Design and Fabrication of Hand Pump Operated Water Purification System using Reverse Osmosis

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Abstract

Drinking water is a necessity to which millions of people throughout the world have limited access. Water is often seen as the most basic and accessible element of life, and seemingly the most plentiful. More than a billion people lack access to drinking Water. Simply providing access to clean Water could save two million lives each year. As the population grows, the freshwater available to each resident dwindles. Water purification is the removal of contaminants from untreated water to produce drinking water that is pure enough for human consumption. Substances that are removed during the process include parasites, bacteria, algae, viruses, fungi, minerals (including toxic metals such as lead, copper and arsenic), and man-made chemical pollutants. In this paper, an apparatus and methods for producing purified drinking water are disclosed. A hand pump is used in a closed system to generate pressure to pass the water through a series of filters and a reverse osmosis membrane to obtain potable water at the outlet. The flow obtained was analysed using ANSYS and the system delivering highest output was chosen. The project facilitates the availability of pure drinking water without using any electrical components or devices. It is a cheap and efficient means to produce drinking water.
Keywords: Hand Pump, Water Purification, Sediment Filter

I. INTRODUCTION

Safe drinking water is essential to humans and other life forms even though it provides no calories or organic nutrients. Access to safe drinking water has improved over the last decades in almost every part of the world, but approximately one billion people still lack access to safe water and over 2.5 billion lack access to adequate sanitation. However, some observers have estimated that by 2025 more than half of the world population will be facing water-based vulnerability. Water that is not potable may be made potable by filtration or distillation, or by a range of other methods. Currently, about a billion people around the world routinely drink unhealthy water.

Globally, improving water, sanitation and hygiene has the potential to prevent at least 9.1 per cent of the disease burden, or 6.3 per cent of all deaths. Deaths due to water related diseases in India are in the range of nearly 80%. The availability of fresh and good quality drinking water to all Indians remains a concern.

As such we decided to design an apparatus that could produce clean and safe drinking water at low cost and effectively and also without using electricity since majority of the remote areas of our country still don't have access to electricity.

Hence an attempt was made with following objectives:

- To design a simple device that could produce clean and safe drinking water.
- To develop a solid model of the device in Solid Works and meshing was done using ICEM CFD.
- To conduct analysis using ANSYS FLUENT.
- To analyse different configurations and based on the results the working model is fabricated.
- To test the purity of water hence obtained.

II. THEORY

A. Water Purification:

Water purification is the process of removing undesirable chemicals, biological contaminants, suspended solids and gases from contaminated water. The goal of this process is to produce water fit for a specific purpose. Most water is disinfected for human consumption (drinking water) but water purification may also be designed for a variety of other purposes, including meeting the requirements of medical, pharmacological, chemical and industrial applications. In general the methods used include physical processes such as filtration, sedimentation, and distillation, biological processes such as slow sand filters or biologically active carbon, chemical processes such as flocculation and chlorination and the use of electromagnetic radiation such as ultraviolet light.

The purification process of water may reduce the concentration of particulate matter including suspended particles, parasites, bacteria, algae, viruses, fungi; and a range of dissolved and particulate material derived from the surfaces that water may have made contact with after falling as rain. The standards for drinking water quality are typically set by governments or by international standards. These standards will typically set minimum and maximum concentrations of contaminants for the use that is to be made of the water.

B. Hand Pump:

Hand pumps are manually operated pumps they use human power and mechanical advantage to move fluids or air from one place to another. They are widely used in every country in the world for a variety of industrial, marine, irrigation and leisure activities. There are many different types of hand pump available, mainly operating on a piston, diaphragm or rotary vane principle with a check valve on the entry and exit ports to the chamber operating in opposing directions. Most hand pumps have plungers or reciprocating pistons, and are positive displacement.

C. Pre Carbon Filter:

Carbon filtering is a method of filtering that uses a bed of activated carbon to remove contaminants and impurities, using chemical absorption.

Each particle/granule of carbon provides a large surface area/pore structure, allowing contaminants the maximum possible exposure to the active sites within the filter media. One pound (450 g) of activated carbon contains a surface area of approximately 100 acres (40 Hectares).

Active charcoal carbon filters are most effective removing chlorine, sediment, volatile organic compounds (VOCs), taste and odor from water. They are not effective at removing minerals, salts, and dissolved inorganic compounds. Typical particle sizes that can be removed by carbon filters range from 0.5 to 50 micrometers. The particle size will be used as part of the filter description. The efficacy of a carbon filter is also based upon the flow rate regulation. When the water is allowed to flow through the filter at a slower rate, the contaminants are exposed to the filter media for a longer amount of time. .

D. Reverse Osmosis Filter:

Reverse osmosis (RO) is a water purification technology that uses a semi permeable membrane to remove larger particles from drinking water. This membrane technology is not considered a proper filtration method. In reverse osmosis, an applied pressure is used to overcome osmotic pressure, a colligative property, that is driven by chemical potential, a thermodynamic parameter. Reverse osmosis can remove many types of molecules and ions from solutions, including bacteria, and is used in both industrial processes and the production of potable water. The result is that the solute is retained on the pressurized side of the membrane and the pure solvent is allowed to pass to the other side. To be "selective", this membrane should not allow large molecules or ions through the pores (holes), but should allow smaller components of the solution (such as the solvent) to pass freely.

E. Sediment Filter:

Sediment is any particulate matter that can be transported by fluid flow and which eventually is deposited as a layer of solid particles on the bed or bottom of a body of water or other liquid. Sedimentation is the deposition by settling of a suspended material. In a water plant these particles may be rust flakes from the water pipes, sand grains, small pieces of organic matter, clay particles, or any other small particles in the water supply. Water that has a high sediment level can change the aesthetic value of the finished beverage. It also can have a detrimental effect on the performance of your equipment. Sediment can cause blockages in the strainers, flow controls and even the solenoids inside your equipment.

III. MATERIALS AND METHODS

The system uses a hand pump of suction type pre-filtration membrane, a sediment filter, a pre-carbon filter (and an RO membrane. The hand pump used has a flow rate of 0.32 litres/second at the outlet. the pre-filtration membrane has apore size of 0.5 microns. The sediment filter and the pre-carbon filter are placed before the RO membrane in order to prevent any damage to it. The maximum pressure the sediment filter can withstand is 125 psi.

A 2-D model is created using SOLIDWORKS Software and Meshing was done using ICEM CFD. Analysis is done using ANSYS FLUENT. For analysing, four different configurations were used and based upon the results, the working model was fabricated. The water from the outlet is then tested for purity.

IV. RESULTS AND DISCUSSIONS

A. *Configurations and Output Pressures:*

In order for more economical and high output efficiency different configurations were analysed. The different configurations that were analysed are Carbon filter at the end configuration, Pre-filtration and RO membrane only configuration; Carbon filter not included configuration and RO membrane at the end configuration. The output pressure from these configurations were analysed and the configuration with the maximum output pressure was finally chosen.

1) *Configuration with Carbon Filter at the End:*

In this arrangement, the outlet from the hand pump is given into the preliminary filter cartridge. The losses occurring in the filter cause a considerable reduction in pressure of the flow. The fluid then flows into the sediment filter, where particles of size higher than 0.3 micron get caught up in it.The fluid from the sediment filter goes into the reverse osmosis membrane where the dissolved salts get removed from the water. The pressure of the flow is reduced considerably after this stage. The low pressure flow then goes into the carbon filter. The output from the filter is obtained at $-5.78*10^4$ Pascal. The figure 1 shows the analysis of this arrangement done in ANSYS FLUENT software.

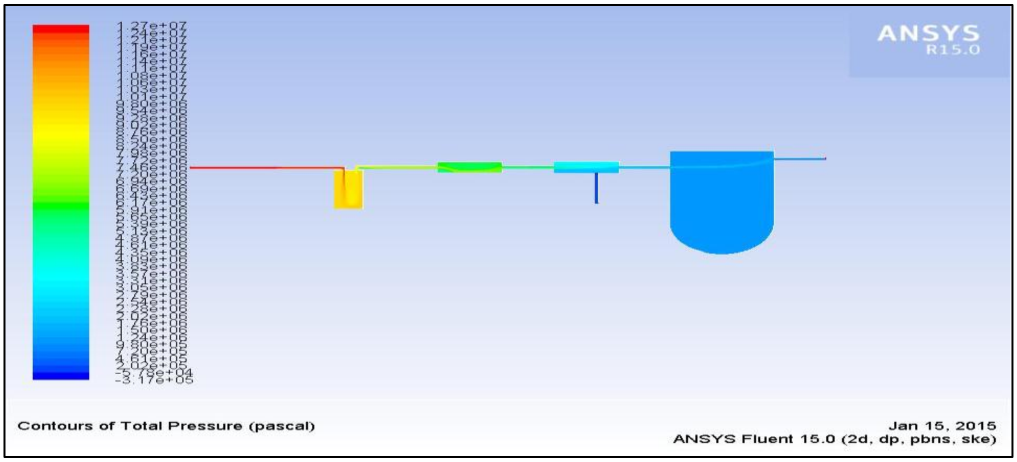

Fig. 1:

2) *Configuration Excluding Carbon Filter and Sediment Filter:*

This configuration does not have a carbon and sediment filter in the arrangement. In this configuration, the output of the hand pump is fed to the preliminary filter cartridge. The losses occurring in this filter causes a considerable reduction to the pressure of the flow. The fluid from the preliminary filter then enters the RO membrane where the dissolved salts get removed. The pressure of water entering the RO filter is considerably higher than its specified inlet pressure as well as since there is no other filters to filter out particles other than the preliminary filter, it may cause damage to the RO membrane. This calls for more frequent replacement of the RO membrane. The output from the RO membrane is obtained at 8.59*105Pascal. The figure 2 shows the analysis of this arrangement done in ANSYS FLUENT software.

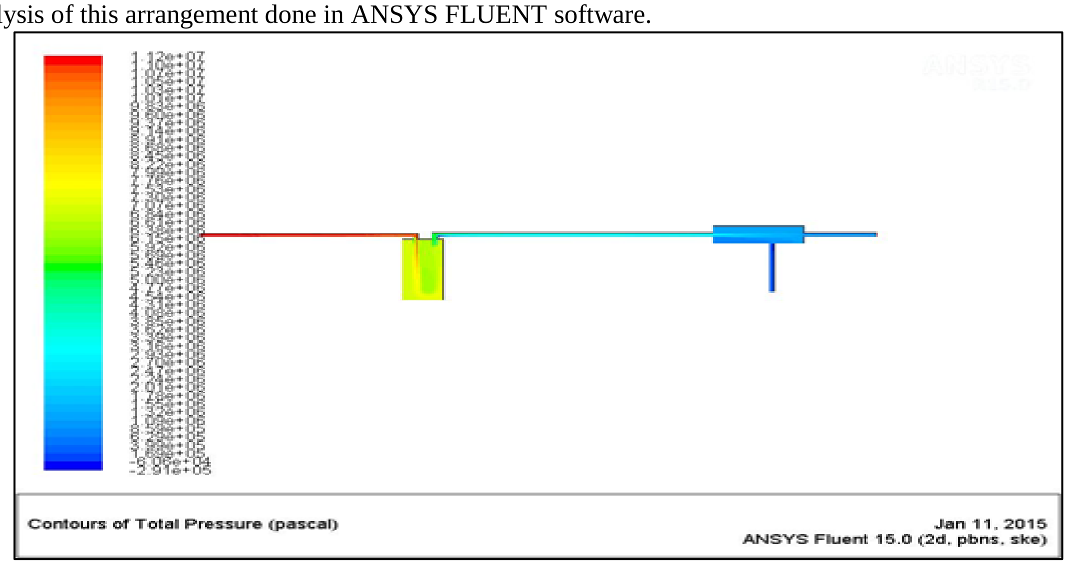

Fig. 2:

3) *Configuration Excluding Carbon Filter:*

In this arrangement, the outlet from the hand pump is given into the preliminary filter cartridge. The losses occurring in the filter cause a considerable reduction in pressure of the flow. The fluid then flows into the sediment filter, where particles of size higher than 0.3 micron get caught up in it.The fluid from the sediment filter goes into the reverse osmosis membrane where the dissolved salts and micro-organisms get removed from the water. The output from the RO membrane is obtained at $7.43*10^3$ Pascal. The figure 3 shows the analysis of this arrangement done in ANSYS FLUENT software.

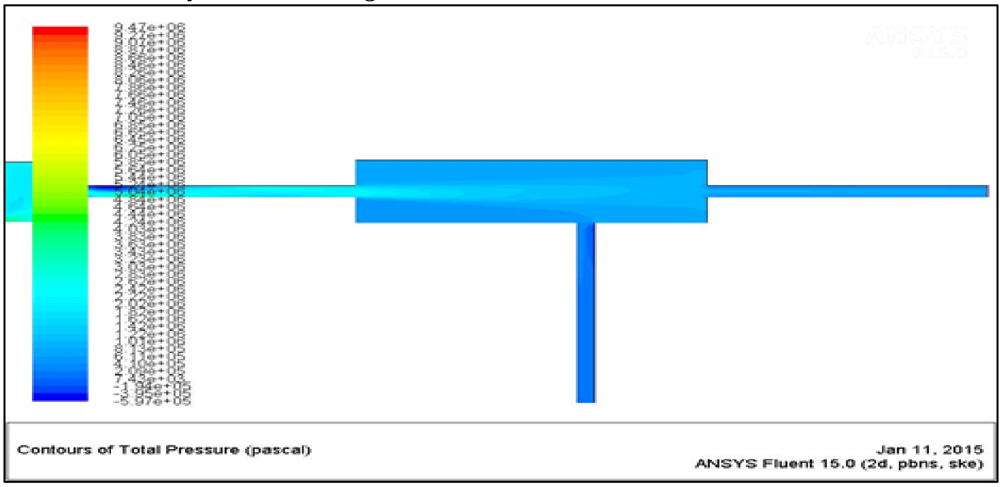

Fig. 3:

4) *Configuration with RO Membrane at the End:*

In this arrangement, the outlet from the hand pump is given into the preliminary filter cartridge. The losses occurring in the filter cause a considerable reduction in pressure of the flow. The fluid then flows into the sediment filter, where particles of size higher than 0.3 micron get caught up in it. The flow then enters the carbon filter. The output from the carbon filter is having sufficient pressure so as to be fed into the RO membrane where the dissolved salts and the micro-organisms present in the water are removed. . The output from the RO membrane is obtained at $2.24*10^5$ Pascal. The figure 4 shows the analysis of this arrangement done in ANSYS FLUENT software.Table 1 shows the output values of different configurations.

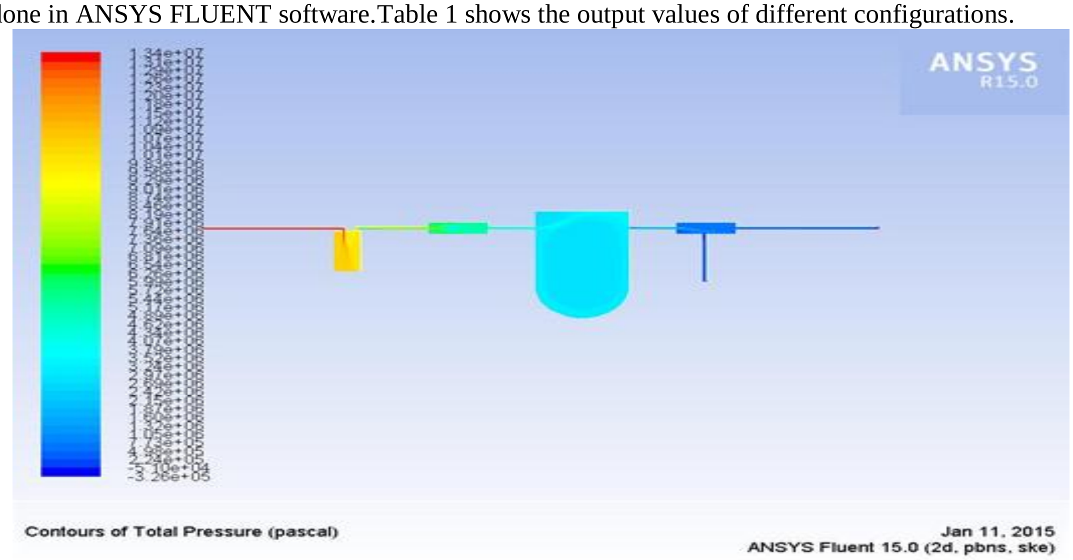

Fig. 4:

Table -1:

Configuration type	*Output pressure(Pascal)*
Carbon filter at the end	$-5.78*10^4$
Pre-filtration and RO membrane only	$8.59*10^5$
Carbon filter not included	$7.43*10^3$
RO membrane at the end	$2.24*10^5$

5) *Final Geometry:*

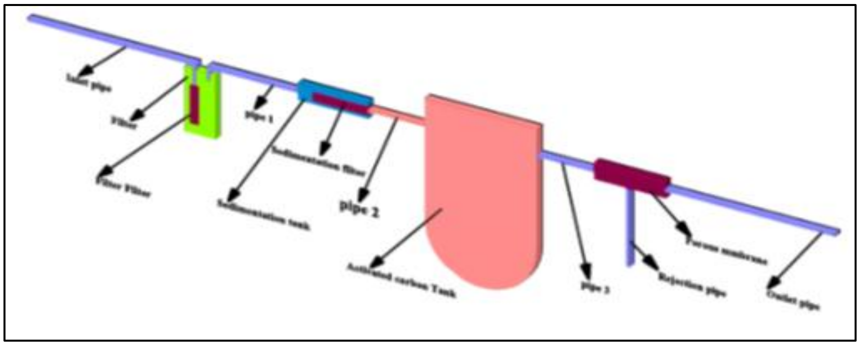

Fig. 5:

The following graphs show the concentration of impurities and other parameters in comparison of proposed model with aquaguard water purification system.

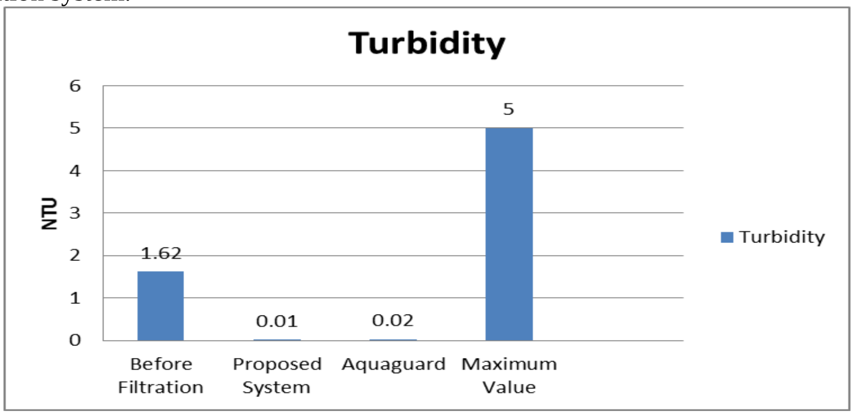

Fig. 6:

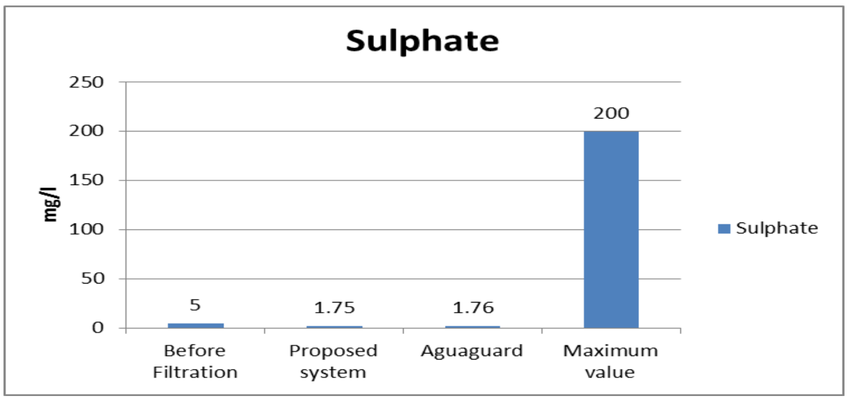

Fig. 7:

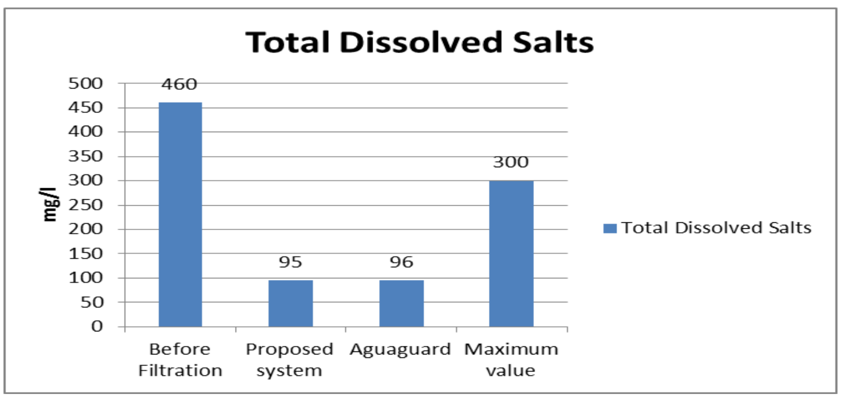

Fig. 8:

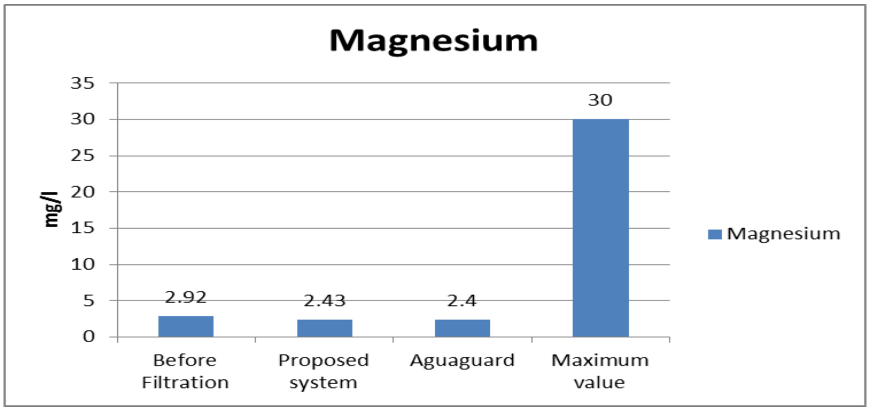

Fig. 9:

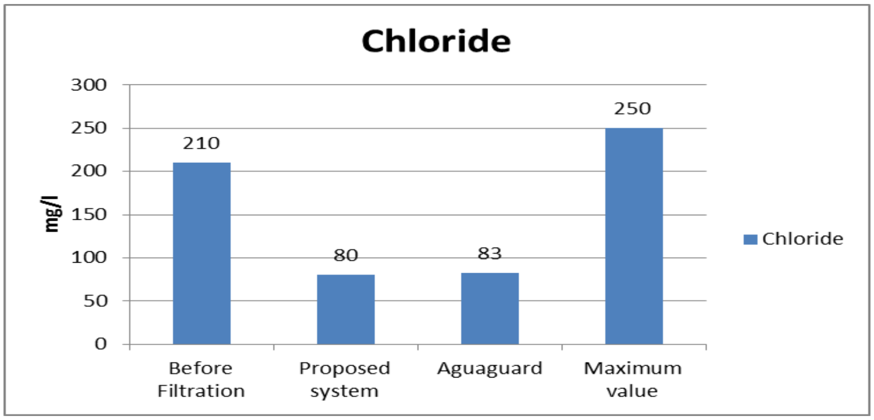

Fig. 10:

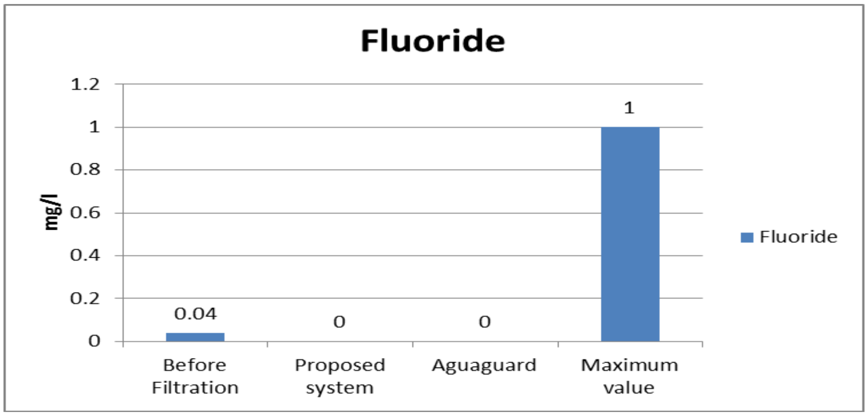

Fig. 11:

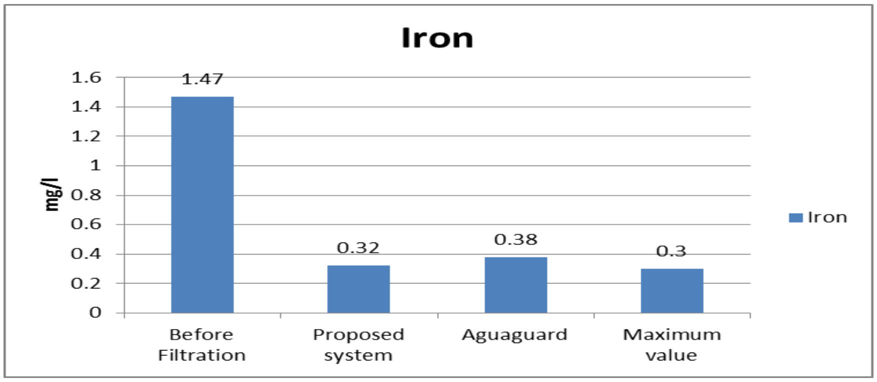

Fig. 12

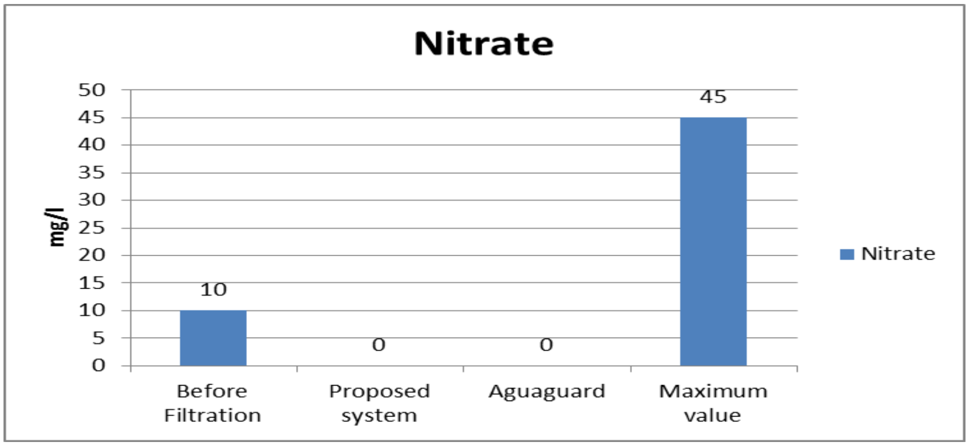

Fig. 13:

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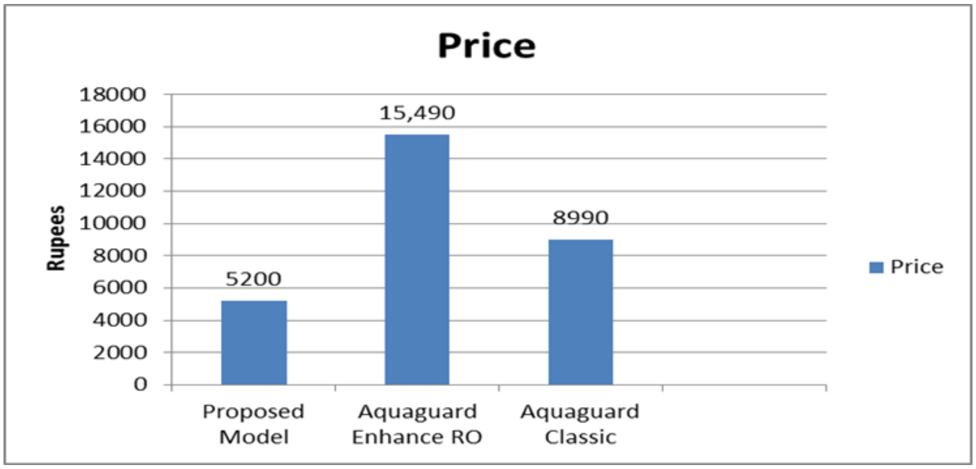

Fig. 14:

V. CONCLUSIONS

The fabricated model was designed based on the results of the analysis performed and it delivers pure drinking water at a high output pressure.

The purity tests performed on the output from the system showed that there was a large reduction in the concentration of impurities. The output showed increased reduction in concentration of certain impurities compared to commercially available models.

The cost comparison with various commercially available products showed that the fabricated model was a cheaper alternative. The designed model provides drinking water without using electricity and is a cheap and energy saving option.

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