Water Dispenser Manganese Greensand Filter on Product Design and Industrial Engineering Perspectives

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Abstract

This paper is intended and has objective of providing solutions through creation of clean water access that can be a challenge, but the technology exists to ensure everyone can drink safely. This paper addresses specific challenge refers to solve iron-polluted water resources and design an add-ons filter cartridge to eliminate the iron content for drinking water. With a population of 270 million people in 2020, Indonesia is the fourth most populous country in the world and claims Southeast Asia's largest economy. For many households, water sources are distant, contaminated, or expensive, and household sanitation is unaffordable. The Director-General of WHO once said that safe water, sanitation, and hygiene at home should not only be a privilege of only those who are rich or live in urban centers. These are some of the most basic requirements for human health, and all countries have a responsibility to ensure that everyone can access them Manganese greensand is a specially processed medium for iron, manganese, and hydrogen sulphide removal. This premium non-proprietary filter medium is processed from glauconitic greensand on which a shiny, hard finite thickness manganese oxide coating is formed and is firmly attached on every grain by a controlled process. Ultimately, this paper is elaborated within research methodology perspectives on Product Design Engineering and Industrial Engineering.

Keywords
Water Dispenser, Manganese Greensand Filter, Product Design Engineering, Industrial Engineering

1. Introduction

Indonesia with its 270 million population in 2020, is deemed the fourth most populous country worldwide and as Southeast Asia's largest economy. Most of households, water sources are distant, contaminated or expensive, and household sanitation is unaffordable (Water.org 2021). BPSI source in 2020 indicates 90,21% coverage of safe drinkable water has been achieved for households across the nation. Unfortunately 27 million Indonesians have yet to gain access vis-à-vis clean and safe drinkable water for their daily needs (BPS 2021).

Availability of clean water access is deemed challenging. Fortunately, the technology is available to ensure everyone can drink safely. Nazava Water Filters, as empirical implementation as one of companies, holds access to safe and affordable drinking water. The clean water is manufactured by Nazava filters, with its benefit of exposure to pathogens and illness to be prevented in ubiquitous households. It translates saving efforts within several hours per week not looking for fuel wood. In addition to that, saving money is achieved to avoid avoiding expensive bottled water or originated from merchants. (Bergendahl 2020)

2. Literature Review

2.1. Drinking Water

Joint Monitoring Programme (JMP) indicates that "safe drinking water" is defined as water from an "improved water source," These sources includes household connections, public standpipes, boreholes, protected dug wells, protected springs and rainwater collections. According to the same organization, "access to safe drinking water" is defined as the availability of at least 20 litre per person per day from an "improved" source within 1 km of the user's dwelling. (Dinka 2018)

While there are certainly circumstances in which water needs increase, healthy people generally don't need to be consuming water in such large quantities. On the other hand, not drinking enough water can cause mild dehydration, defined as the loss of 1–2% of body weight due to fluid loss. In this state, you may experience fatigue, headache, and impaired mood. (Palsdottir 2021)

2.2. Chemical Composition

Mineral water, including drinking water, comprises wide variety of chemical composition. Iron is one of the minerals within drinking water. To some intensive amount, Iron create chemical hazard in water supplies. Making up at least 5 percent of the earth's crust, iron is one of the earth's most plentiful resources. Rainwater as it infiltrates the soil and underlying geologic formations dissolves iron, causing it to seep into aquifers that serve as sources of groundwater for wells. Although present in drinking water, iron is seldom found at concentrations greater than 10 milligrams per litre (mg/L) or 10 parts per million. However, as little as 0.3 mg/l can cause water to turn a reddish-brown colour and food contact safe materials (Rauner 2010).and (Gulden 2017)

Iron is available in various forms, as either the soluble ferrous iron or the insoluble ferric iron. Water containing ferrous iron is clear and colorless because the iron is completely dissolved. When exposed to air in the pressure tank or atmosphere, the water turns cloudy and a reddish-brown substance begins to form. This sediment is the oxidized or ferric form of iron that will not dissolve in water. Iron also promotes undesirable bacterial growth ("iron bacteria") within a waterworks and distribution system, resulting in the deposition of a slimy coating on the piping. (WHO 2003)

2.3 Manganese Greensand

Manganese greensand is a specially processed medium for iron, manganese, and hydrogen sulphide removal. This premium non-proprietary filter medium is processed from glauconitic greensand on which a shiny, hard finite thickness manganese oxide coating is formed and is firmly attached on every grain by a controlled process. (Hungerford & Terry, 2003),

As one type of adsorbent, manganese greensand ($K_2Z.MnO.Mn_2O_7$) is a material that functions as ion exchanger that can then oxidise Fe and Mn into insoluble substance in water that can then be separated through filtration. The occurring reaction is:

$$K_2Z.MnO.Mn_2O_7 + 4\ Fe(HCO_3)_2 \rightarrow K_2Z + 3\ MnO_2 + 2\ Fe_2O_3 + 8\ CO_2 + 4\ H_2O$$

Manganese greensand can become fully saturated when all the surface has reacted completely with Fe/Mn. Therefore, activation with $KMnO_4$ must be done in order to clean it due to its high cell potential (E^0) of +1.51 V.

3. Methods

3.1 Pugh Matrix

The Pugh Matrix is a criteria-based decision matrix which uses criteria scoring to determine which of several potential solutions or alternatives should be selected. The technique gets its name from Stuart Pugh and has become a standard part of Six Sigma methodology. It is typically used after the development of the VOC (Voice of the Customer) and after the creation of a QFD (Quality Function Design).

The Pugh Matrix method is systematic and quantitative in nature. Every time a decision has to be made, subjective outlook about one option against another option can be viewed as objective. Moreover, this technique can handle sensitive analysis. One example is to distinguish how much an outlook can be changed in order for a less favoured alternative to outscore a contended alternative. This technique is also used to smooth the progress of a controlled, team-based procedure for generating concept and selection. Numerous concepts are assessed according to their strong points and limitations versus an allusion concept which is also the standard concept (also called the datum). (Adams 2022).

3.2 Kobayashi Colour Image Scale

Shigenobu Kobayashi, the founder of Nippon Color and Design Research Institute Inc., developed a Hue and Tone System based on the Munsell Color System, referring to the ISCC-NBS method of designating colour and a dictionary of colour names during the process. A particularly noteworthy feature of this system is its tone settings, which successfully represent the entire world of colour in just 130 colours. Kobayashi used these 130 systematically and psychologically representative colours as research samples in various studies using methods such as the semantic differential technique, and developed a Colour Image Scale that clearly demonstrated the semantic space of colours. (Horiguchi & Iwamatsu 2022)

4. Data Collection

In this paper, Data collection is collected vis-à-vis research methodology on development in which the water filter basic mechanism such as adsorption and effects of iron in drinking water helps to narrow down data. Market research and material exploration are also performed to help formulating the design criteria. Additionally, experiments done to design and test effectiveness of adds on filter cartridge are also to be collected.
The data collection in this paper proceed to design process, in which this process form design criteria and guidelines as the explicit goals this project must achieve in order to evaluate recommended designs of products and test procedures. ("Design and Decision Criteria" 2020.)

After listing design criteria and guidelines, idea sketches are made to lay out possible design solutions that can help reducing the iron content in water as well as achieving good rate of filtration. Furthermore, prototyping stage is done to test out for its efficiency followed by the iron content water and rate of filtration testing. Last but not least, a 3D model and its mechanical drawing will be made for its specific measurements.

5. Results

5.1 Design Result

Given the situation on the research methodology and design methodology, the design results convey the design solution for filter cartridge made by the chemistry intern at Nazava concludes its requirement as follows, as illustrated in Figure 1.

1. Placement of the filter cartridge is better positioned before water is filtered through the original ceramic filter by Nazava in the hope of lessening the added work for the main filter to reduce the iron in water.
2. The minimum height of filter cartridge is 15 cm according to a literature journal that proves its effectiveness up to 97%.
3. Market research shows that many filter is 15-20 cm in height.
4. The smaller the diameter, the faster the rate of filtration, and vice versa.
5. The position of filter cartridge is better done horizontally (filtration with the help of gravity)
6. Additional water container to contain prefiltered water before filtration with ceramic filter.

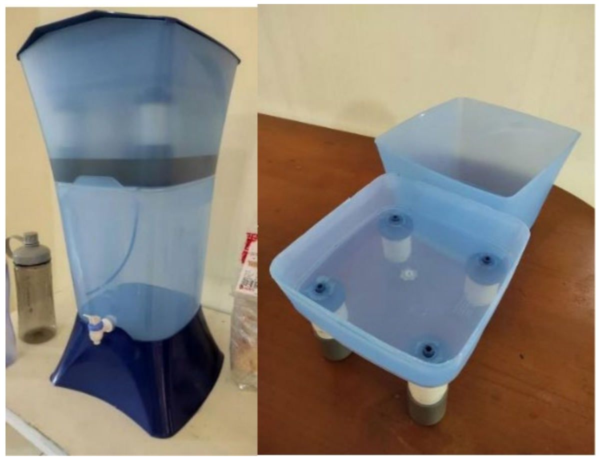

Figure 1 Filter Cartridge designs

Based upon the above Figure 1, there is the need on additional container to contain the prefiltered water that contains iron. The options to position the additional container only remain to putting it inside the upper container, as shown, or stack another upper container. The latter idea was scratched because it would mean an additional height for Riam® that is troublesome based on user experience. Moreover, the additional container made during internship was too small (±3.5 litres) and takes half an hour for every refill to filter the water from the upper container to the lower container. Added with the small diameter of the hole for water to pass means lack of pressure contributes to the slow filtration rate (Filter 2018). To proceed to the observation, this paper elaborates chemistry intern of the design made during research is tabulated below in Table 1:

Table 1. Iron Concentration Observations

Day	**Filtered Water (L)**	**[Fe] in prefiltered water (mg/L)**	**[Fe] in filtered water (mg/L)**	**Observations**	**Rate of Filtration (min/L)**
2	8	2.33	1.09	Water turns dark	6,67
3	5	3.35	3.26	Water turns dark	15,5
4	10	2.33	2	Water is yellowish	34,3
5~	-	-	-	Filter is clogged	>2 days

The observations took place on the second day because the experiment was conducted along with other projects of combining it with water dispenser design. However, the water dispenser design did not come fruitful due to the loss of water samples during the experiment. Therefore, the data collection started from day 2.

From the table above, it can be seen that the iron concentration difference before and after filtration with the manganese greensand filter design is so small to the point it is insignificant. This means that the current design is not effective and efficient enough to reduce the iron contaminant in the filtered water. Additionally, the rate of filtration is reduced greatly from day to day. Taking the fifth day as an example, the filter cartridge is clogged completely and did not let any water pass through. Factors contributing to this result are:

1. The water sample had too many small particles that clogged the filter completely.
2. The height of pipe is not 15 cm, which was the minimum requirement.
3. An additional part to connect pipe and the upper container that has a very small diameter while the pipe has a bigger diameter. Pressure may then become inadequate.
4. The bottom end of pipe has very small holes to allow access for filtered water to pass through.

At this point, a survey was made regarding water dispenser and customer's inputs for its current capability. The survey was held on August 19th 2021 on Google Form with 27 respondents with 92.6% of them claimed to have water dispensers. Inputs about their current water dispensers are collected as Voice of Customers (VOC) and is shown below:

1. Automatic water buoy sensor
2. Aesthetic Design
3. Space-saving
4. Nozzle/hose can be cleaned (for bottom loader)
5. Cup holder system
6. Temperature control
7. pH control
8. Electrical durability
9. Easy to clean
10. Water from tap does not spill
11. Durability & reliability of hot & cold feature
12. Water volume indicator

From here, design criteria can be formulated by creating a list of the functions, characteristics, usage, performance and appearance needed and wanted by the users to further help its application for the prototype stage. The design criteria for the overall water dispenser and its cartridge are shown below Table 2.:

Table 2. Design Criteria for Filter Cartridge

No.	**Aspect**	**Design Criteria**
1	User	Effective, Ease of Use
2	Product	Easy to clean, Organic, No Electrics
3	Environment	Durable, Space-saving, No Spills
4	Task	Reduces iron content, Fast rate of filtration

The next step is to form a design requirement, which is divided into two criteria: Primary and Secondary. Primary criteria focus on the main thing that user needs the most, to be part of and produced into the developing product, while secondary criteria help the performance of the product and is based on what user wants. However, this criterion is not the main part of product's design solution; it becomes the supporting factor for a better quality of the product. Therefore, the discussed design requirement below includes for the main water dispenser as well:

6. Conclusion

From view point of households, water sources are distant, contaminated, or expensive, and household sanitation is unaffordable. The Director-General of WHO once said that safe water, sanitation, and hygiene at home should not only be a privilege of only those who are rich or live in urban centers. These are some of the most basic requirements for human health, and all countries have a responsibility to ensure that everyone can access them Manganese greensand is a specially processed medium for iron, manganese, and hydrogen sulphide removal.

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Biography

Khristian Edi Nugroho Soebandrija is a practitioner in the field of engineering, with study and working exposures in Europe, Asia and United States of America. Currently, he is one of lecturer specialist PhD level, in BINUS ASO School of Engineering. He has been awarded as distinguished honor membership in Sigma Gamma Tau, known as Aerospace Engineering Honor Society; and Tau Beta Pi, known as National Honor Society in USA. He is one of Institute of Industrial Engineers (IIE), in which IIE is now becoming Institute of Industrial and Systems Engineers (IISE).

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