International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

An Intelligent Engineering Based Water Treatment Injection Portable Type for Drinking Water Fulfilment in Disaster Conditions (Engineering Design)

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Submitted: 04/11/2023 **Revised**: 23/12/2023 **Accepted**: 05/01/2024

Abstract: In times of disaster, water is a natural resource crucial for preserving human life and other life forms. Access to water during a disaster is crucial, especially for drinking, cooking, and maintaining hygiene in refugee camps. It also helps to stop the spread of *water-borne diseases*. Typical issues include cloudy water, damage to the piping installation system and water treatment, issues with the water distribution system, and a lack of water in evacuation shelters and evacuation areas. Activated charcoal, silica sand, and zeolite media were used in this study to test the efficacy of *Portable Injection-Type* Water Treatment by evaluating physical, chemical, and microbiological parameters. A pretest-posttest research design characterizes the experimental nature of this study. After filtering river water samples, the following parameters were measured: turbidity, TDS, pH, iron (Fe), manganese (Mn), and the MPN (*Most Probable Number*) Index of *Coliform* and *E. coli*. For data analysis in this study, the *T-test* is used. The findings of this study demonstrate the ability of *portable injection* with a *triple-up flow* device in filtration to obtain a percentage of reduced water quality, with a yield of 78.3% water turbidity, 19.5% dissolved solids, 1.62% pH level, 21.61% organic matter, water hardness content of 10.7%, *Coliform* 83.99%, *E. coli* 95.19%. Analysis using the *T-test* yielded a *p-value*<α, so statistically, there were differences in river water parameters before and after using the *Portable Injection* tool.

***Keywords**: Processing, Injection Portable, water*

Introduction

One of a person's most basic needs is clean water.[1] Water resources in Indonesia have been governed by Law No. 7 of 2004 since that year. Water is a substance, matter, or element necessary for all currently known life forms on Earth but not on other planets.[2] Water is a big issue, both for clean water availability in cities and rural areas. The advancement of science has shown how crucial water is to various phenomena. Water resources, though, are limited, and improper processing can lead to issues. Consequently, it is essential to develop and refine water resources on a global scale. The issue is that it is frequently discovered that the quality of the community's groundwater and river water does not meet the standards for healthy drinking water. In some places, it is not even suitable for consumption.[3] There cannot be life on Earth without water because it is essential to all life processes. However, water can be disastrous if it is available under poor quality or quantity conditions. Humans require clean water for their daily needs, industrial needs, city sanitation needs, and other purposes.[4] The issue of water needs more serious attention in the modern era.[5]The condition that most forces people to use water of poor quality is during a disaster.[6] Determination of water quality needs to be done as a reference in monitoring water quality pollution.[7]

Natural disasters are defined as catastrophes brought on by a single natural disaster or a chain of related natural disasters, such as floods, landslides, earthquakes, tsunamis, volcanic eruptions, droughts, and hurricanes (Article 1 of Law No. 24 of 2007).[8]

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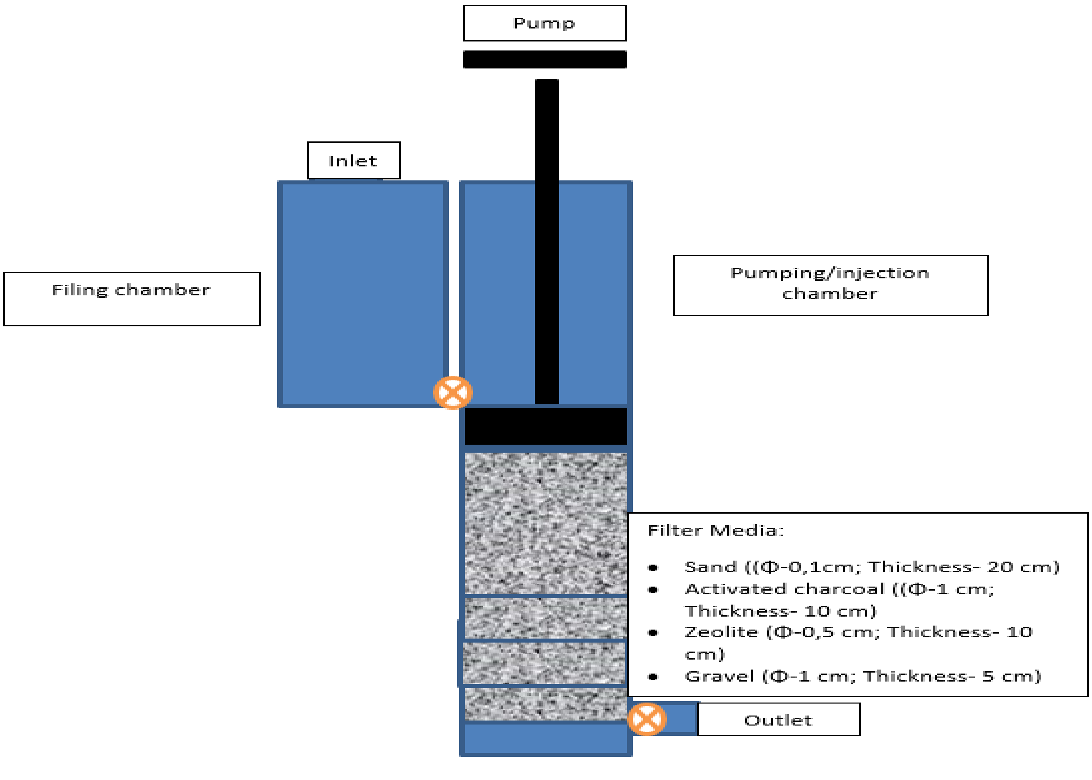
Water is a natural resource crucial for sustaining life, particularly when a disaster strikes. When a disaster strikes, having access to water is crucial for activities like drinking, cooking, and supporting the environment during an evacuation and preventing the spread of water-based (*water-borne diseases*). Water problems can be disrupted due to disasters, including water sources with disturbed quality, namely water becoming cloudy, damage to the piping and water treatment installation systems, problems with the water distribution system, and water scarcity in evacuation areas and evacuation areas.[9] Therefore, when a disaster strikes, it is necessary to apply the proper clean water treatment technology.[10] Since there is a significant need for water for bathing, washing, and using the restroom, evacuation areas are given priority when handling clean water through a communal system. Water for drinking was most urgently required at the beginning of the catastrophe. In the interim, boiling the water must treat it before drinking it in the long run. People typically use straightforward, simple, and easy-to-operate processing systems for remote and difficult-to-reach areas.[10] Water supply technology for emergency response has the following qualities: 1) it can work with all types of water conditions; 2) it can work easily; 3) it does not need much maintenance; 4) it uses few chemicals; and 5) it is portable and simple to disassemble. Sometimes, communities lack the knowledge necessary to treat water so that it is clean. If the community knows how to process water, they will undoubtedly run into problems when using the equipment and carrying out the process.Based on these reasons, the authors are interested in making *injection portable*-type water treatment for drinking water fulfilment in disaster conditions in 2022. The filter media in the tool are sand, zeolite, activated charcoal and gravel, which will be used for simple water treatment so that it can be tested to get good quality water, so the tool can be used during a disaster condition, especially during floods so that the water can be processed into clean water so that it can be used for household activities such as washing, mopping, bathing, and other.

Method

This kind of study uses a one-group pretest-posttest research design and is pre-experimental. In 2022, this study was conducted at Tanjungkarang Health Polytechnic's Laboratory of the Department of Environmental Health. This study aimed to create a portable injection-type filter using activated charcoal, silica sand, and zeolite filter media.Plan as shown in Figure 1 below:



By measuring turbidity, TDS, pH, iron (Fe), manganese (Mn), and the MPN (*Most Probable Number*) Index of *E. coli* and *Coliform* after the screening, river water samples are used in the screening process. The procedure is repeated 12 times in this stage. With the subsequent research progression:

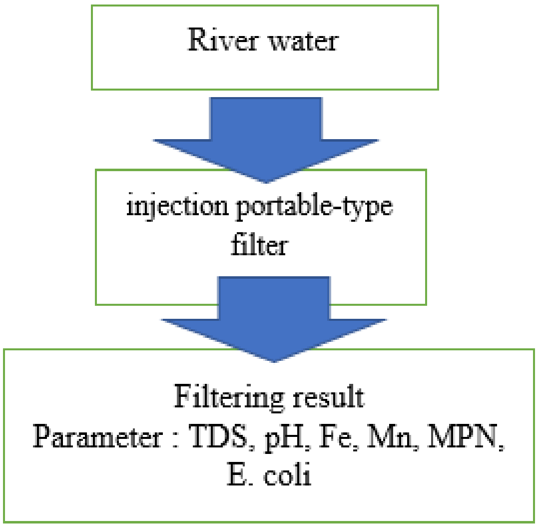


Fig 1. Research process

The data analysis used is the ratio of decreasing parameter values before and after filtering by paired T-test with an alpha of 0.05. Using the formula, determine whether the reduction was effective:

$$Ef = \frac{X1 - X2}{X1} \; x \; k$$

Note: Ef = Reduction Effectiveness

X_1 = Average parameter value before treatment (mg/l)

X_2 = Average parameter value after treatment (mg/l)

k = 100

Result

The following are the findings of a study on river water treatment that used *injection portable-type* water treatment in the context of providing drinking water in disaster conditions:

1. Chemical Parameters (Hardness, pH, and Organic Matter)

Tabel 1. Analysis of water's chemical parameters (hardness, pH, and organic matter) in the filtering process with the Triple-Up Flow Model in 2022.

No.	**Hardness (standard 500)**		**Water's pH (standard 6,5-8,5)**		**Organic Matter (standard 10)**	
	Before (mg/l)	**After (mg/l)**	**Before (mg/l)**	**After (mg/l)**	**Before (mg/l)**	**After (mg/l)**
1	67,6	63,2	7,12	6,97	21,99	19,84
2	67,6	58,4	7,12	6,96	21,99	19,21
3	67,6	54	7,12	6,91	21,99	17,32
4	67,6	55,6	7,12	6,89	21,99	18,58
5	67,6	61,6	7,12	6,95	21,99	16,56

6	67,6	61,2	7,12	7,05	21,99	19,97
7	67,6	65,2	7,12	7,11	21,99	21,11
8	67,6	64,8	7,12	6,99	21,99	13,39
9	67,6	57,6	7,12	6,98	21,99	16,68
10	67,6	67,6	7,12	7,03	21,99	17,69
11	67,6	61,2	6,86	6,86	34,38	16,18
12	67,6	60,3	6,86	0,30833	34,38	25,28
Ave-rage	**67,6**	**60,4**	**7,08**	**0,31667**	**24,06**	**18,48**

Note: * Minister of Health regulation of quality standards no. 492/Men.Kes/Per/IV/2010

The average hardness value before processing is 67.6 mg/l, and the average hardness value after processing is 60.4 mg/l, according to Table 1. The reduction's effectiveness is:

Ef = 67,6 mg/l-60,4 mg/l)/(67,6 mg/l) x 100 %

Ef = 10,7 %

Before processing, the average pH was 7.08, and it was 6.96 after processing. The reduction's effectiveness is as follows:

Ef= 7,08-6.96/7,08 x 100 %

Ef = 1,62 %

The average number of organic matter before processing was 24.06 mg/l, and the number of organic matter after processing was 18.48 mg/l. The effectiveness of the decrease is:

Ef = 24,06 mg/l-18,48 mg/l/24,06 mg/l x 100 %

Ef = 21.61 %

2. Decrease in Physical Parameters (Turbidity and Dissolved Solids)

Tabel 2. Analysis of Water's Physical Parameters (Turbidity and Dissolved Solids) in the Filtration Process with the Triple Up Flow Model in 2022.

No.	Turbidity (standard 5)		Dissolved Solids (b500)	
	Before (NTU)	After (NTU)	Before (mg/l)	After (mg/l)
1	156,7	17,7	225	161
2	156,7	41,8	225	210
3	156,7	56	225	210
4	156,7	54,3	225	225
5	156,7	41,1	225	210
6	156,7	43,2	225	128
7	156,7	26,6	225	130
8	156,7	33,6	225	140
9	156,7	188,7	225	195
10	156,7	29,2	225	200
11	93,3	12,5	225	184
12	93,3	8,7	225	180
Ave-rage	**146,1**	**32,8**	**225**	**181,1**

Note: * Minister of Health regulation of quality standards no. 492/Men.Kes/Per/IV/2010

According to Table.2, the average turbidity before processing is 146.1 NTU, while the average turbidity after processing is 32.8 NTU. The following describes how well turbidity is reduced:

Ef = 146,1 NTU - 32,8 NTU)/(146,1 NTU/l) x 100 %

Ef = 78,3 %

Before processing, there were typically 225 mg/l of dissolved solids, and there were 181.1 mg/l of dissolved solids after processing. The reduction's effectiveness is:

Ef = 225mg/l-181,1 mg/l/(225 mg/l) x 100%

Ef = 19,5 %

3. Microbiological Parameters (Coliform and E.Coli)

Tabel 3. Analysis of Water Microbiological Parameters (Coliform and E.Coli) in the Filtration Process with the Triple-Up Flow Model Tool in 2022.

No.	Coliform (standard 50)		Feces Coli (standard * MPN /100ml = 0)	
	Before (mg/l)	After (mg/l)	Before (MPN/100ml)	After (MPN/100ml)
1	≥ 1898	116	≥ 1898	116
2	≥ 1898	116	≥ 1898	116
3	≥ 1898	116	≥ 1898	116
4	≥ 1898	116	≥ 1898	116
5	≥ 1898	116	≥ 1898	116
6	≥ 1898	438	≥ 1898	438
7	≥ 1898	438	≥ 1898	438
8	≥ 1898	438	≥ 1898	438
9	≥ 1898	438	≥ 1898	438
10	≥ 1898	438	≥ 1898	438
11	≥ 1898	438	≥ 1898	438
12	≥ 1898	438	≥ 1898	438
Ave-rage	**1898**	**303,83**	**1898**	**303,83**

Note: * Minister of Health regulation of quality standards no. 492/Men.Kes/Per/IV/2010

The average coliform number before processing was 1898 MPN/100 ml, and the coliform number following processing was 303.83 MPN/100 ml, according to Table 3. The reduction's efficiency is equal to:

Ef = 1898-303,83/1898 x 100 %

Ef = 83,99 %

Before processing, the average faecal coli count was 1898 MPN/100 ml; after processing, it was 91.25 MPN/100 ml. The reduction's effectiveness is as follows:

Ef = 1898-91,25/1898 x 100 %

Ef = 95,19 %

4. Analisis T-Test

Tabel 4. T-Test Analysis Results.

No.	Parameter	Average Separation	Sig. (2-tailed)
1.	Hardness before-Hardness after	7,24	0,000
2.	Turbidity before-Turbidity after	113,30	0,000
3.	TDS before-TDS after	43,92	0,001
4.	pH before-pH after	0,08	0,002
5.	Organic matter before-Organic matter after	5,57	0,002
6.	Coliform before-Coliform after	1.594,17	0,000
7.	Fecal coli before-Fecal coli after	1.806,75	0,000

The analysis results using a *T-test* obtained *p-value* < α, so statistically, there are differences in river water parameters before and after using the tool triple-up flow, so the hypothesis is accepted.

Discussion

1. Hardness Reduction

Hardness is the amount of calcium (Ca) and magnesium (Mg) minerals dissolved in raw water. In contrast, organic matter indicates the amount of organic matter suspended or dissolved in the water. Water that has a high mineral content is said to be hard.[1];[11] According to the findings of the laboratory analysis, the hardness level before filtration was, on average, 67.6 mg/l; after filtration, it was 60.4 mg/l. The analysis's findings align with the quality standard (threshold value) established by Minister of Health Regulation No. 492/Men.Kes/Per/IV/2010, which has a maximum water hardness standard value of 500 mg/l.[12];[13]

Calcium (Ca) and magnesium (Mg) minerals will experience a reduction in water hardness due to being trapped in the grain pores, and some of it is filtered in the spaces between the media grains. The presence of sand media causes a reduction in water hardness.[13] Zeolite has several qualities, including the ability to readily rebind water molecules in moist air after being heated and to release water when heated readily. Zeolite has several qualities, including the ability to readily rebind water molecules in moist air after being heated and to release water when heated readily. Zeolite is commonly used as a drying agent because of its qualities.[14] Also, replacing the cations in the zeolite with new ones is simple. By binding to calcium or magnesium, zeolite can replace the sodium it once bound. Zeolite is used to soften water due to this property as well.[15]

2. Turbidity reduction

Small particles and colloids between 10 nm and 10 m in size give water its turbidity. You can find quartz, clay, plant remains, algae, and other small particles and colloids in nature.[16] The initial sample of river water was analyzed to determine the turbidity level, which was found to be 156.7 NTU before filtration and decreased to an average of 32.8 NTU after filtration. The results of the turbidity parameter analysis of the water in the Way Kandis River do not meet the standards for clean water quality.

Activated carbon causes the turbidity level to drop during the filtration process. The adsorption surface area of activated carbon can range from 300 to 3500 cm^2 /gram and has a sizable absorption surface to obtain clear water by using it as a particle cleaner within turbid water. It can lower water turbidity levels (Manado Industrial Research and Development Center, 1988). Adsorption is a phenomenon that can be classified into three different categories based on how it manifests itself. One category is chemisorption, caused by *chemical bonds* forming between molecules of the *solute* and the adsorbent. It is impossible to reverse (*irreversible*) this adsorption, which is very exothermic.

The presence of zeolite media in the triple up-flow filtration system can also reduce turbidity.

Zeolite is a mineral made up of silica (SiO_4) and alumina (AlO_4). It has cavities filled with water molecules and metal ions, most commonly alkali and alkaline earth metals.

Because zeolite has molecular-sized pores, it can separate/filter molecules of a particular size. Ion exchange is by far the most important action mechanism in zeolite media. A charged molecule will form a chemical bond with a surface when it comes into contact with one with the opposite charge. (http://id.wikipedia.org/wiki/Zeolit)

3. Dissolved Solids Reduction

Total dissolved solids are dissolved or colloidal substances that take the form of chemical compounds or other substances. These substances are not filtered on filter paper with a 0.45 mm diameter. The main contributors to total dissolved solids, or TDS, are usually inorganic substances that take the form of ions frequently present in water.[17;18]

Rock weathering, soil runoff, and anthropogenic influences (in the form of domestic and industrial waste) significantly impact the TDS value of water. In natural waters, suspended and dissolved materials are not toxic, but the turbidity level may rise if there are too many of them.[19;20] Following filtration, the initial sample of river water had an average dissolved solids level of 181.1 mg/l as opposed to the initial sample's average dissolved solids level of 225 mg/l before filtration. The analysis results showed that the water met the clean water quality standards, namely less than 1500 mg/l according to the Minister of Health Regulation no. 492/Men.Kes/Per/IV/2010. The decreased TDS levels in the filtration process are due to activated carbon. Chemical bonds can be formed between activated carbon's carbon atoms, including those of oxygen, hydrogen, nitrogen, and sulphur. On the one hand, water pollutants can be bound, and on the other, the polar properties of activated carbon can be significantly altered.

Four effects, including adsorption, biochemical decomposition, catalytic decomposition, and desorption, can be attained using activated carbon. Four processes are carried out on the water to reduce the TDS level in water as a result of this process. These processes allow dissolved and colloidal materials, such as chemical compounds and other materials, to be broken down.

4. PH quality

The initial sample of river water tested had an average pH level of 7.08 before and after filtering and a pH level of 6.98. Clean water's pH level should be neutral, not acidic or alkaline, or at least close to 7. According to the analysis's findings, the pH of the water is between 6.5 and 8.5, which is within the parameters set for the water of a certain quality.

Sand media, activated carbon, and zeolite react differently to pH levels during filtration. The degree to which the parameters of the water being treated degrade depends on the pH, with an excessively alkaline or acidic pH reducing each medium's capacity to adsorb. (Deperindag RI, 2004)

5. Organic Substance Reduction

Organic matter is derived from biodegradable suspended solids (floating), such as hummus, plant remains, weathered wood, twigs, the living organism remains, and aquatic biota (Effendi, H. 2003). According to the analysis, the organic matter content was consistently above the clean water quality standard of 10 mg/l before filtering, averaging 24.06 mg/l before and 18.48 mg/l after.

The presence of fine sand media causes the organic matter content to decrease because it filters the organic matter that is large enough to be trapped in the pores of the grains, and some of it filters in the spaces between the media grains. This filtration process occurs when organic matter content is present in the water and has a size that is large enough to be filtered by the sand media. In addition, zeolite media can contribute to the decline in organic matter content.[21] Ion exchange is the most important action mechanism in zeolite medium.[22] Flowing raw water containing the parameters mentioned above through an ion exchange medium causes the parameters to interact with the medium, removing iron and turbidity by ion exchange.[23]

Through adsorption, activated carbon media can also lessen contaminates.[24] Filters for water purification frequently use activated carbon. "Activated carbon filter to remove organic matter, odor, taste and other micro pollutants."[25]

6. Coliform reduction

The human digestive system contains a class of intestinal bacteria called coliforms. Coliform bacteria are a sign of other pathogenic bacteria in an environment. Because there is a positive correlation between the number of colonies and the presence of pathogenic bacteria, detecting Coliform is a sign of contamination. Coliform detection is also much quicker, cheaper, and easier than other pathogenic bacteria (Widiyanti, 2004). The analysis revealed that the average coliform content before filtering was 1898 MPN/100 ml. It decreased to an average of 303.83 MPN/100 ml after filtering, which was still above the clean water quality standard of 50 MPN/100 ml.

Because fine sand filters water, coliform is trapped in the pores of the grains, and some are filtered in the spaces between the media grains, which is why the presence of fine sand media results in a decrease in coliform. Bacteria find it challenging to escape the sand media due to its density. Coliform levels in water can be decreased by using activated charcoal. Water treatment frequently employs activated carbon as a filter. "Activated carbon filters to remove organic substances, odors, tastes and other micro pollutants." (Said, 1999: 107); the adsorbent mechanism in activated charcoal can absorb coliform in water.

7. Fecal coli reduction

Fecal coliform bacteria serve as indicators of pathogenic bacterial contamination. Bacteria called *fecal coliforms* are produced when feces are disposed of in the water.[26] If this bacteria in the human intestine is present in water, it indicates that fecal disposal has contaminated the source.[27] The analysis found that the fecal coli concentration averaged 1898 MPN/100 ml before filtering. Afterward, it dropped to an average of 91.25 MPN/100 ml, but it was still above the clean water standard of 0 MPN/100 ml.

The decrease in fecal coli is the same as the decrease in coliform caused by the fine sand media, and this is because good sand processes water by filtration by the sand media and is trapped in the pores of the grains. Some are filtered in the gaps between the media grains, and the sand media's density makes it difficult for bacteria to escape.[28]

Using activated charcoal can also lower the number of fecal coli in water because it has an adsorbent mechanism that can take up the fecal coli in the water. Additionally, zeolite media can lessen the number of fecal coli in water because zeolite has adsorbent qualities that allow it to take up the fecal coli bacteria in the water.

The analysis results using the *T-test* obtained a *p-value*<α so that statistically, there are differences in river water parameters before and after using the *triple-up flow* tool, so the hypothesis is accepted. There is a sizable difference between the parameters examined overall between the *triple-up flow* tool and the control group. Activated charcoal, zeolite, and fine sand are used as a combination of filter media in the *triple-up flow* tool to reduce the parameters of hardness, turbidity, pH, organic matter, dissolved solids, coliform, and fecal coli from river water before and after it has passed through the device.

Conclusion

According to the research, the *Portable Injection* device with the *triple-up flow* in filtration can reduce the percentage of water quality reduction by turbidity by 78.3%, dissolved solids by 19.5%, pH level by 1.62%, organic matter by 21.61%, water hardness by 10.7%, *Coliform* by 83.99%, and Coli by 95.19%. The analysis results using the *T-test* obtained a *p-value*<α so that statistically, there are differences in river water parameters before and after using the *Portable Injection* tool, so the hypothesis is accepted.

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