Combination of Gallery Well Reactor and Slow Sand Filtration for Clean Water Reclamation in Flooded Area (Study Case: Morowudi Village, Gresik District)

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Abstract
In Morowudi Village, Gresik, flooding is a known problem frequently brought on by excessive rainfall and inadequate drainage infrastructure. The ensuing floods make it difficult for the nearby towns to have safe drinking water. Sand Slow filter technology is suggested as a solution to this problem. Establishing parameter levels, lowering parameters, and evaluating the efficiency of different filtration media in lowering turbidity, iron metal, and total coliforms in flooded raw water in the Morowudi, Gresik area are the goals of this study. Using a batch method, the research will be conducted in a laboratory setting after the floodwater has been using the gallery well procedure. The study will concentrate on three different types of filtration media: 70 cm of silica sand media will be used in the first reactor, iron sand filtration media will be used in the second reactor, and beach sand filtration media will be used in the third reactor. Sand media with sizes ranging from 0.25 to 0.5 mm will be used in all reactors, and layers of 5–10 mm and 10–20 mm gravel will be added as supplements in total of 20 cm. The result showed that the efficacy of turbidity reduction can exceed 57.62%. The efficacy of TDS reduction is established at 10.26%, whereas the efficacy of total coliform reduction is established to be over 83%.

Keywords**:** *Flooding, Turbidity, Ferrous Metal, Total Coliform, Slow Sand Filter.*

Abstrak
Permasalahan banjir sering terjadi di Desa Morowudi, Gresik dikarenakan faktor intensitas hujan yang tinggi dan sistem drainase yang kurang memadai. Banjir seringkali menjadi hambatan masyarakat setempat untuk mendapatkan air bersih layak pakai. Untuk mengatasi permasalahan tersebut salah satu cara yang dapat diterapkan adalah dengan menggunakan teknologi Sand Slow filter. Penelitian ini bertujuan untuk mengetahui kadar parameter, untuk melakukan penurunan

terhadap parameter, dan untuk mengetahui perbedaan penggunaan media terhadap penurunan kadar kekeruhan, logam besi, dan total coliform pada air baku genangan banjir daerah Morowudi, Gresik. Penelitian berskala laboratorium ini menerapkan sistem batch pada operasionalnya dan akan diterapkan setelah air genangan banjir melalui pre-treatment menggunakan sumur galeri. Variabel penelitian ini adalah perbedaan jenis media filtrasi, reaktor pertama menggunakan media pasir silika 70 cm, reaktor kedua menggunakan media filtrasi pasir besi, dan reaktor ketiga menggunakan media filtrasi pasir pantai. Seluruh reaktor menggunakan media pasir dengan ukuran 0,25–0,5 mm. Terdapat media tambahan yakni kerikil berukuran 5–10 mm dan 10–20 mm dengan ketinggian 20 cm. Hasil menunjukkan bahwa penurunan pada turbidity mencapai 57.62%, TDS 10.26% dan total coliform hingga lebih dai 83%.

Keywords: *Banjir, Kekeruhan, Logam Besi, Total Coliform, Slow Sand Filter*.

1. Introduction

Providing clean water to the community is critical for enhancing the environment's or community's health. Water is an important aspect of human life and is used for a variety of functions, including domestic, public, and industrial use. However, we continue to have water issues, ranging from floods caused by surplus water to water shortages that create drought in numerous locations, and access to safe drinking water is becoming increasingly problematic. Because water is one of the most important aspects of human life, supplying clean water to the community is critical for enhancing the health of both the environment and the population (Gabriela Tambalean Alex Binilang, 2018).

The quality of groundwater has been significantly damaged as a result of repeated flooding disasters. During flooding events, not only does water inundate the land, but it also introduces a mixture of undesirable substances into our underground water sources. Visualize floodwaters as unwelcome guests, transporting a multitude of dangerous substances such as bacteria, viruses, farm chemicals, heavy metals from factories, and greasy substances from urban runoffs. These pollutants not only render the water unfit for consumption, but also inflict damage onto the ecosystem in which we reside (Saeed et al., 2014).

The National Disaster Management Agency (BNPB) reported that in 2020, there were a total of 1,518 flood incidents, marking the greatest number on record. The calamity led to fatalities, anguish, interruption of educational opportunities, diminished general well-being, and challenges in obtaining clean water. During a flood, the water that is normally clean and used by the local community becomes turbid due to the mixing of sediment, rendering it unsuitable for daily use.

Annually, Morowudi Village experiences the detrimental impact of flooding. In this scenario, flooding happens when the amount of rainfall is not at its highest point. Factors that influence the occurrence of flooding include,

- The shape of the river,
- The capacity of the river that is too small, and
- The presence of buildings on the riverbanks.

Based on the statements of people, floods can persist for a duration of one week. There are multiple regions with varying levels of flooding. The most severely flooded areas can reach a maximum height of 50 cm, covering around 17% of the whole area. Areas with moderate flooding can reach a height between 20 and 50 cm, covering around 19% of the total area. Areas with low flooding experience a maximum height of less than 2 cm, covering 64% of the total area (Pungut et al., 2023).

Common treatment methods for providing drinking water in rural regions include cost-effective options such as drip chlorination, chlorine tablets, sun disinfection, slow sand filters (SSFs), and ceramic filters (for eliminating sediment and bacteria) (Vu & Wu, 2022).

In order to produce water of higher quality for daily use, this project will integrate slow sand filtering with gallery well technology. This technology utilizes a filtration method with a smaller particle diameter compared to a rapid sand filter, allowing for the filtration of pollutants to produce clean water (Barkouch et al., 2019; Huisman & Wood, 1974; H.-L. Liu et al., 2023)

2. Method

This laboratory-scale research was carried out to process flood water that had passed through filtration using a gallery wall. The water sample is puddle water and is located in Morowudi Village, Cerme District, Gresik Regency. Water treatment in this research was carried out to improve water quality compared to previous treatments. The initial stage in the research process was to conduct initial tests in the laboratory to determine the characteristics of flood water in terms of iron metal parameters, turbidity and total coliforms. Then, tools and materials are prepared for the next stage of the processing equipment design process. Processing to reduce iron metals, turbidity and total coliforms uses slow sand filter technology(Agrawal et al., 2021; Barkouch et al., 2019; Huisman & Wood, 1974; H.-L. Liu et al., 2023). The filtration method uses silica sand, iron sand, and beach sand, along with additional gravel media. It is envisaged that by using this approach, current pollutants will be reduced.

2.1 Material Preparation

Treatment of standing water is carried out in stages directly on-site by installing filters designed in the flooded area (gallery well). In this research, furt her processing is carried out to obtain better quality. The reactor design in this research uses slow sand filter criteria, using PVC pipes as a filter container using sand media with a diameter of 0.25-0.5 mm with a height of 70 cm, small gravel with a diameter of 5-10 mm with a media height of 30 cm, and large gravel with a diameter of 10-20 mm with a media height of 30 cm. When preparing the media, each partition is given a barrier in the form of non-woven geotextile so that the media is not mixed or carried away by water when flowing. This research used three variables: silica sand media, beach sand, and Lumajang sand.

This research was carried out for eight months: survey as a research object, location survey, sampling, preliminary survey, proposal preparation, research preparation, and research implementation stages, which included data collection, tool making, laboratory tests, and data analysis. The application of this research uses three replications to strengthen the validation of the results and reduce random errors in obtaining the results. Then, the research samples were analyzed at the PDAM Surya Sembada Surabaya laboratory.

Before processing, an analysis of the turbidity of the water resulting from the initial pre-treatment (gallery well) is carried out as an initial sample before treatment. Testing for turbidity concentration, total dissolved solids, and total coliforms to provide basic data for each parameter. This initial data in Table 1 is used to see the effectiveness of reduction after treatment using a filter with several sand media as a comparison in reducing levels in flood water, which has been adjusted to the slow sand filter criteria. The flow diagram of the research carried out can be seen in Figure 1.

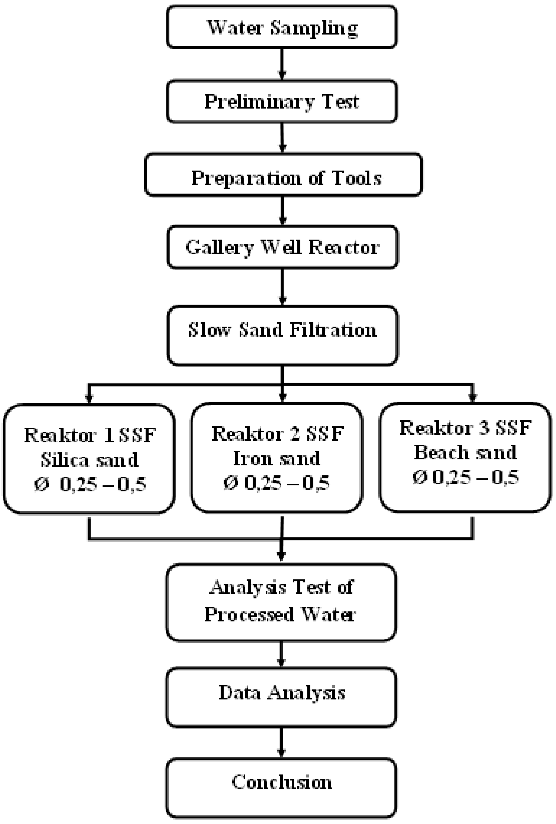

Figure 1. Research Scheme

Table 1. The Quality of Initial Water

Parameter	Unit	Result	Quality standards
Turbidity	NTU	3.42	< 3
Total *Dissolved solid*	mg/L	585	< 300
Total *Coliform*	CFU/1000ml	31,000	0

2.2 Media Porosity

Media porosity is used to determine the percentage of water that can seep through the pores of the media. Porosity calculations were done on silica sand, iron sand and beach sand (Marsono et al., 2022).

The way to calculate the porosity of the media is to fill a 1000 ml measuring cup with water, then fill the measuring cup with the same volume as the media whose porosity is calculated. Next, water is poured into a measuring cup filled with media until the media floats. Then, look at the volume of water absorbed by the media and calculate the porosity using the formula (1).

$$\text{Porosity } \% = \frac{\text{Bulk Vol.} - \text{Grain Vol.}}{\text{Bulk Vol.}} \times 100\% \quad (1)$$

Bulk volume is the total volume of a material, including the volume of its particles, the space between the particles, and the internal pore volume of the particles and grain volume is the amount of space occupied by grains

2.3 Reactor Design

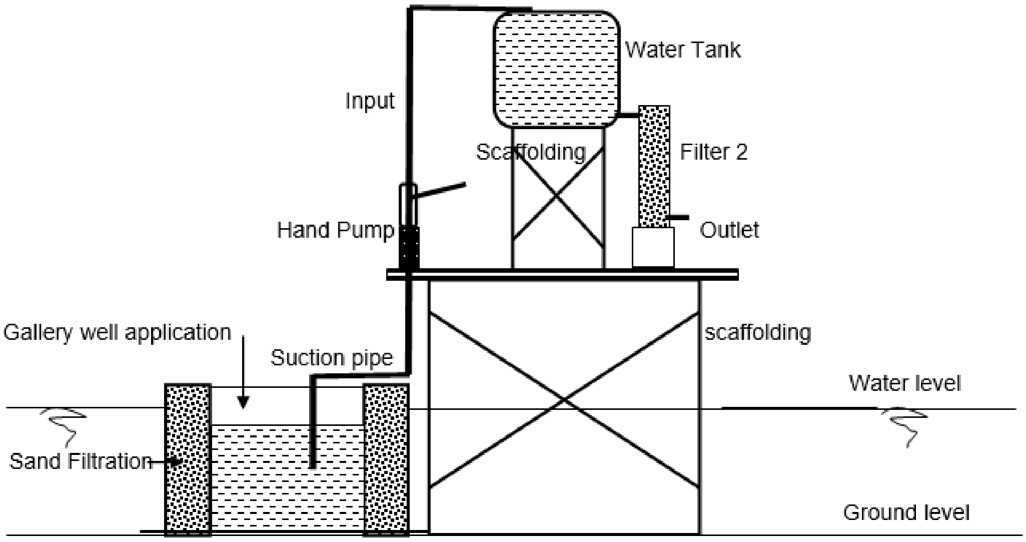

Figure 2. The combination of Gallery Well Technique and Slow Sand Filtration Technologies

The reactor was designed used PVC pipe with a height of 150 cm with space for media of 60 cm. The variable in this research is the difference in media height, so it requires 3 (three) reactors. Reactor 1 is silica sand with a diameter of 0.25–0.5 with a height of 70 cm, gravel with a diameter of 5–10 mm with a height of 20 cm, and gravel with a diameter of 10–20 mm with a height of 20 cm. Reactor 2 is iron sand with a diameter of 0.25–0.5 with a height of 70 cm, gravel with a diameter of 5–10 mm with a height of 20 cm, and gravel with a diameter of 10–20 mm with a height of 20 cm. Reactor 3 is iron sand with a diameter of 0.25–0.5 with a height of 70 cm, gravel with a diameter of 5–10 mm with a height of 20 cm, and gravel with a diameter of 10–20 mm with a height of 20 cm. Silica sand, iron sand and beach sand media use a size of 0.25–0.5 mm.

The provided image depicts a proposed concept for managing floodwater through the utilisation of a combination of gallery well method and gradual sand filtration.

1) Reactor Volume

Volume = Π x r^2 x height

2) Freeboard

The SSF reactor is designed to have a freeboard height of 40 cm.

3) Volume Effectivity

Diametre = 10 cm
Height = 150 cm
Freeboard = 40 cm
Volume = Π x r^2 x height

4) Debit

Debit slow sand filter (SSF), using formula (2) below:

$$Q = \frac{\Sigma\, porosity \times Volume}{time\ detention} \quad (2)$$

The selection of pumps for a wastewater treatment plant is based on the flow rates, which include the average discharge, peak discharge, and minimum discharge for phases I and II in the anticipated area.

3. Result and Discussion

This study aimed to address the community's future need for clean water in flood-affected areas by reducing turbidity, total dissolved solids, and total coliform. Based on data collected by other proponents, Morowudi Village in Gresik Regency is frequently affected by annual floods, resulting in a growing challenge to obtain clean water.

During the pre-treatment phase, the gallery well technique was used; there was a notable decrease in turbidity and total coliform, although it was insufficient to meet the requirements for clean water quality standards. On the other hand, the levels of total dissolved solids exhibited an upward trend. The pre-treatment yielded the following results: the turbidity level was 3.45 NTU, with a reduction percentage of 99%; the total coliform count was 27,000 CFU/100 ml, with a reduction percentage of 92%; and the TDS concentration increased by 746 mg/L, with an increase percentage of 36%.

The laboratory conducted analyses on turbidity parameters, total dissolved solids, and total coliforms utilizing their respective methods of analysis. Three replicates of processed water sample were conducted to enhance result validity, minimize random errors, and establish a foundation for more rigorous statistical analysis. The purpose was to assess the efficacy of each procedure.

The graph in Figure 3A-C illustrates the efficacy of reducing turbidity concentrations in the three reactors. The initial findings from the first reactor, which utilized silica sand as the media, indicate an average reduction in turbidity levels with an efficacy rate of 43%. Reactor 2, utilizing beach sand medium, demonstrated a mean efficacy of 57% in diminishing turbidity levels. Reactor 3, which utilized Lumajang sand media, demonstrated a moderate amount of success in lowering turbidity levels, with a reduction of 35%.

The slow sand filtration reactor is coated with a layer of sand and appears dirty on the surface, which causes the filtration process to take longer. The schmutzdecke layer contains a multitude of bacteria and microorganisms that reduce turbidity (Yaman, 2003). The schmutzdecke layer efficiently removes contaminants by forming a matrix composed of microorganisms' excrement, which thrives in the media (Rizki, 2013).

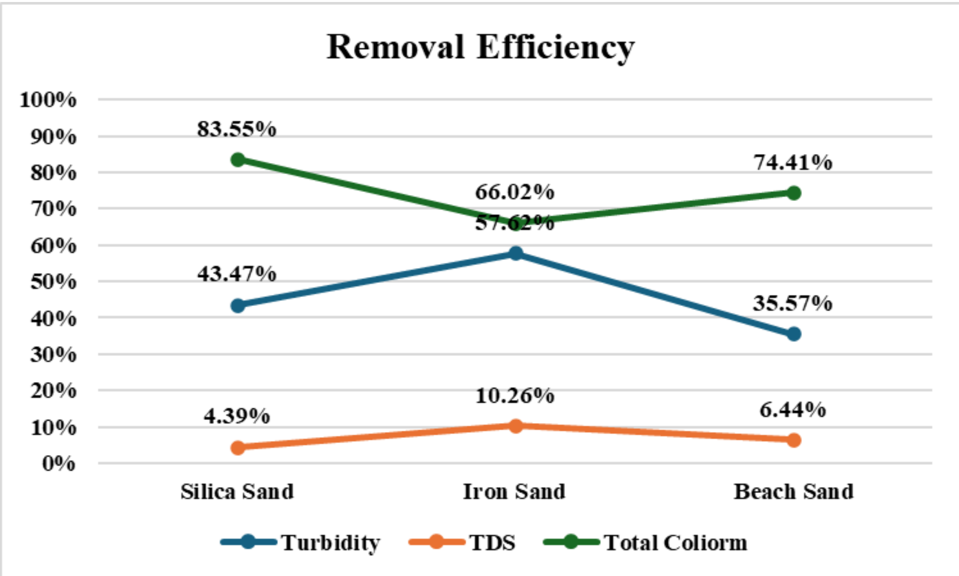

Figure 3A-C. Removal Efficiency of The Combination between Gallery Well Technique and Slow Sand Water Technology

The efficacy of decreasing total dissolved solids (TDS) concentrations from the three reactors. The graph depicting the performance of the initial reactor, with silica sand as the media, illustrates an average reduction in Total Dissolved Solids (TDS) levels with an efficacy of 4.39%. Reactor 2, which utilized beach sand media, had a mean efficacy in decreasing total dissolved solids (TDS) levels, achieving a reduction of 10.26%. The utilization of Lumajang sand media in Reactor 3 showd a moderate efficacy in decreasing Total Dissolved Solids (TDS) levels, with an average reduction of 6.44%.

The efficacy of decreasing the quantities of Total Coliforms in the three reactors. The graph depicting the results of the initial reactor utilizing silica sand media demonstrates an average efficacy of 83.55% in lowering Total Coliform levels. Reactor 2, which utilized beach sand media, had an average efficacy of 66.02% in lowering Total Coliform levels. Reactor 3, which utilized Lumajang sand media, had a mean efficacy of 74.41% in lowering Total Coliform levels.

The application of filter treatment with sand media to stagnant water demonstrates variations in the reduction of turbidity parameters, total dissolved solids, and total coliforms. These variations are significant and rely on the specific filter media or kind of sand employed. The efficacy of the reduction is influenced by the type of media used, as different forms of sand possess distinct characteristics, including particle size, hardness, and ability to bear pressure and sustain filtration effectiveness. The sand's capacity to endure pressure is crucial, particularly when the filtration procedure entails high pressure or sand regeneration, ensuring that the suitable sand yields extremely efficient reduction (Mesquita et al., 2019).

As the filtration rate increases, more scraping activities are carried out. Excessive scraping will harm the schmutzdecke layer, thereby impeding the efficient functioning of biological elimination (Khumalasari & Hadi, 2010). Furthermore, the efficacy of slow sand filters in eliminating total coliforms is evaluated based on the duration of contact and the rate of filtration (Matuzahroh et al., 2020).

Table 2. Comparison with Other Studies

Treated Wastewater	Removal	Media	Reference
Domestic	Turbidity 45.9 % Ammonia 16.7 % Phosphate 19.4 %	Sand and clam shells	(Fitriani et al., 2023)
Domestic	Total coliform 99 %	Sand	(Nasser Fava et al., 2022)
Domestic	Suspended solid 99.4 % Ammonia 99.6 % Total phosphorus 91.8 %	Filtralite	(Mažeikienė, 2019)
Sewage	Turbidity 31.1 % Ammonia 7.1 % Total phosphorus 33.8 %	Biochar	(Kaetzl et al., 2020)
Contaminated Lake	Ammonia 89 %	Sand	(Subari et al., 2018)
Rainwater	Turbidity 99 % Ammonia 95 %	Sand	(L. Liu et al., 2019)

As compared to previous studies in Table 2, the result that is now being provided is deemed average. Previous study (Mažeikienė, 2019), presented the results of a small-scale filtering unit that removed 99.4% of suspended particles, 99.6% of ammonia, and 91.8% of total phosphorus from home wastewater. Used biochar as an alternative filter medium, Kaetzl et al. (Kaetzl et al., 2020) were able to remove 31.1% of turbidity, 7.1% of ammonia, and 33.8% of total phosphorus from sewage. In addition to treating domestic wastewater, SSF can also be used to treat rains and lakes, removing up to 99% of the turbidity and 89% of the ammonia, respectively (Liu et al., 2019; Subari et al., 2018). However, as SSF is shown to be effective in eliminating coliforms, it might be worthwhile to include additional parameters that concentrate on E. coli and total coliform removals (Nasser Fava et al., 2022).

4. Conclusion

The utilization of the Gallery well technique with Slow Sand Filtration technology has been proven to decrease turbidity, total dissolved solids (TDS), and total coliform in flood water in Morowudi Village, Gresik. The efficacy of turbidity reduction can exceed 57.62%. The efficacy of TDS reduction is established at 10.26%, whereas the efficacy of total coliform reduction is established to be over 83%. The processed water, in accordance with Minister of Health regulations number 2 of 2023 regarding environmental health, meets the quality standards for clean water for community sanitation.

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