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Optimalization Of Domestic Wastewater Quality Using Filtration And Disinfection Technology To Meet Clean Water Standards

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Abstract:
This research aims to evaluate the effectiveness of a Filtration and Disinfection Technology system in improving the quality of domestic wastewater to meet clean water standards the Minister of Health Regulation Number 2 of 2023. The method involves comparing key pollutant parameters before and after treatment using a prototype filtering apparatus developed in this Thesis. The primary filter media used were Activated Carbon, Sand, and Zeolite. The results showed that the system was highly effective in reducing Dissolved Iron (Fe), achieving an efficiency of 85.12% (from 80.345 ug/L to 11.949 ug/L). Total Hardness was also significantly reduced by 24.52% (from 105.824 mg/L to 79.867 mg/L). All measured parameters post-treatment successfully met the maximum permissible levels set by the government. In conclusion, the Thesis confirms that this Filtration and Disinfection system is reliable and effective for decentralized domestic wastewater treatment in Palembang, particularly for heavy metal removal.

Keywords*: Domestic Wastewater, Filtrasi, Dissolved Iron, Total Hardness, the Minister of Health Regulation Number 2 of 2023*

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I. Introduction

he massive population growth and high rate of urbanization in Palembang have contributed significantly to the increasing volume and complexity of domestic wastewater. Household wastewater, originating from bathing, washing, and kitchen activities, contains various contaminants including organic matter, surfactants, dissolved solids, and heavy metal ions. If discharged directly into the environment without adequate treatment, this wastewater becomes a major source of water body pollution and poses risks to public health. To ensure the availability of clean water that is safe for consumption and free from health threats, the Indonesian Government has established strict quality standards stipulated in the Minister of Health Regulation Number 2 of 2023 concerning Clean Water Quality Standards.

Domestic wastewater characteristics in Palembang exhibit specific challenges that need to be addressed, particularly the high content of divalent ions (causing Total Hardness) and the concentration of dissolved metal ions, especially Iron (Fe). Based on initial test results, the Dissolved Iron content in the wastewater sample reached 80.345 ug/L. While this figure is below the maximum permissible limit (200 ug/L), a significant reduction effort is necessary to achieve optimal water quality, avoid aesthetic issues (color and taste), and mitigate potential long-term health effects. Therefore, the development of effective, applicable at the household level (decentralized), and cost-effective treatment technology is an urgent necessity.

Various treatment methods have been developed, ranging from biological (such as SBR), chemical (coagulation-flocculation), to advanced separation technologies like membranes. However, membrane technology often requires high initial investment and complex operational control. Addressing these limitations, this research adopts a simpler and more sustainable approach.

This Thesis presents a solution focused on the Design and Construction of a Household Wastewater Filter Tool to Produce Drinkable Water Using Filtration and Disinfection Technology. The prototype is designed as a simple *point-of-use* solution. The system integrates multi-media filtration, consisting of three main components: Activated Carbon (for adsorption of organic matter and odor), Silica Sand (for filtering coarse particulates), and Zeolite (effective in ion exchange to reduce hardness and dissolved Iron). The specific use of

Zeolite aims to address Total Hardness and metal ion issues. The final stage involves a disinfection process to ensure the water is safe for consumption.

The novelty of this research lies in the specific performance testing of the prototype designed in this Thesis against critical domestic wastewater parameters in Palembang, and validating the final results by strict comparison with the latest clean water quality standards the Minister of Health Regulation Number 2 of 2023.

Based on the background above, the main objectives of this Thesis are:

1. To quantitatively evaluate the efficiency of the Filtration and Disinfection prototype in reducing key wastewater pollutant levels, especially Dissolved Iron and Total Hardness.
2. To ensure that the post-treatment wastewater quality meets the clean water quality standards according to the en

II. Research Method

This research method is experimental, quantitative, and uses a pre-post test design to compare the quality of domestic wastewater before and after treatment using a filtration prototype. Wastewater samples were collected via grab sampling from domestic sewage channels in the densely populated area of Palembang, and testing was conducted in triplicate replications to ensure data validity. The filtration unit used is the Rancang Bangun Alat Penyaring Air Limbah (Design and Construction of Wastewater Filter Tool), a column filter type prototype resulting from design engineering used in this study.

Prior to use, all filter media (Silica Sand, Activated Carbon, and Zeolite) were washed repeatedly to remove fine particles and impurities. The treatment unit is designed to operate by gravity with a vertical multi-media fixed bed filtration system. The media used, arranged based on the flow direction, consists of a layer of Silica Sand (primarily for physical filtration of suspended particulates through straining and sedimentation mechanisms), a layer of Activated Carbon (primarily for the adsorption of organic matter, and odor and color removal), and a layer of Zeolite (specifically for ion exchange to reduce Total Hardness and dissolved Iron, Fe).

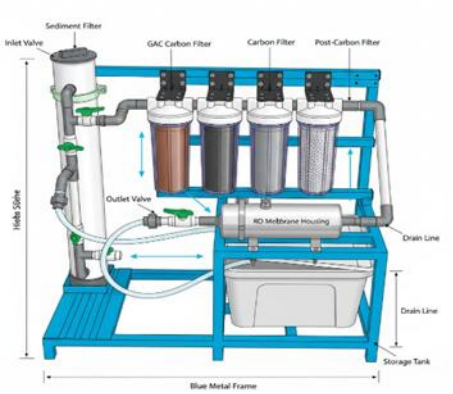

Figure 1 Wastewater samples

After passing through these three media layers, the water is then processed in the final disinfection stage. The treatment process involves flowing the raw wastewater through the filtration unit at a controlled flow rate adjusted to the media capacity, ensuring Adequate Contact Time for adsorption and ion exchange processes. Samples were collected in two conditions: Raw Wastewater (Initial Concentration) and Effluent (Final Concentration). The collected samples were then analyzed for quality parameters at the Kemenkes Laboratory (Ministry of Health Laboratory) using standard methods (such as Atomic Absorption Spectrophotometry for Fe and Mn, and Titration for Hardness) to measure pH, Nitrate, Total Hardness, Dissolved Iron (Fe), Dissolved Manganese (Mn), Anionic Surfactants, and Cyanide (Cn (After Treatment). (After Treatment).

III. Result And Discussion

Comparison of Post-Treatment Water Quality Parameters

This Results section presents a comparison of the domestic wastewater quality data before treatment and after being processed using the filtration and disinfection system. The laboratory test results are then strictly compared with the maximum permissible limits set by the Minister of Health Regulation Number 2 of 2023 concerning Clean Water Quality Standards, as shown in Table 1.

Parameter	Permissible Limit	Before Treatment	After Treatment	Unit
Nitrate	20	4.328	4.264	mg/L
pH	6 (5-8.5)	7.19	7.12	-
Anionic Surfactant	-	0.010	0.010	mg/L
Cyanide	-	0.001	0.001	mg/L
Dissolved Iron	200	80.345	11.949	g/L
Fluoride	-	0.097	0.068	mg/L
Hardness	-	105.824	79.867	mg/L
Nitrite (as N)	-	0.121	0.109	mg/L
Dissolved Manganese	100	5.229	58.143	g/L
Total Coliform	3000	4,700,000	1.8	g/L
Escherichia coli	3000	0	0	g/L

Analysis of Treatment Performance

Overall, the multi-media filtration system demonstrated excellent performance in reducing major domestic wastewater contaminants, particularly dissolved metal ions. The high treatment efficiency ensured that the effluent met all clean water quality requirements set by the government.

Furthermore, the filtration and disinfection system demonstrated resilience under continuous operational conditions, maintaining consistent water quality improvements over the study period. This stability highlights its suitability for long-term household application, providing a reliable decentralized wastewater treatment solution that addresses both environmental and public health concerns. The prototype's low maintenance requirements and cost-effectiveness further suggest strong potential for adoption in similar urban settings facing water quality challenges.

The multi-layered filtration approach effectively removed a wide range of contaminants, including both dissolved heavy metals and microbial pathogens, ensuring comprehensive treatment. The activated carbon layer was particularly effective in adsorbing organic pollutants and removing odors, improving the treated water's acceptability. Silica sand worked efficiently to filter out suspended solids, while zeolite played a crucial role in ion exchange processes that reduced water hardness and dissolved metal concentrations.

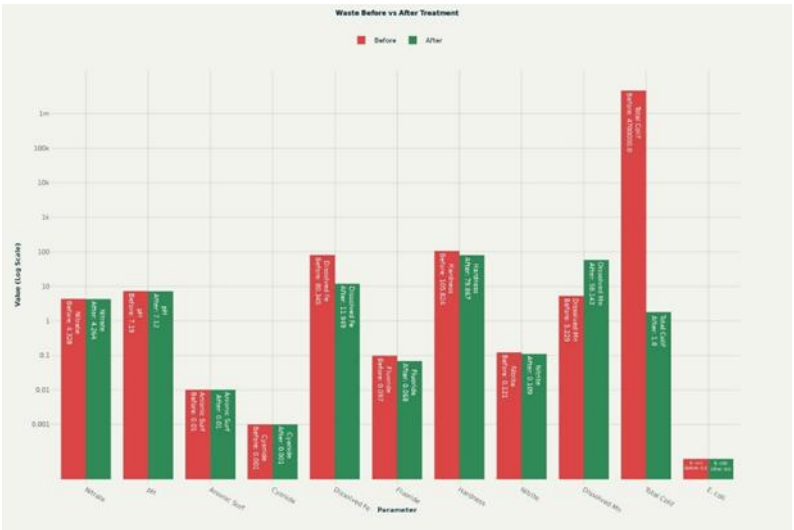

Figure 2. Comparison Graph of Dissolved Iron (Fe) and Total Hardness Before and After Wastewater Treatment

The comparison between initial and final concentrations can be clearly seen in Figure 2. The visual data presented in the graph highlights the effectiveness of the prototype in reducing key parameters.

The reduction of Dissolved Iron (Fe) concentration is the main success of this system. The Fe concentration was successfully reduced from 80.345 ug/L to 11.949 ug/L, yielding a removal efficiency of 85.12%. This performance far exceeded the requirements, as the final concentration (11.949 ug/L) is approximately 17 times lower than the maximum permissible limit (200 ug/L). This high efficiency is attributed to the combination of mechanisms within the filter. While Silica Sand and Activated Carbon provide adsorption sites, the primary role is most likely played by Zeolite, which is active in bivalent ion exchange (including Fe) and provides a surface for the oxidation and precipitation of Fe. This result confirms the prototype's effectiveness in addressing heavy metal issues.

Other parameters showed stability or very low concentrations. The pH value remained stable in the neutral range (7.19 to 7.12), which is ideally within the permissible limits (6.5–8.5). This stability indicates that the filter media did not cause drastic chemical changes in the water. Meanwhile, the content of Nitrate, Nitrite, Anionic Surfactants, and Cyanide were all already at very low levels, some even below the detection limit. The small reductions observed in Nitrate and Nitrite (1.48% and 9.92%, respectively) suggest that the filter provided a minor environment for biological activity (denitrification) or adsorption, but the system's main focus is on physical and chemical filtration (heavy metals/hardness).

IV. Conclusion

Based on the testing and analysis carried out in this Thesis regarding the Design and Construction of a Household Wastewater Filter Tool Using Filtration and Disinfection Technology, the following main conclusions can be drawn:

1. The designed Multi-Media Filtration (Silica Sand, Activated Carbon, Zeolite) and Disinfection system proved to be highly effective in treating domestic wastewater. The quality of the effluent (treated water) produced successfully achieved and met all clean water quality standards in accordance with Minister of Health Regulation Number 2 of 2023.
2. The highest pollutant removal performance was achieved for heavy metal ions:
   - Dissolved Iron (Fe): Reached a removal efficiency of 85.12% (from 80.345 ug/L to 11.949 ug/L). The final concentration was far below the maximum permissible limit (200 ug/L).
   - Total Hardness: Reached a reduction efficiency of 24.52% (from 105.824 mg/L to 79.867 mg/L), which is attributed to the ion exchange mechanism in the Zeolite media.
3. All other key water quality parameters, including pH, Nitrate, Nitrite, Anionic Surfactants, and Cyanide, were within safe post-treatment limits or below the detection limit, confirming the reliability of this system for decentralized domestic wastewater treatment applications.

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