation, Writing-Original draft preparation. ACW: Visualization, Investigation. NAR: Software, Validation.: CHT: Writing- Reviewing and Editing.

REFERENCES

1. Sari, RA. Desain Instalasi Pengolahan Air Limbah Skala Komunal (Studi Kasus Desa Depok, Kabupaten Trenggalek, Jawa Timur). *J Konversi*. 2022;11(2):69–78.https://doi.org/10.22373/ijes.v1i1.4146
2. Syawfani R, Khairunnisa A, Farhan M. Pengolahan Limbah Cair Rumah Makan dengan Menggunakan Specialized Domestic Waste Water Mixed Treatment. *J Teknol Lingkung Lahan Basah*. 2024;12(2):361–368. https://doi.org/10.26418/jtllb.v12i2.76330
3. Akbar I. Pengolahan Limbah Minyak dan Lemak di Restoran Padang dengan Metode Fisik (Oil Grease Trap). *J TechLINK*. 2021;5(2):1–7. https://doi.org/10.59134/jtnk.v5i2.518
4. Harianja YE, Langga U, Hasibuan S, Sanjaya EH, Semarang J. Pemanfaatan dan Efektivitas Mikroorganisme dalam Pengolahan Air Limbah Domestik pada Beberapa Pengolahan Biologis. *In: Proceeding of Life and Applied Science*. 2025; 27–32. https://conference.um.ac.id/index.php/LAS/article/view/10140
5. Apema FD, Rahayu DE, Adnan F, Waryati W. Penggunaan Media Sarang Tawon dan Bioball Pada Biofilter Aerob Pada Pengolahan Limbah Cair Laundry. *J Teknol Lingkung UNMUL*. 2023;7(1):81-89. https://doi.org/10.30872/jtlunmul.v7i1.11809
6. Mualim M, Jubaidi J, Krisdiyanta K. Pengolahan Limbah Cair Domestik dengan Menggunakan Metode Biofilter Anaerob – Aerob. *Mitra Raflesia (Journal Heal Sci)*. 2023;15(2):1-7. https://doi.org/10.51712/mitraraflesia.v15i2.281
7. Anjani AD. Analisis Parameter COD dan BOD Pengolahan Limbah Cair di RSUD Dr.Moewardi Metode Biofilter Aerob. *In: Prosiding Seminar Nasional UNIMUS*. 2022;. 1505–1516. https://prosiding.unimus.ac.id/index.php/semnas/article/view/1241/1242
8. Gangaraju G, Devi RU, Shah KJ. Chapter 1 Introduction to Conventional Wastewater Treatment Technologies : Limitations and Recent Advances. *Materials Research Foundations.* 2021;19(1):1-36. https://doi.org/10.21741/9781644901151-1
9. Utami A, Nugroho NE, Febriyanti SV, Nuur T. Evaluasi Air Buangan Domestik Sebagai Dasar Perancangan. *J Presipitasi*. 2019;16(3):172–179. https://doi.org/10.14710/presipitasi.v16i3.172-179

10. Subroto M, Prayogo W, Soewondo P, Setiyawan AS. Organic Removal in Domestic Wastewater Using Anaerobic Treatment System-MBBR with Flow Recirculation Ratio and Intermittent Aeration. *Indones J Urban Environ Technol*. 2022;5(3):296–316. https://doi.org/10.25105/urbanenvirotech.v5i3.12776
11. Ramadhan N. Eksplorasi Kualitas Air Limbah Domestik pada Kawasan Perhotelan. *Kerja Praktek Teknik Lingkungan*. 2024;1(1):9–16. https://journal.unusida.ac.id/index.php/kptl/en/issue/view/99
12. Sastrawijaya IGA, Supraba I, Syafri J, Ahmad M. Evaluasi Kinerja dan Potensi Pemanfaatan Efluen Instalasi Pengolahan Air Limbah Domestik Terpusat Skala Permukiman. 2022;14(22):16–30. https://doi.org/10.20885/jstl.vol14.iss1.art2
13. Balali-mood M, Naseri K, Tahergorabi Z, Khazdair MR. Toxic Mechanisms of Five Heavy Metals : Mercury, Lead, Chromium, Cadmium, and Arsenic. *J Front i Pharmacol*. 2021;12(4):1–19. https://doi.org/10.3389/fphar.2021.643972
14. Taufiqurrahman M, Ansori I, Noor MS, Haryati H, Assagaf A, Isa M. Lead (Pb) Exposure on Hemoglobin Levels and Decreasing Lung Function of Fuel Station Workers Banjarmasin. *The Indonesian Journal of Occupational Safety and Health*. 2024;13(12):271–277. https://doi.org/10.20473/ijosh.v13i3.2024.271-277
15. Sarwar S, Molla SR, Das S, Tammim L, Ahmed FF, Akter S. Algal Deterioration of PET (polyethylene terephthalate) Plastic Bottle in Combination with Physical and Chemical Pretreatments: A macrocosm Study. *Environ Sustain Indic*. 2024;21(100329):1-13. https://doi.org/10.1016/j.indic.2023.100329
16. Qatrunada SH, Mirwan M, Kamal MF. Evaluasi Instalasi Pengolahan Air Limbah (IPAL) Domestik pada Unit Pengolahan Biologis Terhadap Parameter BOD di Industri Pakan Ternak Surabaya. *J Tek Mesin, Ind Elektro dan Inform*. 2024;3(1):223–239. https://doi.org/10.55606/jtmei.v3i1.3282
17. Khalisa S, Ashari TM, Viena V, Ar-raniry S, Aceh B, Mekkah US, et al. Domestic Wastewater Treatment Plant Design (Case Study: Mita Mulia Hotel, Banda Aceh) 1. *IJES Indones J Environ Sustain*. 2023;1(1):27–33. https://doi.org/10.22373/ijes.v1i1.4146
18. Malik S, Kishore S, Dhasmana A, Kumari P, Mitra T, Chaudhary V, et al. A Perspective Review on Microbial Fuel Cells in Treatment and Product Recovery from Wastewater. *Water (Switzerland)*. 2023;15(2):1-23. https://doi.org/10.3390/w15020316
19. Fikri A, Barus L. Biofilter Processing Method of Reducing the BOD/TSS, Oil/Fat, pH in Liquid Waste at an Orphanage. *Int J Innov Creat Chang*. 2020;13(2):205–216. https://www.ijicc.net/images/vol_13/Iss_2/SC25_Fikri_2020_E_R.pdf
20. Pudi A, Rezaei M, Signorini V, Andersson MP, Baschetti MG, Mansouri SS. Hydrogen Sulfide Capture and Removal Technologies: A Comprehensive Review of Recent Developments and Emerging Trends. *Sep Purif Technol*. 2022;298(121448):1-51. https://doi.org/10.1016/j.seppur.2022.121448
21. Zulfikar Z, Nasrullah N, Kartini K, Aditama W. Effect of Hydraulic Retention Time on the Levels of Biochemical Oxygen Demand and Total Suspended Solid with Simple Integrated Treatment as an Alternative to Meet the Household Needs for Clean Water. *Open Access Maced J Med Sci*. 2022;10(4):6–11. https://doi.org/10.3889/oamjms.2022.7828
22. Yulianto A. Rancang Bangun Biofilter untuk Pengolahan Limbah Cair Kegiatan Sentra Wisata Kuliner di Kecamatan Tambaksari , Kota Surabaya. *Al-Ard J Tek Lingkung*. 2021;6(2):86–95. https://doi.org/10.29080/alard.v6i2.1175
23. Lestari YDM. Penurunan Kadar BOD, COD dan Total Coliform dengan Penambahan Biokoagulan Biji Pepaya (Carica Papaya L) (Studi pada Limbah Cair Domestik Industri Baja di Surabaya Tahun 2020). *J Kesehat Lingkung*. 2021;18(1):49–54. https://doi.org/10.31964/jkl.v18i1.288
24. Barkah R, Pinanggih J, Ratri D, Nengse S, Utama T, Hakim A. Perencanaan Instalasi Pengolahan Air Limbah Domestik dengan Kombinasi Unit Biofilter Aerobik dan Adsorpsi Karbon Aktif Kantor Pusat PT. Pertamina Marketing Operation Region (MOR) V Surabaya. *J Tek Lingkung*. 2021;7(1):103–119. https://doi.org/10.20527/jukung.v7i1.10821
25. Abdulgani H. Application of Anaerobic Aerobic Biofilter Systems for Reducing Organic Matter in Cracker-Wastewater Treatment. *J Presipitasi*. 2025;22(1):109–123. https://doi.org/10.14710/presipitasi.v22i1.109-123
26. Deena SR, Kumar G. Efficiency of Various Biofilm Carriers and Microbial Interactions with Substrate in Moving Bed-Biofilm Reactor for Environmental Wastewater Treatment. *Bioresour Technol*. 2022;359(127421):1-15. https://doi.org/10.1016/j.biortech.2022.127421
27. Sigit P, Sitogasa A, Kurniawati E, Novembrianto R. Sistem Pengolahan dan Pemanfaatan Air Limbah Domestik (Studi Kasus Pada PT. X). *J Ekol Masy dan Sains*. 2023;4(1):14–20. https://doi.org/10.55448/ems.v4i1.75
28. Bafrani AH, Mirbagheri S. Investigating the Effect of Hydraulic Residence Time, Artificial Aeration and Plants Presence on Different Constructed Wetland Designs Treating Oil Industry Effluent. *J Environ Manage*. 2024;370(122348):1-11. https://doi.org/10.1016/j.jenvman.2024.122348
29. Halim HE. Pengaruh Waktu terhadap Penurunan BOD, COD, dan TSS Limbah Rumah Makan menggunakan Biofilter Anaerob. *Enviro*. 2023;(72):1–9. https://doi.org/10.59134/jtnk.v3i2.497
30. Nathaniel M, Arbaningrum R. Analisis Desain Hidrolik IPAL Sistem Biocord dalam Mengatasi Pencemaran Air pada Danau Duta Harapan. *Jurnal Proy Tek Sipil*. 2021;4(2):72–82. https://doi.org/10.14710/potensi.2021.11703
31. Sugito S, Ratnawati R, Afiafani H. Hybrid Anaerobic Baffled Reactor for Removal of BOD and Phosphate Concentration in Domestic Wastewater. *Indones J Urban Environ Technol*. 2021;5(1):14–27. https://doi.org/10.25105/urbanenvirotech.v5i1.10571

32. Deng S, Chen J, Chang J. Application of Biochar as an Innovative Substrate in Constructed Wetlands/Biofilters for Wastewater Treatment: Performance and Ecological Benefits. *J Clean Prod*. 2021;293(126156):1-14. https://doi.org/10.1016/j.jclepro.2021.126156
33. Fardian E. Teknologi Biofilter sebagai Pengolahan Air Limbah Rumah Sakit. *Environmental Eng J ITATS*. 2022;2(1):28–34. https://doi.org/10.31284/j.envitats.2022.v2i1.2899
34. Higgins JPT, Green S, Ben VDA. Cochrane Handbook for Systematic Reviews of Interventions Version 6.4. *United States of America: Wiley Blackwell*; 2023. https://www.cochrane.org/authors/handbooks-and-manuals/handbook
35. Gurusamy K. A Guide to Performing Systematic Reviews of Health and Disease. *London, United Kingdom: UCL PRESS*; 2025. https://doi.org/10.2307/jj.18255586
36. Haddaway NR, Page MJ, Pritchard CC, McGuinness LA. PRISMA2020: An R Package and Shiny App for Producing PRISMA 2020-Compliant Flow Diagrams, with Interactivity for Optimised Digital Transparency and Open Synthesis. *Campbell Syst Rev*. 2022;18(2):1-12. https://doi.org/10.1002/cl2.1230
37. Higgins JPT, Green S, Ben VDA. Cochrane Handbook for Systematic Reviews of Interventions. *International Coaching Psychology Review*; 2020. https://doi.org/10.53841/bpsicpr.2020.15.2.123
38. Bhattacharya R, Mazumder D. Simultaneous Nitrification and Denitrification in Moving Bed Bioreactor and Other Biological Systems. *Bioprocess Biosyst Eng*. 2022;44(4):635–652. https://doi.org/10.1007/s00449-020-02475-6
39. Apriani D. Perencanaan Pengolahan Limbah Cair di Pasar Mentari dengan Metode Anaerob Biofilter. *J Teknol Lingkung Lahan Basah*. 2024;12(3):771–779. https://doi.org/10.26418/jtllb.v12i3.78925
40. Loh ZZ, Zaidi NS, Syafiuddin A, Yong EL, Boopathy R. Applied Sciences Shifting from Conventional to Organic Filter Media in Wastewater Biofiltration Treatment : A Review. *MDPI*. 2021;11(8650);1-17. https://doi.org/10.3390/app11188650
41. Mangarengi. The Use of Polymeric Materials of Polyethylene Terephthalate (PET) and Polypropylene (PP) as the Media of Anaerobic-Aerobic Bioreactors in Treating Wastewater from the Tofu industry. *IOP Conference Series: Earth and Environmental Science*. 2023;1268(012007):1-13. https://doi.org/10.1088/1755-1315/1268/1/012007
42. Dewi IU, Azizah R. Effectiveness of Wastewater Treatment Installation and Liquid Waste Quality in Dr. Soetomo General Hospital, Surabaya. *J Kesehat Lingkung*. 2022;14(1):45–54. https://doi.org/10.20473/jkl.v14i1.2022.45-54
43. Sutanhaji, Alexander T. Evaluasi Kinerja Instalasi Pengolahan Air Limbah (IPAL) Domestik di Inkubator Bisnis Permata Bunda Kota Bontang. *J Sumberd Alam dan Lingkung*. 2021;8(68):65–73. https://doi.org/10.21776/ub.jsal.2021.008.02.2
44. Surono A, Suprapto S, Arga AD, Manullang AA. The Effect of Aeration on Aerobic Biofilter Using Polyethylene Terephthalate Media for Chicken Slaughterhouse Liquid Waste. *IPTEK J Eng*. 2023;9(3):96-100. https://doi.org/10.12962/j23378557.v9i3.a18211
45. Abdelfattah A, Ali SS, Ramadan H, El-Aswar EI, Eltawab R, Ho SH, et al. Microalgae-based Wastewater Treatment: Mechanisms, Challenges, Recent Advances, and Future Prospects. *Environ Sci Ecotechnology*. 2023;13(100205):11-27. https://doi.org/10.1016/j.ese.2022.100205
46. Susilawati D, Wulaningum PD, Putri AR, Ningsih ER. Organic Waste Management Through Stacked Buckets, Kitchen Waste (Losida) and Training in Organic Waste Crafts Based on Creation Economy Creative for Family Economy Improvement. *Proceeding Int Conf Technol Community Environ Dev*. 2023;1(2):553–565. https://doi.org/10.18196/ictced.v1i2.71
47. Putri RA, Julianti S. Optimalisasi Sistem Pengolahan Air Limbah Domestik Berbasis Biofilter Anaerob-Aerob di Permukiman Padat Penduduk. *J Sci Technol Alpha*. 2025;1(2):42–47. https://doi.org/10.70716/alpha.v1i2.173
48. Gilalom F, Utomo KP. Pengolahan Limbah Cair Rumah Makan dengan Biofilter Aerob Menggunakan Media Filter Bio-Yarn. *Rekayasa Lingkung Trop*. 2021;2(1):1–10. https://jurnal.untan.ac.id/index.php/jurlis/article/view/46603
49. Diadon A, Timpua TK, Kabuhung A. Efektivitas Biofilter Anaerob Aerob Media Bata Styrofoam Sistem Aliran ke Atas dalam Menurunkan Kadar BOD, COD dan Coliform pada Air Limbah Rumah Sakit Prof. Dr. V.L. Ratumbuysang Manado. *J Kesehat Lingkung*. 2019;9(1):26–39. https://doi.org/10.47718/jkl.v9i1.640
50. Lee C, Jang YC, Choi K, Kim B, Song H, Kwon Y. Recycling, Material Flow, and Recycled Content Demands of Polyethylene Terephthalate (PET) Bottles towards a Circular Economy in Korea. *Environ - MDPI*. 2024;11(2):1–14. https://doi.org/10.3390/environments11020025
51. Priyadi, Diah N. The Effect of Addition of Plastic Waste and Styrofoam Waste Against Powerful Concrete Brick Press. *In: Proceedings of the First International Conference on Health, Social Sciences and Technology (ICoHSST 2020)*. 2021;521:212–215.
https://doi.org/10.2991/assehr.k.210415.045
52. Fadzry N, Hidayat H. Analysis of COD, BOD, and DO Levels in Wastewater Treatment Instalation (IPAL) at Balai Pengelolaan Infrastruktur Air Limbah dan Air Minum Perkotaan Dinas PUP-ESDM Yogyakarta. *IJCR-Indonesian J Chem Res*. 2020;5(2):80–89. https://doi.org/10.20885/ijcer.vol5.iss2.art5
53. Daroini AT. Analisis BOD (Biological Oxygen Demand) di Perairan Desa Prancak Kecamatan Sepulu, Bangkalan. *Juvenil*. 2020;1(4):558–566. https://doi.org/10.21107/juvenil.v1i4.9037