Design of Dual Media Water Filtration System in Debesmscat Mabigo Water Reserve

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CHAPTER ONE

INTRODUCTION

A. Background of the Study

Our health, communities, and economy all depend on clean water. To have healthy populations downstream, we need clean water upstream. Rivers, lakes, bays, and coastal waters are all dependent on the streams and wetlands that feed them. Communities benefit from streams and wetlands because they trap floodwaters, recharge groundwater supplies, filter pollution, and offer habitat for fish and wildlife. The total volume of fresh water on Earth far outweighs human demands. Out of the overall water resources on Earth, about 97% can be found in the oceans while the remaining 3% remains available for direct exploitation; however, out of this 3%, the quantity of water that is available for use by humans is estimated at onehundredth (Eakin and Sharman 2010; Gleick 1993).

Water filtration is usually considered a simple mechanical process that includes physical and chemical adsorption, straining, sedimentation, interception, diffusion, and inertial compaction. It is the process of removing or reducing the concentration of particulate matter, including suspended particles, parasites, bacteria, algae, viruses, and fungi, as well as other undesirable chemical and biological contaminants from contaminated water to produce safe and clean water for a specific purpose, such as drinking, medical, and pharmaceutical applications (N. Mao, 2016).

The first application of filtration as a means of removing debris from liquids is lost in antiquity. The first public works application is usually considered to have occurred in 1852 when the City of London was required by Parliament to filter its water through sand filters. The first successful filters in the United States were installed in Poughkeepsie, New York, in 1872 (Fair, Geyer, and Okun, 1968). Filtration, in the early days, had been used in potable water production for the removal of solids. The same principle was later applied to treat wastewater. As technology progressed through the years, more efficient filters have been developed by modifying the original sand filters. Dual media filters with sand and anthracite coal and multimedia filters with sand, anthracite coal, and garnet have been found to be more efficient than the original sand filters which contained unstratified and later stratified sands. Filters with upward flow direction have been tried with some success, but the conventional downflow unit is still more popular because of its simplicity (Tebbutt, 1971).Nowadays, filtration system of various types has been widely used in underdeveloped countries around the world such as residential filters, slow sand filters, rapid sand filters, dual media filters, and mixed media filters. It has a low construction cost (manual labor), and no chemicals required, although flocculent aids are sometimes used in conjunction with large-scale filtration systems. Filtration is a well-accepted technology when applied in the treatment of industrial and public water supplies.

The Dr. Emilio B. Espinosa Sr. Memorial State College of Agriculture and Technology (DEBESMSCAT) is the lone State College in the Province of Masbate. It is located in a municipality that lacks a water system that serves the entire population. DEBESMSCAT established its own water reserve system for a water supply because it requires a considerable volume of water to suit its demands.

Mabigo Water Reserve is one of the sources of DEBESMSCAT'S water supply. It is a dam-like structure with its main purpose of holding back the water from the stream. This water facility reserves water that can be used for household purposes such as for bath, laundry, dishwashing, cooking, watering, etc., but is not safe for drinking water. It is also primarily used in agriculture such as in irrigation, spraying, drinking water for livestock, and washing down livestock buildings. It is a great source of free water supply, however, on rainy days water from Mabigo Water Reserves becomes muddy (lightish brown in color).Chemicals, waste materials, and other dangerous contaminants can be picked up by floodwaters as they sweep across the landscape and end up in human water supplies. Wells and reservoirs that are overtopped by floodwater are especially vulnerable to pollution. Water filtration system can help reduce the concentration of many types of contaminants in water.

In this project, the researchers proposed a design of dual media filtration systemas a water filtration system inMabigo Water Reserve which is highly needed especially when raining. Dual filters attract large number of particles present in water. This happens because of the many filter layers with different levels of pores. The usual design of a dual-media filter consists of a layer of anthracite coal above a layer of fine sand. The upper layer of coal traps most of the large floc, and the finer sand grains in the lower layer trap smaller impurities.

B. Statement of the Problem

Filtration system of Mabigo Water Reserve only uses gravel of various sizes to limit the amount of unnecessary solid particles carried by the waterflow. Rainy days increases the flow of water, as well as the accumulation of unwanted solid particles resulting the water to become muddy (lightish brown in color).

The proposed water filtration system design is a dual media filtration system. A dual media filter utilizes two layers for the filter process.

Specifically, this study aims to answer the following problems:

- What is the design of the dual media filtration system?
- How effective is the dual media filtration system in filteringthe muddy (lightish brown in color) water?
- How effective is the proposed dual media filtration system compared to the existing method of filtration in improving the colorof the water during rainy days?

C. Objectives of the Study

The general objective of this study is to design a dual media water filtration system in DEBESMSCAT Mabigo Water Reserve to improve the color of the water during rainy days.

Specifically, this study aims to:

- Design a dual media water filtration system in Mabigo Water Reserve using charcoal and sand as filter media.
- Determine theability of dual media filtration system in filtering themuddy (lightish brown in color) water in terms of:
  - ✓ Turbidity
  - ✓ Total Suspended Solids
  - ✓ Dissolved Oxygen
  - ✓ pH Level
- Compare thequality of the filtratebetween the proposed dual media filtration from the old method of filtration in Mabigo Water Reserve in terms ofits color.

D. Hypothesis of the Study

The proposed dual media filtration design was effective in improving the color of the water compared to the existing method of filtration of Mabigo Water Reserve.

E. Scope and Delimitations of the Study

This proposal was focused on designing a water filtration system, dual media filter, in Mabigo Water Reserve of DEBESMSCAT. The filtration system design is basically composed of layers of gravel, sand, and charcoal. The evaluation of the appearance of the filtrate would only be limited to the comparison of the existing filtration method and the proposed filtration system design in terms of improving the color. The efficiency of the proposed dual media filtration system design would only be based on the results of the laboratory testing of the filtrate.The types of charcoal and sand used in the study were not stated because they were not taken into account in the whole design process.

F. Time and Place of the Study

This study was conducted at DEBESMSCAT, Mandaon, Masbate from the Month of February to May, Year 2022.

G. Significance of the Study

Filters, as commonly understood in water treatment generally consist of a medium within which it is intended most of the particles in the water will be captured.

This study can provide valuable contributions to:

- **The Government and Community.** This study is beneficial to the government and community since the materials needed in the proposed dual media filtration system design to filter the water are readily available, affordable, and disposable material. In addition, the community can adapt to the idea of having their own water filtration system.
- **Industry.** This study benefits the supplier of the materials used in the proposed water filtration system design.
- **Future Researchers.** This study provides information and idea to future researchers to further improve the study in proposing a new filtration system design.

H. Definition of Terms

- **Dissolved Oxygen (DO)**. A measure of how much oxygen is dissolved in the water - the amount of oxygen available to living aquatic organisms.
- **Dissolved Oxygen Meter.** Use to measure the amount of dissolved oxygen in the water.
- **Filtrate.** A liquid which has passed through a filter.
- **Filtration.** Process of separating suspended solid matter from a liquid, by causing the latter to pass through the pores of some substance, called a filter.
- **Nephelometric Turbidity Unit (NTU)**. The unit used to measure the turbidity of a fluid or the presence of suspended particles in water.
- **pH Level.** A measure of how acidic/basic water is.
- **pH meter.** An instrument used to measure the acidity/alkalinity of a solution.
- **Total Suspended Solids (TSS).** A water quality parameter that is defined as the quantity of material suspended in a known volume of water that is trappable in a filter.
- **Turbidimeter.** Used to measure the relative clarity of a fluid by measuring the amount of light scattered by particles suspended in a fluid sample.
- **Turbidity.** It is a measurement of the amount of light that is scattered by material in the water when a light is shined through the water sample.
- **US-EPA.** United States Environmental Protection Agency

I. ENDNOTES

- Eakin and Sharman, 2010, Volumes of the World's Oceans from ETOPO1. NOAA, National Geophysical Data Center,http://www.ngdc.noaa.gov/mgg/global/etopo1_ocean_volumes.html, Accessed April 2022.
- Mao, N. 2016, Advances in Technical Nonwovens, Woodhead Publishing Series in Textiles, https://www.sciencedirect.com/topics/chemical-engineering/water-filtration, Accessed April 2022.
- Fair, Geyer, and Okun, 1968, Water and Wastewater Engineering, John Wiley and Sons, Inc., https://doi.org/10.1177/146642406908900123, Accessed April 2022.
- Tebbutt, T. H. Y. 1971, An investigation into tertiary treatment by rapid filtration, Water Research, https://doi.org/10.1016/0043-1354(71)90123-0, Accessed April 2022.
- Dissolved Oxygen and Water, Online Resource,https://www.usgs.gov/special-topics/water-science-school/science/dissolved-oxygen-and-water#overview. Accessed April 2022.
- Filtration, Online Resource,https://www.lenntech.com/chemistry/filtration.htm#:~:text=The%20liquid%20which%20has%20passed%20through%20the%20filter%20is%20called%20the%20filtrate. Accessed April 2022.

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- What is NTU, Online Resource,https://www.tecnoconverting.com/technical-articles/what-is-ntu/#:~:text=NTU%20stands%20for%20Nephelometric%20Turbidity,the%20higher%20the%20turbidity%20is. Accessed April 2022.
- pH and Water, Online Resource,https://www.usgs.gov/special-topics/water-science-school/science/ph-and-water#:~:text=oil%20or%20alcohol.-,pH%20is%20a%20measure%20of%20how%20acidic%2Fbasic%20water%20is,hydroxyl%20ions%20in%20the%20water. Accessed April 2022.
- Total Suspended Solids (TSS), Online Resource,https://www.corrosionpedia.com/definition/6165/total-suspended-solids-tss. Accessed April 2022.
- Turbidity and Water, Online Resource,https://www.usgs.gov/special-topics/water-science-school/science/turbidity-and-water#:~:text=Turbidity%20is%20the%20measure%20of,light%2C%20the%20the%20h he%20turbidity. Accessed April 2022.

CHAPTER TWO

REVIEW OF RELATED LITERATURE AND STUDIES

This section of the study covers the related literature and studiesthat the researchers reviewed while designing a dual media filtration system for Mabigo Water Reserve.

A. Sand Filter

According to Wikipedia, sand is a granular material composed of finely divided rock and mineral particles. Sand filters are used as a step in the water treatment process of water purification. There are two types: rapid (gravity) sand filters and slow sand filters. Rapid sand filtration is a purely physical treatment process. As the water flows through several layers of coarse-grained sand and gravel, relatively large particles are held back safely (DIJK & OOMEN, 1978). It usually requires power-operated pumps, regular backwashing or cleaning, and flow control of the filter outlet (Bruni and Spuhler, 2019). It is a type of filter used in water purification and is commonly used in municipal drinking water facilities as part of a multiple-stage treatment system (USEPA, 1990). Rapid sand filters were first developed in the 1890s, and improved designs were developed by the 1920s (Logsdon, 2011). The first modern rapid sand filtration plant was designed and built by George W. Fuller in Little Falls, New Jersey (Fuller, June 1903). It uses relatively coarse sand and other granular media to remove particles and impurities that have been trapped in a floc through the use of flocculation chemicals-typically alum. The unfiltered water flows the filter medium under gravity or under pumped pressure and the floc material is trapped in the sand matrix (Denver, 2003). In general, construction, operation and maintenance costs for rapid sand filters are significantly higher than costs for slow sand filters (UNEP, 1998).

Slow sand filtration on the other hand, has been an effective water treatment process for preventing the spread of gastrointestinal diseases for over 150 years, having been used first in Great Britain and later on other European countries (Logsdon, 2002). A Slow sand filter consists of a box, often made of concrete in which bed of sand is placed over a layer of gravel and perforated pipes. These pipes collect treated water (Veenstra and Visscher, 1985). The first documented use of sand filters to purify the water supply dates to 1804, when the owner the bleachery in Paisley, Scotland, John Gibb, installed an experimental filter created by engineer Robert Thom, selling his unwanted surplus to the public (Buchan, 2003). This method was refined and culminated in the first treated public water supply in the world installed by Engr. James Simpson for the Chelsea Waterworks Company in London in 1829 (Christman, 1998). This installation provided filtered water for every resident of the area, and the network design was widely copied throughout the United Kingdom in the following decades.

Rapid sand filters were later favored over slow sand because of the large area required by the latter to maintain a sufficient output and the excessively low filtration rates (0.1–0.3 m/h, or lower), also due to the smaller size of the sand grains (Gray, 2010). Slow sand filtration on the other hand, is not, however, effective when dealing with high levels of turbidity and algae because of a limited removal ability and long ripening times (Ratnayaka et al.,2009). Slow sand filters are also poor in removing color. Color is a substitute for organics as well as an aesthetic indicator of water quality. The dissolved fraction of color is referred to as true color. Color is mainly caused by the presence of organic humic substances (Montgomery, 1985). Due to the stabilizing nature of humic substances on dissolved particles, it is expected that color is difficult to remove in slow sand filters. The average expected removal of true color in slow sand filters is 30% (Elllis, 1985). In fact, the common reason for the declining use of slow sand filtration in the United Kingdom is its limited ability in removing organic color and dissolved organic carbon (Lambert and Graham, 1995).

B. Charcoal filter

Water filters use a special type of charcoal known as activated charcoal to purify water. Activated charcoal is a charcoal that has been treated with oxygen to open up millions of tiny pores between the carbon atoms. During water filtration through activated carbon, contaminants adhere to the surface of the carbon granules or become trapped in the small pores of the activated carbon (Amirault et al.2003). This is referred to as adsorption. Some organics can be removed using activated carbon filters. It is not, however, efficient against other pollutants.

Activated charcoal is extremely porous. It has a vast surface area which dramatically improves the adsorption process. A gram of activated carbon can have a surface area of more than 1,500 square meters. Activated carbon filtration is widely used to generate drinking water in centralized treatment plants and at the household level, as well as in industries to treat effluent. It is also a new method in removing micropollutants in drinking water production, and in purifying treated waste water before disposal. Two of the types of water filters are particulate filters and absorptive (reactive filters). In particulate filters, the particles were excluded by size, and in adsorptive filters, a material or medium adsorb or react with a contaminant in water. Adsorptive activated carbon filtration and other adsorption material has the same principle. The contaminant is attracted to and held (adsorbed) on the surface of the carbon particles. The efficiency of adsorption is influenced by the features of the carbon material (particle and pore size, surface area, surface chemistry, and so on). Most other filtering solutions are compatible with charcoal filters. When used together, they can improve the purifying process. One example is the use of charcoal filters in conjunction with reverse osmosis (RO), where charcoal can assist extend the life of the RO system by conducting a round of filtration prior to reverse osmosis. By removing the larger particle first, the pores of the semipermeable membrane are not clogged as quickly. The elimination of residues of volatile compounds from distillates is another application of double filtration with charcoal. The technique improves the liquid's purity.

The use of carbon in the form of charcoal has been used since antiquity for many applications. In Hindu documents dating from 450 BC charcoal filters are mentioned for the treatment of water. Charred wood, bones, and coconut charcoals were used during the 18th and 19th centuries by the sugar industry for decolorizing solutions. Activated carbon is a material prepared in such a way that it exhibits a high degree of porosity and an extended surface area (Lemly et al 1995). Water filtering systems are crucial investments for homes and commercial premises. Although charcoal filters are low cost and can allow consumers to avail a pocket- friendly price. Musa et al., (2020) suggested in their thesis entitled, “Evaluation of potential use of charcoal as a filter material in water treatment” that charcoal material should be incorporated with other filter material of higher filtration capability to provide a combined filter media which will be more effective in removing turbidity as well as microbial contaminants.

C. Gravel Filter

A loose accumulation of rock particles is known as gravel. Gravel is developed in huge amounts commercially as crushed stone and occurs naturally around the world as a result of sedimentary and erosive geologic processes. It is found naturally, mostly in lake, river, and ocean beds. Commonly, gravel is a phrase that is used to describe a mixture of various sizes of stone combined with sand and sometimes some clay. In the Udden-Wentworth scale gravel is categorized into granular gravel (2–4 mm or 0.079–0.157 in) and pebble gravel (4–64 mm or 0.2–2.5 in). ISO 14688 grades gravels as fine, medium, and coarse, with ranges 2–6.3 mm to 20–63 mm.

Asa filter medium, gravel has the ability to hold back precipitates containing impurities. Gravel filters were proven to be quite effective in removing sediments and heavy metals under all water level regimes, even as the system clogged with time. Despite the fact that the sediment particle size distribution was much smaller than the pore size of the filter media, sediment and related contaminants were effectively contained in the gravel filter's top layer. Gravel filters, on the other hand, were less effective at removing nutrients, especially dissolved nutrients.

Gravel filter media are extensively used in stormwater management systems for attenuation and treatment of runoff, such as infiltration trenches/basins, porous pavements, and soak ways. These approaches aid in the restoration of pre-development hydrology by reducing a watershed's effective impervious surface while also allowing rainwater detention and infiltration into the surrounding soils. Filter gravel is used to support sand and coal filters in water filters. For maximum performance, filter gravel should have the right hardness and be rounded rather than angular.

D. Dual Media Filter

Regarding the design and capabilities of water filtration systems, numerous inventions and improvements have been performed. A dual media filtration system is a combination of the stated three filters above. As single sand medium filters cannot always perform adequately to achieve the treatment tasks, a solution was found in the introduction of dual media filters by placing a denser material at the bottom and a lighter one at the top, with decreasing size. In the most common configuration, a layer of anthracite is placed on top of a sand layer; in some cases, an additional layer of garnet is added (Binnie and Kimber, 2013). Zouboulis et al., (2007) compared the performance of a single medium sand filter and a dual media sand/anthracite filter for conventional and direct filtration. During conventional filtration, the dual media configuration was able to operate for a longer cycle, leading to a 10% higher water production; the length of a dual media cycle was 2–3 times that of the single medium, with final head loss values being less than half. For turbidity removal, both configurations showed values well below 0.2 NTU, with the dual media configuration performing marginally worse. Direct filtration was more difficult to control. For small doses of coagulant, the single medium did not reach the required level of turbidity, presenting values of 0.5–1 NTU. The dual media filter was more effective, achieving turbidity values slightly higher than those with conventional operations. Conley and Pitman (1960) stated in their study, Test Programs for Filter Evaluation at Hanford, a plant study was made to see if there would be an advantage in using filters made entirely of sand instead of the sand and anthracite combination. The results of a test on one plant size filter showed that the sand filter gave runs which were only half as long as those given by the combination filters. Additional plant tests were run using various depths of anthracite and sand. The tests showed that water quality was improved by increasing the depth of sand and decreasing the depth of anthracite.

E. Filtration System

Filter efficiency is determined by physical characteristics, such as grain size, shape, porosity, and bed depth/ media grain size ratio. Efficient filtration can be achieved if a large portion of the filter bed depth is utilized for suspended solids removal (Baumann and Huang, 1974; Shell and Burns, 1973).

F. Water Usage and Classification

The water quality is assessed based on the set beneficial use as defined in DENR Administrative Order Number 2016-08 as shown in Table 1.

Table 1: Water Quality Guidelines and General Effluent Standards

Classification	Intended Beneficial Use
Class AA	**Public Water Supply Class I.** Intended primarily for waters having watersheds, which are uninhabited and/or otherwise declared as protected areas, and which require only approved disinfection to meet the latest PNSDW.
Class A	**Public Water Supply Class II**. Intended as sources of water supply requiring conventional treatment (coagulation, sedimentation, filtration and disinfection) to meet the latest PNSDW.
Class B	**Recreational Water Class I**. Intended for primary contact recreation (bathing, swimming, etc.)
Class C	1) **Fishery Water** for the propagation and growth of fish and other aquatic resources;

	2) **Recreational Water Class II**. For boating, fishing or similar activities. 3) **For agriculture**, irrigation and livestock watering, etc.
Class D	**Navigable waters**

This is known as "in depth" filtration. "In depth" filtration could be achieved by filtering first through coarse medium and then through progressively finer medium. This will permit long filter cycles because the head loss increase is relatively uniform due to the uniform distribution of suspended solids throughout the bed depth (Holding, 1972). Thus, a dual media bed would increase the capacity of the filter due to "in depth" filtration, allowing longer filter cycles and making more efficient use of the filter bed (Baumann and Huang, 1974). McGivney and Kawamura (2008) suggest using L/d_e ratio for the design of filter beds where L is the depth of the filter bed (mm) and d_e is the effective size of the filter medium. L/d_e ranges between 1000 and 2000 for different filter beds—1000 for ordinary mono- medium sand and dual media beds**.**

G. Parameters for Water Quality Criteria by Classification

Table 2 shows the guidelines for the quality of water in accordance with the DENR Administrative Order No. 2016-08.

Filtration systems of various types has been widely used in developed and underdeveloped countries around the world. It had been used for potable water production. In this study, the researchers decided to design a water filtration system for Mabigo Water Reserve just to improve the quality of the water in terms of its physical appearance (lightish brown in color or clear).

Table 2: Water Quality Guidelines for Primary Parameters

Parameters	**Unit**		**Water Body Classification**							
			A	**B**	**C**	**D**	**SA**	**SB**	**SC**	**SD**
BOD	mg/L	1	3	5	7	15	n/a	n/a	n/a	n/a
Chloride	mg/L	250	250	250	350	400	n/a	n/a	n/a	n/a
Color	TCU	5	50	50	75	150	5	50	75	150
Dissolved Oxygen (Minimum)	mg/L	5	5	5	5	2	6	6	5	2
Fecal Coliform	MPN/100mL	<1.1	<1.1	100	200	400	<1.1	100	200	400
Nitrate as NO_3.N	mg/L	7	7	7	7	15	10	10	10	15
pH (Range)		6.5-8.5	6.5-8.5	6.5-8.5	6.5-9.0	6.0-9.0	7.0-8.5	7.0-8.5	6.5-8.5	6.0-9.0
Phosphate	mg/L	<.003	0.5	0.5	0.5	5	0.1	0.5	0.5	5
Temperature	℃	26-30	26-30	26-30	25-31	25-32	26-30	26-30	25-31	25-32
Total Suspended Solids	mg/L	25	50	65	80	110	25	50	80	110

H. ENDNOTES

- DIJK, J.C. van, OOMEN, J.H.C. 1978, Slow Sand Filtration for Community Water Supply in Developing Countries: A Design and Construction Manual, IRC Technical Paper Series, The Hague, The Netherlands, Accessed May 2022.
- Bruni, M. and Spuhler, D. 2020, Rapid Sand Filtration, SSWM Toolbox,https://sswm.info/sswm-university-course/module-6-disaster-situations-planning-and-preparedness/further-resources-0/rapid-sand-filtration, Accessed May 2022.

- USEPA, 1990, Technologies for Upgrading Existing or Designing New Drinking Water Treatment Facilities, Cincinnati, OH, EPA 625/4-89/023. Accessed May 2022.
- Logsdon, G. S., 2011, Water Filtration Practices, Denver, CO: American Water Works Association, ISBN 978-1613000847. Accessed May 2022.
- Fuller, G.W., June 1903, The Filtration Works of the East Jersey Water Company, at Little Falls, New Jersey, Transactions of the American Society of Civil Engineers, doi: 10.1061/TACEAT.0001566, Accessed May 2022.
- Water Treatment, 3rd ed., 2003, Denver CO: American Water Works Association, ISBN 1583212302. Accessed May 2022.
- UNEP, 1998, Sourcebook of Alternative Technologies for Freshwater Augmentation in Some Countries in Asia, Technical Publication, Osaka/Shiga: United Nations Environmental Programme. International Environmental Technology Centre, Accessed May 2022.
- Logsdon, G., 2002, Slow Sand Filtration for Small Water Systems In: Journal of Environmental Engineering and Science, Accessed May 2022.
- Veenstra, S., Visscher, J.T., 1985, Slow Sand Filtration: Manual for Caretakers, IRC Training Series, The Hague: IRC International Water and Sanitation Centre, Accessed May 2022.
- Buchan, J., 2003, Crowded with Genius: The Scottish Enlightenment: Edinburgh's moment of the mind, New York, Harper Collins, Accessed May 2022.
- Christman, K., 1998, The History of Chlorine, Waterworld, Accessed May 2022.
- Gray, N., 2010, Water Technology, 3rd ed., IWA Publishing, London, UK, Accessed May 2022.
- Ratnayaka, D, Brandt, M, Johnson, K, 2009, Twort's Water Supply, 6th ed., Butterworth-Heinemann, Oxford, MA, USA, Accessed May 2022.
- Montgomery, J.,1985, Water Treatment: Prinicples and Design, John Wiley & Sons, Accessed May 2022.
- Ellis, K., 1985, Slow Sand Filtration, CRC Critical Reviews in Environmental Control, Vol. 15, Accessed May 2022.
- Lambert, S., Graham, J., 1995, A Comparative Evaluation of the Effectiveness of Potable Water Filtration Processes, J. Water SRT-Aqua, Vol. 44, Accessed May 2022.
- Amirault, R., Chobanian, G., McCants, D., McCann, A., Burdett, H., Neptin, B., 2003, Activated Carbon Treatment of Drinking Water Supplies,Healthy Drinking Water for Rhode Islanders, Accessed May 2022.
- Lemley, A., Wagenet, L., Kneen, B., 1995, Activated Carbon Treatment of Drinking Water, Water Treatment Notes Cornell Cooperative Extension, Accessed May 2022.
- Evaluation of Potential Use of Charcoal as a Filter Material in Water Treatment, Online Resource, https://www.irjet.net/archives/V7/i5/IRJET-V7I5373.pdf, Accessed May 2022.
- Test Program for Filter Evaluation at Hanford, Online Resource,https://doi.org/10.1002/j.1551-8833.1960.tb00485.x, Accessed May 2022.
- Evaluation of the Addition of Granular Media Filtration to Wastewater Treatment Plants to Meet New Standards, Online Resource,https://digitalcommons.usu.edu/water_rep/516, Accessed May 2022.
- 11 Benefits of Using a Charcoal Water Filter in Your Home, Online Resource,https://www.discountfilters.com/blog/11-benefits-using-charcoal-water-filter-your-home/, Accessed May 2022.
- Handbook of Water Industrial Treatment, Online Resource,https://www.suezwatertechnologies.com/handbook/chapter-06-filtration?fbclid=IwAR2mhBB3BnCBqC9FZPxDkca2ZxRPnp8eThmv7axLt8xFYaJ8Cxx5dvNscOk, Accessed May 2022.
- Dual Media Filter, Online Resource,https://www.chemtronicsindia.com/dual-media-filter.htm?fbclid=IwAR3dDDkVIr-eMYAm05f-vu5VmBLopAD3uRpXlAyKynw1TET5kPeTYnq7Wtc, Accessed May 2022.
- Part 1 – Introduction to Water Filtration, Online Resource,https://www.ce.memphis.edu/1101/notes/filtration/filtration-

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1.html?fbclid=IwAR0ohjk7otq0j14L6AiaU_UvVag_NfDhQ6SMtiDTyx_vyLpmiHdVl6aG-pw, Accessed May 2022.

- Filtration Systems, Online Resource,https://www.oas.org/dsd/publications/unit/oea59e/ch24.htm?fbclid=IwAR3O-7yKHiB8nSbxP5Fgu3rC1zlIytll5feEgH4y3XyDpuv1-Vx91c_kyrc, Accessed May 2022.
- Filter Gravel, Online Resource, https://www.kleenindustrialservices.com/water-filtration-media-filter-gravel.html?fbclid=IwAR2D9bJG5jTF_c_KcaUTZ3gr4qlV7BTpZ6HSgKketJJSQIyWiXVCZtb3ObI, Accessed May 2022.
- What is the Purpose of Gravel in a Water Filter, Online Resource,https://cementanswers.com/what-is-the-purpose-of-gravel-in-a-water-filter/?fbclid=IwAR2mRiS8XOqosJ2HYh3tJUx7jTvQCQfNarSqipoMXYjmiqooQl4eGNaZTFY, Accessed May 2022.
- Chapter 06- Filtration, Online Resource,https://www.suezwatertechnologies.com/handbook/chapter-06-filtration?fbclid=IwAR2mhBB3BnCBqC9FZPxDkca2ZxRPnp8eThmv7axLt8xFYaJ8Cxx5dvNscOk, Accessed May 2022.
- Gravel, Online Resource,https://www.coursehero.com/file/143977281/GRAVEL-1pptx/, Accessed May 2022.
- Treatment performance of gravel filter media: Implications for design and application of stormwater infiltration systems, Online Resource,https://www.sciencedirect.com/science/article/abs/pii/S0043135407001935, Accessed May 2022.
- Modeling of sediment transport through stormwater gravel filters over their lifespan, Online Resource,https://pubmed.ncbi.nlm.nih.gov/18186343/, Accessed May 2022.
- Binnie, C., Kimber, M., 2013, Basic Water Treatment, 5th ed., ICE Publishing, London, UK, Accessed May 2022.
- Zouboulis, A., Traskas, G., Samaras, P.,2007, Comparison of single and dual media filtration in a full-scale drinking water treatment plant, Desalination, Accessed May 2022.
- Conley, W., Pitman, R., 1960, Test Programs for Filter Evaluation at Hanford, John Wiley & Sons, Inc, https://doi.org/10.1002/j.1551-8833.1960.tb00485.x, Accessed May 2022.
- Baumann, E. R., and J. Y. C. Huang, 1974, Granular filters for tertiary wastewater treatment, Journal Water Pollution Control Federation, Accessed May 2022.
- Shell, G. L., and D. E. Burns, 1973, Advanced wastewater, treatment methods, Effluent and Water Treatment Journal, Accessed May 2022.
- Holding, J. C., 1972, Polishing sewage effluents, Effluent and Water Treatment Journal, Accessed May 2022.
- McGivney, W., Kawamura, S., 2008, Cost Estimating Manual for Water Treatment Facilities, John Wiley & Sons, Inc., Hoboken, NJ, USA, Accessed May 2022.
- Water Filtration Media, Online Resource,https://www.riversands.com.au/application/water-filtration-media/, Accessed May 2022.
- Water Usage and Classification, Online Resource,https://water.emb.gov.ph/?page_id=849, Accessed May 2022.
- Water Quality Guidelines and General Effluent Standards, Online Resourc ıb.gov.ph/wp-content/uploads/2019/04/DAO-2016-08_WATER-QUALITY-GUIDELINES-AN RAL-EFFLUENT-STANDARDS.pdf, Accessed May 2022.

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CHAPTER THREE

METHODOLOGY

This chapter contains the conceptual framework with the conceptual paradigm, all the materials that will be needed, procedures, design and data analysisof the study.

A. Conceptual Framework

This conceptual framework shows the outline of activities that serves as the foundation and guide for the completion of the study.

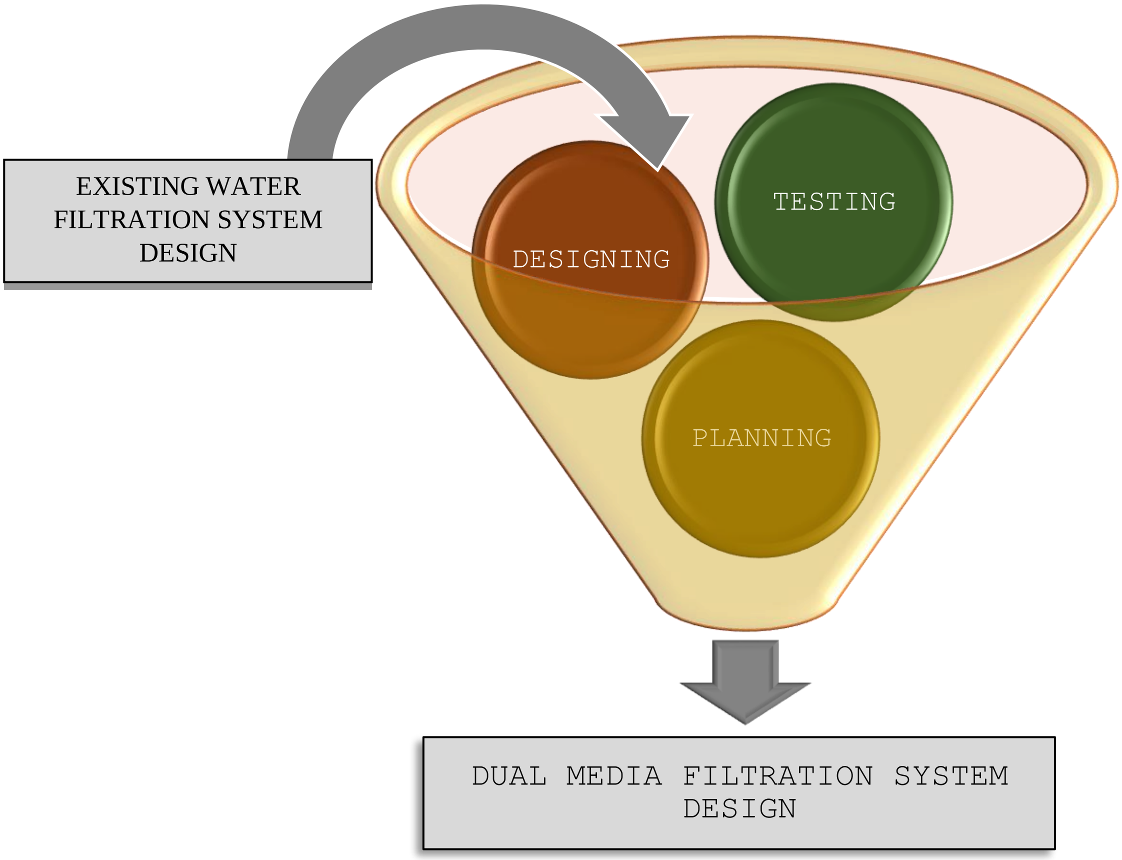

Fig. 1: Conceptual Paradigm

B. Filtration System Design

Figure 2 shows the existing design of Mabigo Water Reserve. It has two parts,the dam- like structure that holds the water from the stream and the 12m long and 1m wide canal with 1.5m depth for the filtration system. The 1m depth and 0.6m wide stone filter is placed at the end of the canal with an outlet pipe for the filtrate. The filtrate is then stored in a tank.

Fig. 2: Mabigo Water Reserve

The proposed dual media filtration system design, as shown in Figure 3, is a 2-layered filter media (sand and charcoal) with layers of gravel.It is composed of 0.240 m bed depth of gravel at the top of the layer to trap unnecessary large solid particles, 0.6 mbed depth of sand to filter smaller particles the first layer failed to trap and 0.360 mbed depth of charcoal at the middle to adhere contaminants to its surface or to trap to its small pores(adsorption). The total depth of the filter beds is 80% of the 1.5 m depth of the filtration canal.Depth of filter beds was designed using McGivney and Kawamura's L/d_e ratio. The total L/d_e of sand and charcoal presented in Appendix Table 1 is equivalent to 1220meeting Kawamura's criterion, $L/d_e \geq$ 1000.

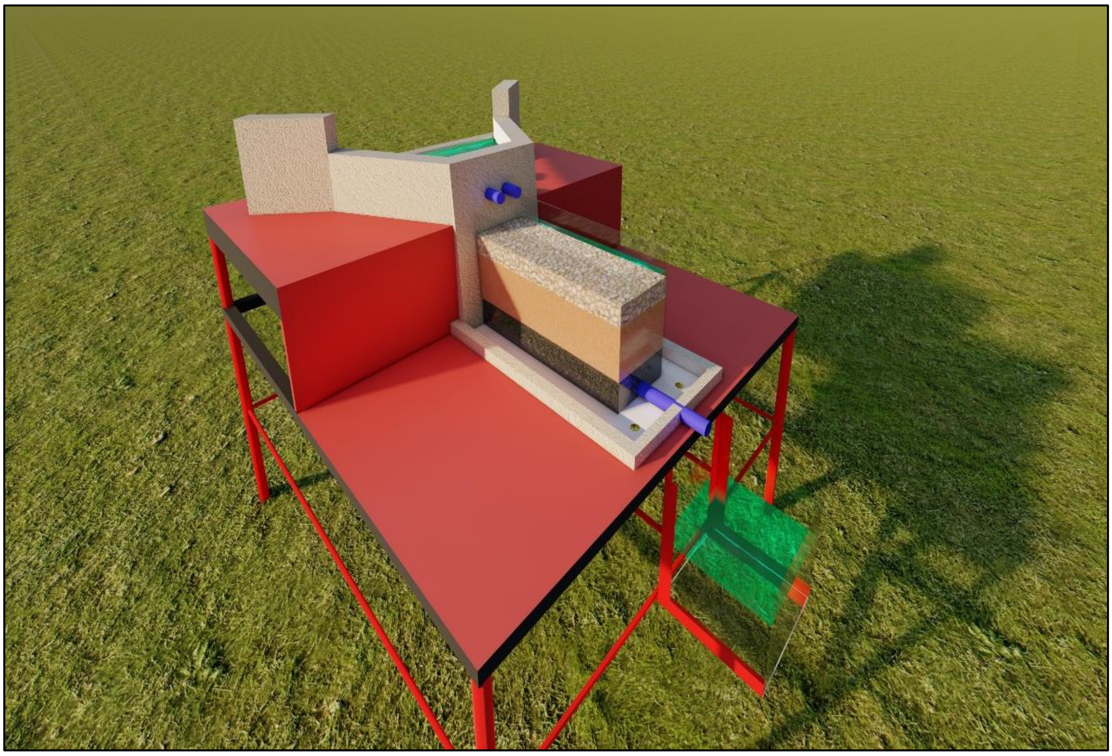

Fig. 3: Proposed Dual Media Filtration System Design Model

C. Materials and Procedures

Table 3: Materials Needed for the Fabrication of Dual Media Filtration System Model

Description	Quantity	Unit
Charcoal	3	plastic bag(s)
Sand	1	plastic bag(s)
Gravel	1	plastic bag(s)
Net (1/8 x 1/8 m)	1	pc
Cement	1	bag
Acrylic (10.32X15.24cm)	1	pc
Glass (45x10.32cm)	2	pcs
Paint	10	pcs
Silicon sealant	1	pcs
Plywood	1	pc
8mm steel bar	1	pc
12mm steel bar	1	pc
Hose (3m)	1	pc
Elbow pipe	1	pc
Aluminum frame	1	pc
¾ B.I pipe	1	pc
¾ pvc pipe	1	pc
Artificial plants		

D. Pilot Testing of Dual Media Filtration System

➢ *Fiter Media Preparation*

The sand was sieved using a strainer of 0.5 mm size to separate sand of sizes greater than 0.5 mm and was then washed thoroughly with clean water, as well as the gravel to remove dirt and unnecessary particles and dried under the sun.

The charcoal was boiled in the water to get rid of the contaminants and to open up the pores, anddried under the sun. It was then crushed into smaller sizes and sieved to remove charcoal powder. The sieved charcoal was soaked in boiled water for 2 hours, and was washed with clean water. Lastly, the charcoal was dried under the heat of the sun.

E. Procedures of Pilot Testing

➢ *Using Plastic Bottles*

Filter media with different sizes were placed in plastic bottles separately. Each cap has a hole that serves as the outlet of the filtered water, and a cotton was placed first to avoid filter media from draining. Both samples have the same thickness of filter media and differs only on its size. Sample A consists of 1 cup of gravel (1 inch) at the top, 1 cup of sand (0.5 mm) at the middle, and ½ cup of charcoal (3 mm) at the bottom. On the other hand, Sample B consists of 1 cup of gravel at the top, 1 cup of sand (>0.5 mm) at the middle, and ½ cup of charcoal (>3 mm) at the bottom. Filter media were measured using a measuring cup. The 100 mL sample muddy water(lightish brown in color) collected from Mabigo Water Reserve was poured into the bottles.

➢ *Using Miniature*

The miniature has four parts: the tank that contains a sample water from Mabigo Water Reserve, the dam-like structure that holds the water from the tank, the filtration canal, and the tank that collects the filtrate.The filtration canal has .450m x .1524m x .254m dimension, approximately 1/1033 of the actual size of the filtration canal of Mabigo Water Reserve. The filter media that were usedwere the on the result of the pilot testing using plastic bottlesand were arranged according to the proposed dual media filtration system design. One (1) gallon of muddy (lightish brown in color) water collected from Mabigo Water Reserve was used.

F. Data Analysis

For the comparison of the existing filtration method and the proposed filtration system design in terms of improving the color, simple description was used. For the efficiency of the proposed dual media filtration system design, filtratewas subjected to laboratory analysis. The following were determined.

➢ *Turbidity*

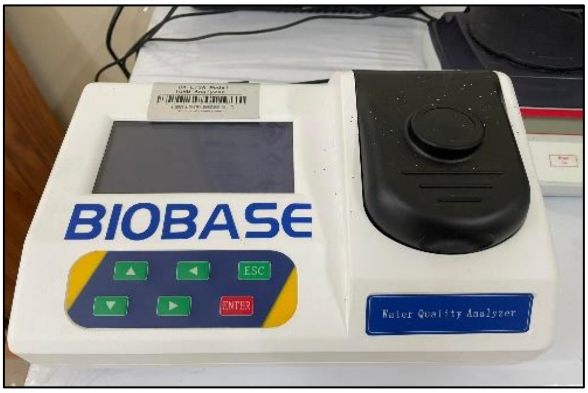

Fig. 4: Turbidity Meter

Table 4: Apparatus and Procedure of Measuring Turbidity

Apparatus	Procedure
• Turbidity Meter • Sample Container	• The sample container in the turbidity meter was washed and was filled with the water sample. The container was then inserted into the turbidity meter and the reading on the screen was observed until it was stable. The value was then recorded.

➢ *Total Suspended Solids (TSS)*

Fig. 5: Weighing Scale and Hot plate

Table 5: Apparatus and Procedure of Measuring TSS

Apparatus	Procedure
• Weighing Scale • Beakers • Hot Plate	• The three (3) beakers filled with and without the filtrate sample of the proposed dual media filtration system design were weighed individually and were then placed in the hot plate to let the water evaporate and the solid particles settle at the bottom of the beakers. The heated beakers with the suspended solids were weighed. Some computations were made to get the amount of total suspended solids.

- Dissolved Oxygen (DO)

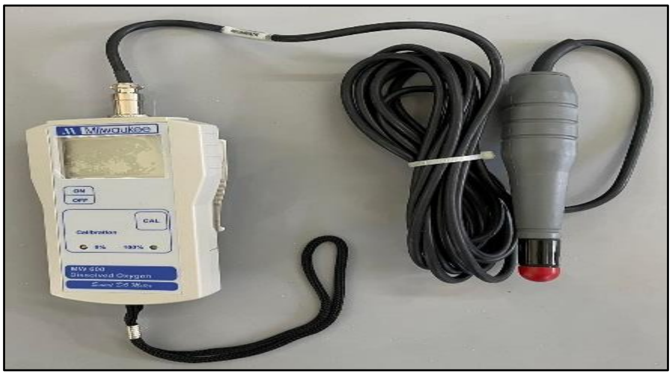

Fig. 6: Dissolved Oxygen Meter

Table 6: Apparatus and Procedure of Measuring DO

Apparatus	Procedure
• Dissolved Oxygen Meter • Sample Container	• The filtrate sample was measured into a sample container, the DO meter was soaked for a few minutes until the reading was stable and data was then recorded

- **pH Level**

Fig. 7: pH Meter

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Table 7: Apparatus and Procedure of Measuring pH

Apparatus	Procedure
• pH Meter • Sample Container	• The process of measuring the pH level of the filtrate was the same process of measuring the DO level. Measurements were recorded.

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CHAPTER FOUR

RESULTS AND DISCUSSIONS

The design of dual media filtration system was based on the result of the conducted pilot testing of dual media filtration: (1) using plastic bottles in order toselect the effective fine size of filter media and (2) using the miniature of the proposed design in order to know the ability of the design to filter the water.

A. Result of Pilot Testing of Dual media Filtration System

- *Using Plastic Bottles*

During the pilot testing using plastic bottles, it was observed that Sample A outperformed Sample B in terms of the color of the filtrate. It was also noticed that the rate of flowof the filtrate of Sample A was slower than of Sample B. It took eight (8) minutes to finish filtering the 100 mL muddy water using Sample A while Sample B took five (5) minutes only.

- *Using Miniature*

During the water filtration testing using the miniature, it was observed that the water quality improved.

Figure 8 shows that the quality of the filtrate using the proposed dual media filtration system was clearer than the filtrate using the old method of filtration in Mabigo Water Reserve.

(a) (b)

Fig. 8: Comparison between the Filtrate Using(a) the Proposed Design and (b) the Existing Method of Filtration

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B. Result of Laboratory Tests

To determine the filtering ability of the proposed dual media filtration system, three samples of unfiltered water and filtrate using the proposed dual media filtration system were collected and tested. The following are the obtained measurements of the parameters from laboratory tests:

- *Turbidity*

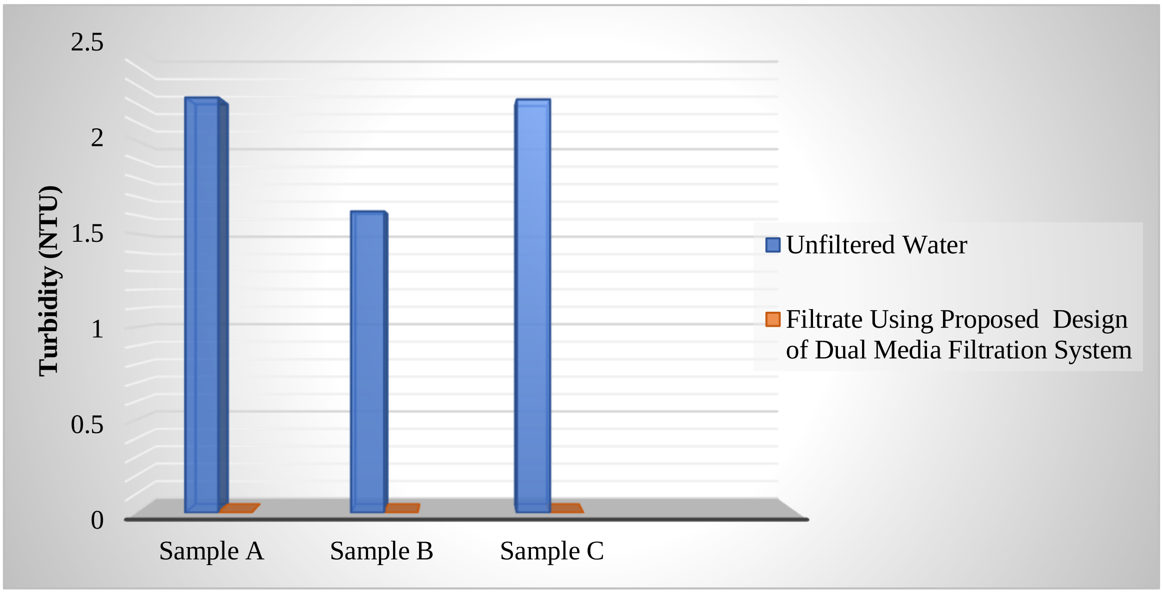

Fig. 9: Amount of Turbidity of the Samples of Unfiltered Water and Samples of Filtrate Using Proposed Design of Dual Filtration System

The 3 samples of unfiltered water have a turbidity of 2.23 NTU, 1.62 NTU, and 2.22 NTU**,** while filtered water from the proposed dual media filtration system have a turbidity of 0.00 NTU. High turbidity indicates that there are many particles floating in the water which prevents the light from passing through. Low turbidity indicates that the water is clearer and contains fewer particles**.** The proposed dual media filtration system shows high turbidity removal efficiency (100%).

- *Total Suspended Solids*

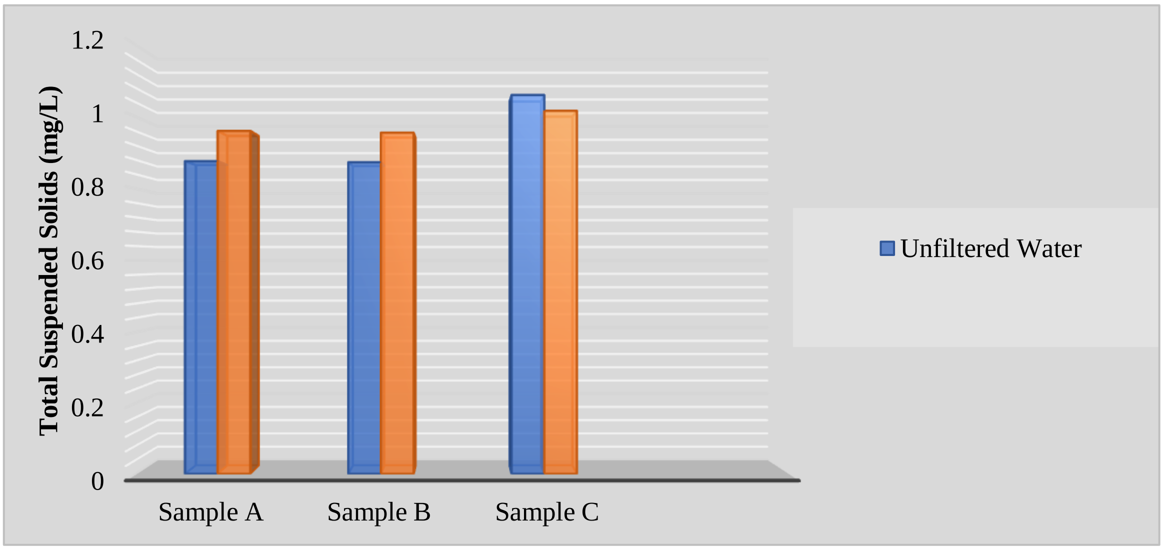

Fig. 10: Amount of Total Suspended Solids of the Unfiltered Water and Filtrate Using the Proposed Dual Media Filtration System

The results obtained shows that the amount of total suspended solids in samples of unfiltered water are 0.877, 0.874, and 1.061. On the other hand, the samples of water filtered by the dual media have a total suspended solid of 0.961 in Sample A, 0.956 in Sample B, and 1.017 in Sample C. Water clarity is influenced by total suspended solids. The more particulates in the water, the less clear it becomes. High total suspended solid levels in water can lower natural dissolved oxygen levels and increase the temperature of the water.

➢ *Dissolved Oxygen*

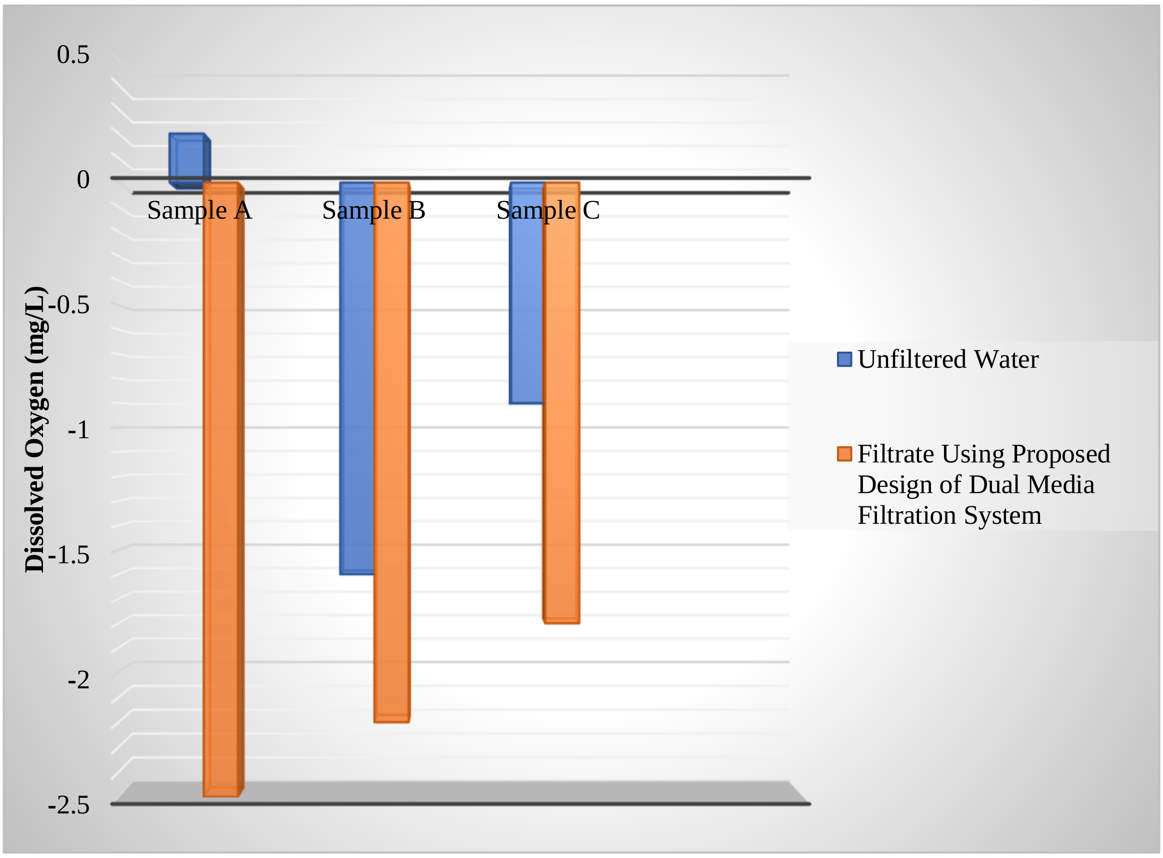

Fig. 11: Amount of Dissolved Oxygen of the Unfiltered Water and Filtrate Using the Proposed Dual Media Filtration System

The amount of total dissolved oxygen of the 3 samples of unfiltered water are 0.2 in Sample A, -1.6 in Sample B, and -0.9 in Sample C, while the filtrate using the proposed dual media filtration system have a total amount of dissolved oxygen of -2.5 in Sample A, -2.2 in Sample B, and -1.8 in Sample C.Filtrate sample using dual media filtration system has a low amount of dissolved oxygen than the filtrate sample from Mabigo water reserve. Greater dissolved oxygen concentrations are associated with high productivity and little or no pollution, hence higher dissolved oxygen concentrations indicate a healthier water body. On the other hand, water with a low concentration of dissolved oxygen may promote the growth of algae. It is also an indication of contamination, and it means the aquatic organisms have no chance of surviving.

➢ *pH*

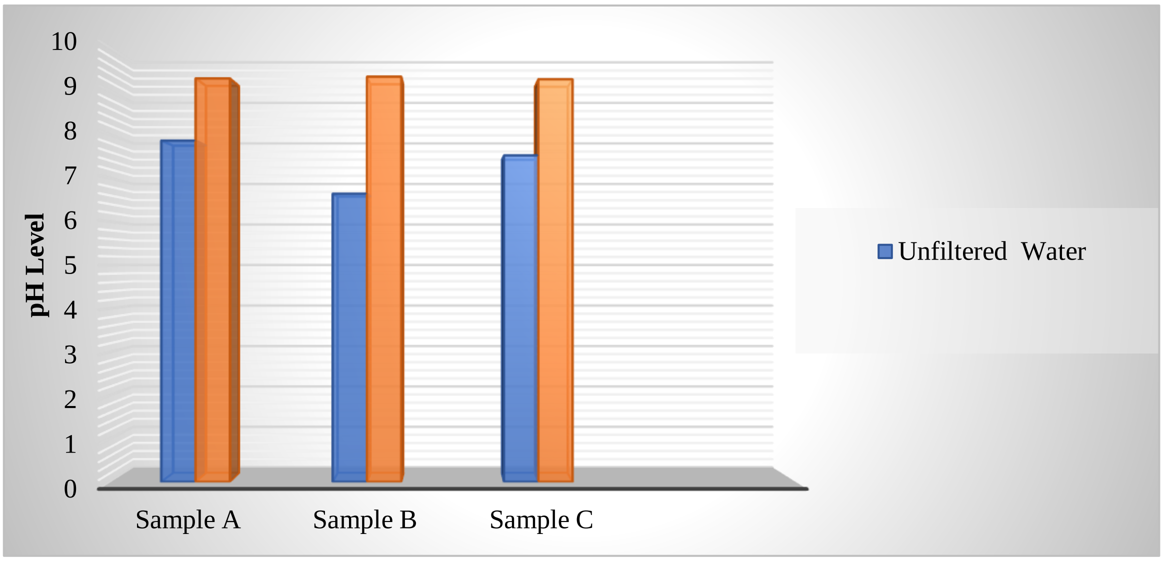

Fig. 12: pH Level of the Unfiltered Water and Filtrate Using the Proposed Dual Media Filtration System

Based on the figure, the three (3) unfiltered water samples have a pH level of 7.86 in Sample A, 6.64 in Sample B, and 7.52 in Sample C. Filtrate samples using the dual media filter was found to have a pH of 9.29 in Sample A,9.33 in Sample B, and 9.27 in Sample C. The pH scale runs from 0 to 14 and measures the acid or base quality of water. A pH of 7 is neutral. A reading below 7 is acidic, and one above 7 is alkaline or basic.The tabulated mean average results of analysis of filtered and unfiltered water with the domestic water standards is shown in Table 8.

Table 8: Comparison of Results of Analysis of Unfiltered and Filtered Water

Parameters	**Unit**	**Sample Water**		**Standards**	**Remarks**
		Unfiltered	**Filtered**		
Turbidity	NTU	2.013	0.0	4	All samples passed
TSS	mg/L	0.949	0.983	80	All samples failed
Dissolved Oxygen	mg/L	-0.8	-2.167	5	All samples failed
pH (Range)		7.333	9.297	6.5-9.0	Unfiltered water sample passed while filtered water failed

**All standards are based on the DENR Administrative Order 2016-08 except for turbidity which was based on US-EPA.*

C. Other Observations and Findings

- During the first trial in filtering the water using the proposed dual media filtration system, the color of the water turned black because of the granular size of charcoal that drains with the water.
- After several trials of filtering muddy (lightish brown in color) water, the result of the filtrate was not that clear anymore compared to the result of the filtrate used in the laboratory testing and other prior trials. The capacity of the proposed design to filter muddy water was only limited to ten (10) gallons.
- Allowing the water to overflow cleans the dirt suspended at the top of the filter media.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

A. Summary

This study aimed to design a dual media water filtration system in Mabigo Water Reserve which is highly needed especially when raining. The specific objectives of this study were to (1) to design a dual media water filtration system in Mabigo Water Reserve using charcoal and sand as filter media, (2) determine the ability of dual media filtration system in filtering the muddy (lightish brown in color) water in terms of turbidity, total suspended solids, dissolved oxygen, and pH level, and (3)compare the quality of the filtrate between the proposed dual media filtration from the old method of filtration in Mabigo Water Reserve in terms of its color.

The proposed dual media filtration system design has a dam- like structure and a canal where the filter media was placed. It is a 2-layered filter media (sand and charcoal) withlayer of gravels that could help to at least separate large solid particles present in the water. It is composed of 0.240 m bed depth of gravel at the top of the layer and 0.360 m bed depth of charcoal at the middle. The total depth of the filter beds is 80% of the 1.5 m depthof the filtration canal.

Pilot testing using a plastic bottle was done on April 20, 2022, at Bello Residence, Mabato-bato, Mandaon, Masbate. Filter media with different sizes were placed in plastic bottles separately. Both samples have the same thickness of filter media and differs only on its size. During the pilot testing, it was observed that the size of filter media used in Sample A is more effective than the filter media used in Sample B. The filter media that were used in the pilot testing using the miniature are the filter media in the Sample A of the pilot testing using plastic bottles and were arranged according to the proposed dual media filtration system design. During the pilot testing using the miniature, it was observed that the clarity of the water improved.

For the testing of the water quality parameters, three (3) samples of unfiltered water from Mabigo Water Reserve and filtrate using the proposed dual filtration system were gathered and brought to the CEng Laboratory of DEBESMSCAT on May 13, 2022.Based on the results obtained, all samples of filtered and unfiltered water passed the standards for domestic water in terms of its turbidity. In terms of total suspended solids and dissolved oxygen, all samples of filtered and unfiltered water failed to reach the required level. When it comes to pH level, only the unfiltered water passed while the filtered water failed but still considered as alkaline or basic. All standards are based on the DENR Administrative Order 201-08 except for turbidity which was based on US-EPA.

Therefore, the proposed dual media filtration system was proven to be effective in filtering water and improving the color compared to the existing method of filtration of Mabigo Water Reserve especially when raining where the flow of water increases. The assumed hypothesis was accepted.

B. Conclusions

Based on the results and findings obtained, the following conclusions were drawn:

- The proposed design of filtration system in Mabigo Water Reserve using charcoal and sand as a dual media filter waseffective in filtering and improving the quality of the water.
- The sizes of the filter media can affect the filtration process; finer size of filter media is more effective in filtering the water.
- The proposed design of dual media filtration system has 100% removal efficiency of turbidity and 0.983 mean average of suspended solids which highly improved the clarity of the water.
- The activated carbon has a great contribution to a lower amount of total dissolved oxygen and a high pH level.
- The filtrate using the proposed dual media filtration system exceeded the standard pH level for domestic water and considered as alkaline or basic.

- From a muddy (lightish brown) color of water due to increase of flow rate of water when raining, the proposed dual media filtration system was able to remove the unnecessary color and make the water clearer compared to the existing method of filtration in Mabigo water reserve based on the appearance of the water sample.

C. Recommendations

The following recommendations were drawn based from the results obtained:

- Use a net with a smaller size of hole than the filter media used or a filter cloth to avoid filter media from draining.
- In laboratory testing, avoid errors in measurements to have an accurate result of data.
- Use a filter cloth in between of sand and charcoal filter to avoid these two filter-media from mixing.
- Drain the proposed dual media filtration canal first with clean water to eliminate the granular charcoal that turns the color of the water into black.
- Maintenance of the filtration system is recommended.

REFERENCES

[1.] 11 Benefits of Using a Charcoal Water Filter in Your Home, Online Resource,https://www.discountfilters.com/blog/11-benefits-using-charcoal-water-filter-your-home/, Accessed May 2022.

[2.] Amirault, R., Chobanian, G., McCants, D., McCann, A., Burdett, H., Neptin, B., 2003, Activated Carbon Treatment of Drinking Water Supplies, Healthy Drinking Water for Rhode Islanders, Accessed May 2022.

[3.] Baumann, E. R., and J. Y. C. Huang, 1974, Granular filters for tertiary wastewater treatment, Journal Water Pollution Control Federation, Accessed May 2022.

[4.] Binnie, C., Kimber, M., 2013, Basic Water Treatment, 5th ed., ICE Publishing, London, UK, Accessed May 2022.

[5.] Bruni, M., Spuhler, D., 2020, Slow Sand Filtration, Online Resource, https://sswm.info/sswm-university-course/module-6-disaster-situations-planning-and-preparedness/further-resources-0/slow-sand-filtration, Accessed May 2022.

[6.] Buchan, J., 2003, Crowded with Genius: The Scottish Enlightenment: Edinburgh's moment of the mind, New York, Harper Collins, Accessed May 2022.

[7.] Cescon, A., Jiang, J., 2020, Filtration Process and Alternative Filter Media Material in Water Treatment, Department of Civil Engineering and Environmental Management, Glasgow Caledonian University, Scotland G4 0BA, https://doi.org/10.3390/w12123377, Accessed May 2022.

[8.] Chapter 06- Filtration, Online Resource,https://www.suezwatertechnologies.com/handbook/chapter-06-filtration?fbclid=IwAR2mhBB3BnCBqC9FZPxDkca2ZxRPnp8eThmv7axLt8xFYaJ8Cxx5dvNscOk, Accessed May 2022.

[9.] Christman, K., 1998, The History of Chlorine, Waterworld, Accessed May 2022.

[10.] Conley, W., Pitman, R., 1960, Test Programs for Filter Evaluation at Hanford, John Wiley & Sons, Inc, https://doi.org/10.1002/j.1551-8833.1960.tb00485.x, Accessed May 2022.

[11.] Dawda, Madhusudan M., Davidson, M. L., and Middlebrooks, E. J., 1976, Evaluation of the Addition of Granular Media Filtration to Wastewater Treatment Plants to Meet New Standards, Reports, Accessed May 2022.

[12.] DIJK, J.C. van, OOMEN, J.H.C. 1978, Slow Sand Filtration for Community Water Supply in Developing Countries: A Design and Construction Manual, IRC Technical Paper Series, The Hague, The Netherlands, Accessed May 2022.

[13.] Dissolved Oxygen and Water, Online Resource,https://www.usgs.gov/special-topics/water-science-school/science/dissolved-oxygen-and-water#overview. Accessed April 2022.

[14.] Dual Media Filter, Online Resource,https://www.chemtronicsindia.com/dual-media-filter.htm?fbclid=IwAR3dDDkVIr-eMYAm05f-vu5VmBLopAD3uRpXlAyKynw1TET5kPeTYnq7Wtc, Accessed May 2022.

[15.] Eakin and Sharman, 2010, Volumes of the World's Oceans from ETOPO1. NOAA, National Geophysical Data Center, http://www.ngdc.noaa.gov/mgg/global/etopo1 _ocean_volumes.html, Accessed April 2022.

[16.] Ellis, K., 1985, Slow Sand Filtration, CRC Critical Reviews in Environmental Control, Vol. 15, Accessed May 2022.

[17.] Evaluation of Potential Use of Charcoal as a Filter Material in Water Treatment, Online Resource, https://www.irjet.net/archives/V7/i5/IRJET-V7I5373.pdf, Accessed May 2022.

[18.] Evaluation of the Addition of Granular Media Filtration to Wastewater Treatment Plants to Meet New Standards, Online Resource,https://digitalcommons.usu.edu/water_rep/516, Accessed May 2022.

[19.] Fair, Geyer, and Okun, 1968, Water and Wastewater Engineering, John Wiley and Sons, Inc., https://doi.org/10.1177/146642406908900123, Accessed April 2022.

[20.] Filter Gravel, Online Resource, https://www.kleenindustrialservices.com/water-filtration-media-filter-gravel.html?fbclid=IwAR2D9bJG5jTF_c_KcaUTZ3gr4qlV7BTpZ6HSgKketJJSQIyWiXVCZtb3ObI, Accessed May 2022.

[21.] Filtration Systems, Online Resource,https://www.oas.org/dsd/publications/unit/oea59e/ch24.htm?fbclid=IwAR3O-7yKHiB8nSbxP5Fgu3rC1zlIytll5feEgH4y3XyDpuv1-Vx91c_kyrc, Accessed May 2022.

[22.] Filtration, Online Resource,https://www.lenntech.com/chemistry/filtration.htm#:~:text=The%20liquid%20which%20has%20passed%20through%20the%20filter%20is%20called%20the%20filtrate. Accessed April 2022.

[23.] Fuller, G.W., June 1903, The Filtration Works of the East Jersey Water Company, at Little Falls, New Jersey, Transactions of the American Society of Civil Engineers, doi: 10.1061/TACEAT.0001566, Accessed May 2022.

[24.] Gravel, Online Resource,https://www.coursehero.com/file/143977281/GRAVEL-1pptx/, Accessed May 2022.

[25.] Gray, N., 2010, Water Technology, 3rd ed., IWA Publishing, London, UK, Accessed May 2022.

[26.] Handbook of Water Industrial Treatment, Online Resource,https://www.suezwatertechnologies.com/handbook/chapter-06-filtration?fbclid=IwAR2mhBB3BnCBqC9FZPxDkca2ZxRPnp8eThmv7axLt8xFYaJ8Cxx5dvNscOk, Accessed May 2022.

[27.] Holding, J. C., 1972, Polishing sewage effluents, Effluent and Water Treatment Journal, Accessed May 2022.

[28.] Lambert, S., Graham, J., 1995, A Comparative Evaluation of the Effectiveness of Potable Water Filtration Processes, J. Water SRT-Aqua, Vol. 44, Accessed May 2022.

[29.] Lemley, A., Wagenet, L., Kneen, B., 1995, Activated Carbon Treatment of Drinking Water, Water Treatment Notes Cornell Cooperative Extension, Accessed May 2022.

[30.] Logsdon, G. S., 2011, Water Filtration Practices, Denver, CO: American Water Works Association, ISBN 978-1613000847. Accessed May 2022.

[31.] Logsdon, G., 2002, Slow Sand Filtration for Small Water Systems In: Journal of Environmental Engineering and Science, Accessed May 2022.

[32.] Magalang, R.T., and Taladro, M J S., March 2013, Design and Construction of Artificial Wetland for Household Wastewater Treatment, Undergraduate thesis, DEBESMSCAT, Cabitan, Mandaon, Masbate, Accessed May 2022.

[33.] Mao, N. 2016, Advances in Technical Nonwovens, Woodhead Publishing Series in Textiles, https://www.sciencedirect.com/topics/chemical-engineering/water-filtration, Accessed April 2022.

[34.] McGivney, W., Kawamura, S., 2008, Cost Estimating Manual for Water Treatment Facilities, John Wiley & Sons, Inc., Hoboken, NJ, USA, Accessed May 2022.

[35.] Modeling of sediment transport through stormwater gravel filters over their lifespan, Online Resource,https://pubmed.ncbi.nlm.nih.gov/18186343/, Accessed May 2022.

[36.] Montgomery, J.,1985, Water Treatment: Prinicples and Design, John Wiley & Sons, Accessed May 2022.

[37.] Musa et al., May 2020, Evaluation of Potential Use of Charcoal as a Filter Material in Water Treatment, https://irjet.net/archives/V7/i5/IRJET-V715373.pdf, Accessed May 2022.

[38.] Part 1 – Introduction to Water Filtration, Online Resource,https://www.ce.memphis.edu/1101/notes/filtration/filtration-1.html?fbclid=IwAR0ohjk7otq0j14L6AiaU_UvVag_NfDhQ6SMtiDTyx_vyLpmiHdVl6aG-pw, Accessed May 2022.

[39.] pH and Water, Online Resource,https://www.usgs.gov/special-topics/water-science-school/science/ph-and-water#:~:text=oil%20or%20alcohol.-,pH%20is%20a%20measure%20of%20how%20acidic%2Fbasic%20water%20is,hydroxyl%20ions%20in%20the%20water. Accessed April 2022.

[40.] Ratnayaka, D, Brandt, M, Johnson, K, 2009, Twort's Water Supply, 6th ed., Butterworth-Heinemann, Oxford, MA, USA, Accessed May 2022.
[41.] Shell, G. L., and D. E. Burns, 1973, Advanced wastewater, treatment methods, Effluent and Water Treatment Journal, Accessed May 2022.
[42.] Tatong, N. A., Jr, Rosales, G. G., and Leona, L. A., March 2012, Use of Carbonized Rice Hull, Carbonized Coconut Shell, Carbonized Coconut Husk in Filtering Domestic and Mining Wastewater, Undergraduate thesis, DEBESMSCAT, Cabitan, Mandaon, Masbate, Accessed May 2022.
[43.] Tebbutt, T. H. Y. 1971, An investigation into tertiary treatment by rapid filtration, Water Research, https://doi.org/10.1016/0043-1354(71)90123-0, Accessed April 2022.
[44.] Test Program for Filter Evaluation at Hanford, Online Resource,https://doi.org/10.1002/j.1551-8833.1960.tb00485.x, Accessed May 2022.
[45.] Total Suspended Solids (TSS), Online Resource,https://www.corrosionpedia.com/definition/6165/total-suspended-solids-tss. Accessed April 2022.
[46.] Treatment performance of gravel filter media: Implications for design and application of stormwater infiltration systems, Online Resource,https://www.sciencedirect.com/science/article/abs/pii/S0043135407001935, Accessed May 2022.
[47.] Turbidity and Water, Online Resource,https://www.usgs.gov/special-topics/water-science-school/science/turbidity-and-water#:~:text=Turbidity%20is%20the%20measure%20of,light%2C%20the%20higher%20the%20turbidity. Accessed April 2022.
[48.] UNEP, 1998, Sourcebook of Alternative Technologies for Freshwater Augmentation in Some Countries in Asia, Technical Publication, Osaka/Shiga: United Nations Environmental Programme. International Environmental Technology Centre, Accessed May 2022.
[49.] USEPA, 1990, Technologies for Upgrading Existing or Designing New Drinking Water Treatment Facilities, Cincinnati, OH, EPA 625/4-89/023. Accessed May 2022.
[50.] Veenstra, S., Visscher, J.T., 1985, Slow Sand Filtration: Manual for Caretakers, IRC Training Series, The Hague: IRC International Water and Sanitation Centre, Accessed May 2022.
[51.] Water Filtration Media, Online Resource,https://www.riversands.com.au/application/water-filtration-media/, Accessed May 2022.
[52.] Water Quality Guidelines and General Effluent Standards, Online Resource,https://emb.gov.ph/wp-content/uploads/2019/04/DAO-2016-08_WATER-QUALITY-GUIDELINES-AND-GENERAL-EFFLUENT-STANDARDS.pdf, Accessed May 2022.
[53.] Water Treatment, 3rd ed., 2003, Denver CO: American Water Works Association, ISBN 1583212302. Accessed May 2022.
[54.] Water Usage and Classification, Online Resource,https://water.emb.gov.ph/?page_id=849, Accessed May 2022.
[55.] What is NTU, Online Resource,https://www.tecnoconverting.com/technical-articles/what-is-ntu/#:~:text=NTU%20stands%20for%20Nephelometric%20Turbidity,the%20higher%20the%20turbidity%20is. Accessed April 2022.
[56.] What is the Purpose of Gravel in a Water Filter, Online Resource,https://cementanswers.com/what-is-the-purpose-of-gravel-in-a-water-filter/?fbclid=IwAR2mRiS8XOqosJ2HYh3tJUx7jTvQCQfNarSqipoMXYjmiqooQl4eGNaZTFY, Accessed May 2022.
[57.] Zouboulis, A., Traskas, G., Samaras, P., 2007, Comparison of single and dual media filtration in a full-scale drinking water treatment plant, Desalination, Accessed May 2022.