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A VISION OVER REVERSE OSMOSIS (RO) TECHNOLOGY AND DETAILED ANALYSIS OF RO

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ABSTRACT

The drinking water consumption rate is growing exponentially whereas the water available for drinking purposes is sinking due to over population, pollution and climatic changes. Therefore we have to harvest water sufficiently for drinking and ensure the quality of living. Reverse osmosis (RO) process helps to meet this problem, where the unwanted particulates, sediments, microbes and chemicals are removed to make the water fit for drinking, this process undergoes various stages. This paper provides overall vision on the RO technology and the ionic concentration of inlet water, Reverse Osmosis (RO) water and rejected water is also founded to know the performance of RO plant.

Keywords: Reverse osmosis (RO), semi permeable membrane, filtration, and treatment.

1. INTRODUCTION

1.1 INTRODUCTION TO RO

Only 2.5% of water in the earth is fresh, out of which only 1% of pure water is easily accessible for drinking and remaining 1.5% is trapped in glaciers and snowfields [I]. Thus the water is limited for drinking and household usage. Nowadays we see water scarcity in many regions due to overpopulation and climatic change, to encounter this problem we want to produce substantial amount of water for drinking [II]. Here comes the need for reverse osmosis, which uses the semi permeable membrane to filter water in rivers, lakes, seas, ponds, and groundwater. So, here we make a detailed study on the reverse osmosis (RO) process and the RO plant in our institution.

1.2 HISTORY OF WATER TREATMENT

Even before 2000 B.C the knowledge about the water treatment process was among the ancient Greek and Sanskrit people with the techniques like boiling, gravel filtration and straining. The only parameter which was considered at that time was turbidity, because there was no knowledge about the micro organisms and chemical contaminants. But the turbidity was also determined based on the color of the water [III]. Around 1500 B.C the Egyptians discovered the concept called coagulation. In 1627 Sir Francis Bacon underwent the desalination of sea water. However, his attempt failed but it paved the discovery of further water treatment process. The discovery of microscope in 1670 helped to view the water microorganisms. In the year of 1700 water purification filters was used for the domestic purpose for the first time. The filter consists of charcoal, sponge, wool and slow sand filtration. This municipal treatment plant was built by Robert Thom in Scotland. After three years the pipes were installed to ensure the distribution of water to all the people equally [IV]. At the time of 1854 the epidemic disease cholera was spread through water, but the infection was less around the people who were drinking the sand filtered water and it was found that that the disease was spread due to sewage contamination. John Snow the British scientist applied chlorine to the water and it paved the way for water disinfection [V]. In 1890's America built the large filters to ensure the safety of public health. The filter consists of slow sand filtration and raid sand filtration. Then the desalination of sea water was also introduced to meet the exponential growth of population. Thus the water treatment process mainly focuses on the removing microbes, chemicals and solid particles and ensures the quality of living.

1.3 OVERVIEW OF OUR WORK

The main aim of our work is to clearly understand the reverse osmosis process and the technology and to make an experiment over the real time plant. We made use of the reverse osmosis plant which is available in our institution. The first identification was on the parameters and chemicals that were used in the plant and a detailed study was made on it. Our study answers the questions such as, what were the contaminants in the water, how such contaminants were removed, what were the parameters involved, to how extreme does the inlet water gets purified, does all the minerals are removed, does the RO water is good for our health. The RO plant was experimented sequentially for about ten days. The readings of inlet water, RO water and outlet water were taken based on the capacitance (at two frequencies) and conductance values. Then the quality of RO water was determined using these values, based upon the removal of minerals.

2. RO PROCESS AND ITS DESCRIPTION

2.1 OSMOSIS

Osmosis is the process where the molecules of the low concentrated solvent will try to move through the semi permeable and reach the solvent of high concentration. The osmosis process is shown in the Fig No. 1.

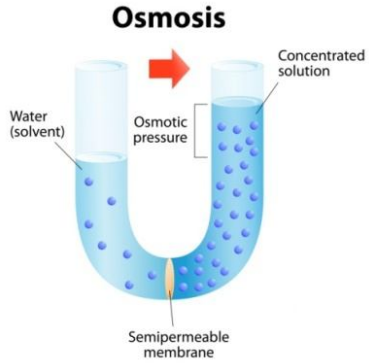

Fig -1: **Osmosis**

2.2 REVERSE OSMOSIS

It is opposite to the osmosis process where the molecules of the highly concentrated solvent are diffused through the semi permeable membrane by applying pressure. The reverse osmosis process is shown in the Fig No. 2. If we apply high pressure the diffusion through the semi permeable membrane takes place rapidly.

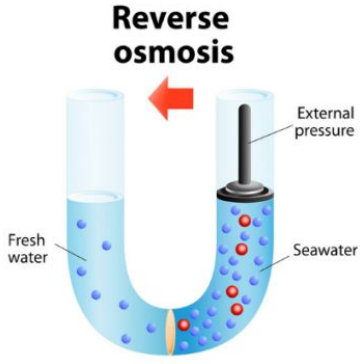

Fig -2: **Reverse Osmosis**

2.3 BLOCK DIAGRAM REVERSE OSMOSIS (RO) PLANT

The RO process consists of various stages namely pretreatment, filtration at the RO membrane and post treatment. Fig No. 3 shows the block diagram of RO plant. The pretreatment process consists of pre sand filtration, active carbon filtration, addition of chemicals and micron cartridge filtration.

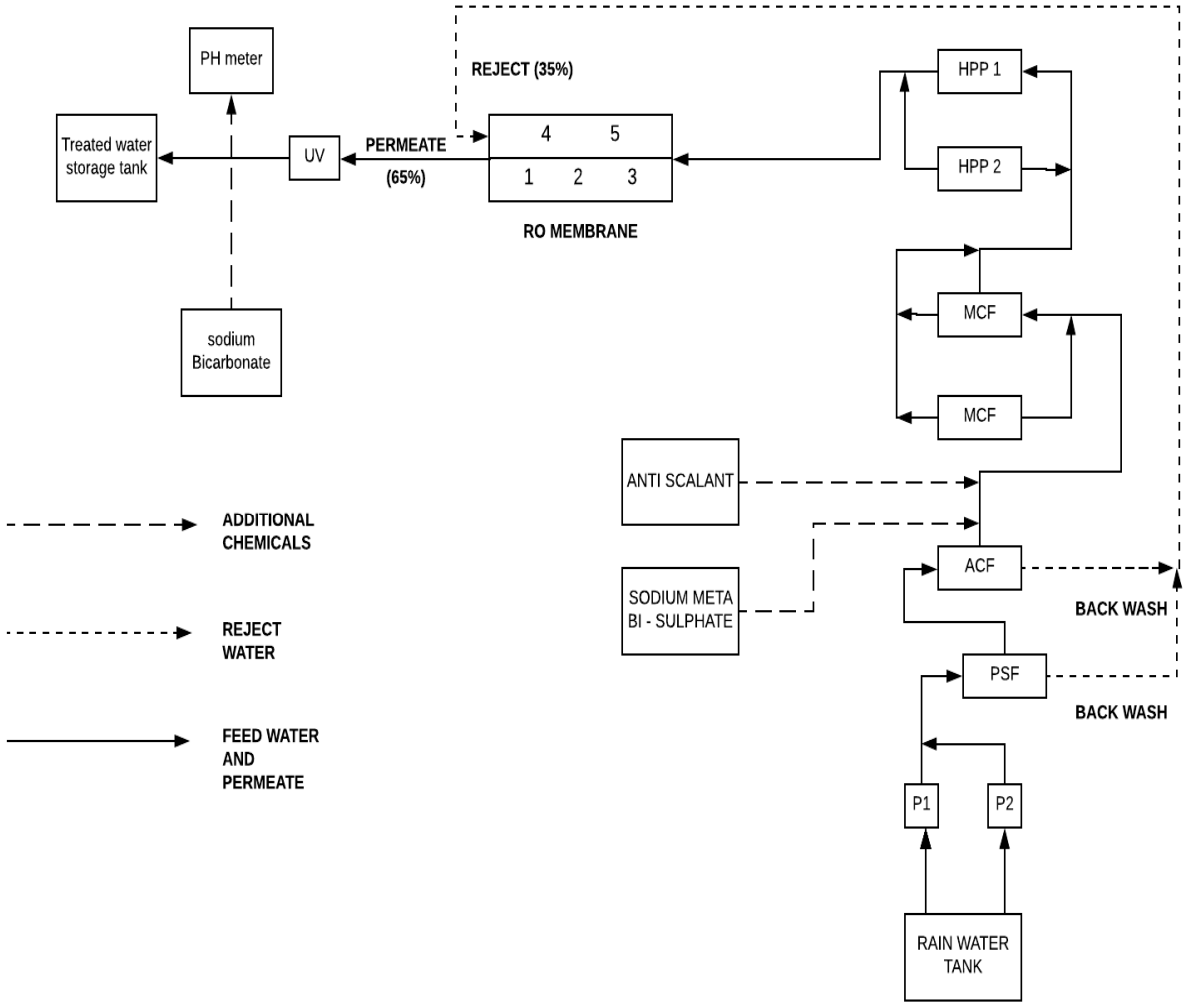

Fig -3: **Block diagram RO plant**

At the RO membrane the water is filtered in number of layers. Ultraviolet filtration, addition of sodium bi carbonate takes place at the post treatment.

3. A DETAILED EXPLANATION OF EACH BLOCK IN THE RO PLANT

3.1 PRE SAND FILTER (PSF)

Sand filter is used to remove the solid particles in the raw water without the use of any chemical reactions thereby producing high quality water. Sand filters are classified into two type's slow sand filters and rapid sand filters. Rapid sand filter provides rapid removal of the solid particles. Rapid sand filter are further subdivided into two types they are rapid gravity sand filters and rapid pressure sand filters. The gravity sand filter consists of stones and sand and the filtration of the solid particles occurs naturally by the gravitational force where the solid particles are trapped in sands and stone. The pressure sand filter consists of numerous layers of sand and the solid particles are trapped in the sandy layers by applying the pressure. However, slow sand filter produces high quality of water than the rapid sand filters.

3.2 ACTIVE CARBON FILTER (ACF)

The active carbon filter is used to adsorb especially chlorine, volatile organic compounds, certain chemicals, taste and odor. Active carbon is a highly porous material and can adsorb the contaminants in the water easily. Its size ranges from 0.5 microns to 50 microns. One gram of active carbon has a surface area of 500-3000m^2. It is very effective in removing minimum 81 chemicals. Active carbon is normally obtained from coconut shell, wood or coal. According to Environmental Protection Agency (EFA), United States activated carbon is the only filter to remove 32 identified organic compounds including THMs (trihalomethanes) which are prone to produce cancer. However it does not show much effect on inorganic compounds, minerals and salts.

3.3 SODIUM META BISULFITE

Sodium Meta Bisulfite is an antioxidant, disinfectant and a preserving agent. It helps to remove excess of chlorine content in water and also acts as oxygen scavenger to remove dissolved oxygen from water. Since, chlorine causes damage to the RO membrane by increasing the membrane flux and salt passage and causes poor filtration and also leads to the replacement of the membrane frequently. Thus, the chlorine is removed using sodium meta bisulfite before the water entering into the membrane.

3.4 ANTI SCALANT

Scaling is the process where the minerals in the water precipitates and tend to form solid deposits. This can occur in the RO membrane when the water passes through it and these deposits can get settled in the membrane. To avoid this we are in need to do anti scaling. The antiscalant is Monosodium Glutamate (C5H8NO4NA).

3.5 MICRON CARTRIDGE FILTER (MCF)

Micron cartridge filtration is the technique where the suspended particles in the fluid by passing the fluid through the pore of having size ranging from 0.1 to 40 micron. These filters must be changed frequently when the water color becomes dark. These filters must be changed in the frequency of 3 to 6 months to get a good yield of water.

3.6 REVERSE OSMOSIS (RO) MEMBRANE

The design consists of multiple leaves that surround the central core tube. These leaves are wrapped by membrane and it consists of a permeate channel spacer. The membrane consists of special Thin Film Composite (TFC) membrane. Thin film composite membrane is additionally split up into three layers. Fig No 4 shows the internal layers RO membrane.

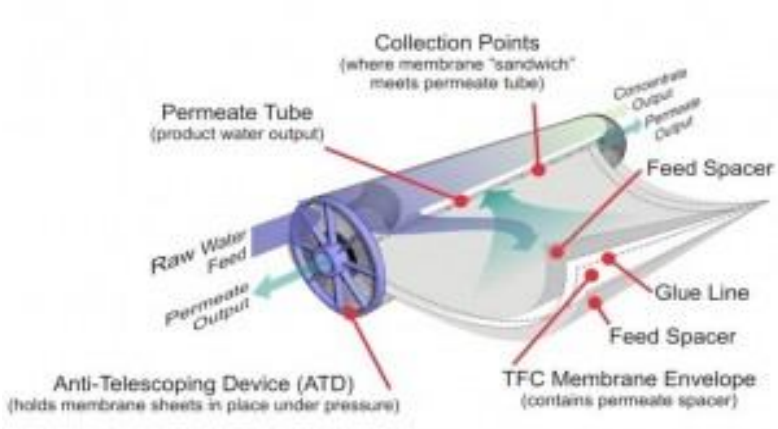

Fig -4: **RO Membrane**

The first layer is the barrier layer of the RO element and sizes around 0.2 microns and made up of polyamide polymer. The salts which are escaped from the pretreatment get trapped here as this layer is ultrathin. The next layer consists of nonwoven polyester web; it acts as a structural support for the RO element. The barrier layer is casted upon the

polyester web. The polyester web size around 120 microns. The polyester layer is coated by a polysulfone layer which is of 40 microns thick. The polyamide layer has a shiny surface and the polyester layer has a dull surface.

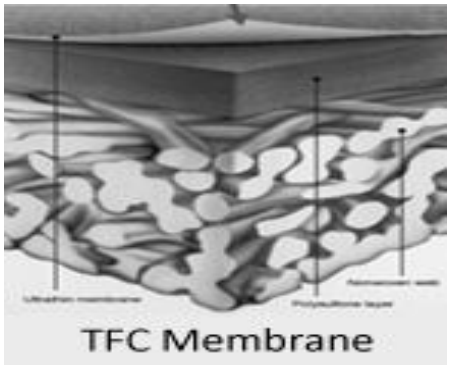

Fig -5: **Thin Film Composite Membrane**

The internal structure of TFC membrane is shown in the Fig No. 5. There are two spacers in the RO element they are feed spacer and permeate spacer. Feed spacer is prepared by propylene which is 28 to 34 mill thick. Permeate layer is prepared by polyester fabric which ranges from 10 to 16 microns in size, as it has the capability to remove the water rapidly from the RO membrane. Thus, the high quality of water is obtained. Feed spacer and permeate spacer is shown in the Fig No. 6.

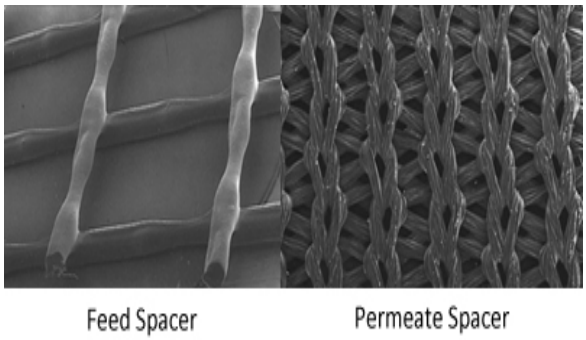

Fig -6: **Feed Spacer and Permeate Spacer**

3.7 ULTRAVIOLET (UV) FILTRATION

Here the water from the RO membrane is exposed to the ultraviolet radiation. Ultraviolet rays can remove the bacteria and viruses which are escaped from pretreatment process and RO membrane. UV rays disrupt the DNA of the microorganism and disable their ability to replicate without any chemical reactions, thereby producing germ free high quality water. However, UV does not affect sediments, particulate and other minerals.

3.8 SODIUM BI CARBONATE

Sodium bi carbonate is used in the water treatment process in order to soften the water by removing the calcium and the magnesium impurities. Thus, the water becomes soft for drinking. This soft water makes the tea or coffee to increase in taste. Sodium bi carbonate regulates the pH of water.

4. PARAMETERS TO BE CONSIDERED

4.1 TURBIDITY

Turbidity is the measure of suspended particles in water. Turbidity is the mostly used parameter to check the quality of water. The acceptable turbidity range is 1 to 5 NTU.

4.2 PH

PH is the parameter that is used to show whether the given solvent is acid or alkaline by measuring the hydroxyl and hydrogen ions. This range must be maintained to ensure the metabolism in the body, since biochemical reactions takes

place in tissues and organs. Thus, the pH of the drinking water must be monitored carefully. The allowable pH of the RO water is 6.5 to 7.5.

4.3 OXIDATION REDUCTION POTENTIAL (ORP)

Oxidation reduction potential defined as the ability of a fluid to accept or release electrons in a chemical reaction. Fluids having higher oxidation potential has the higher ability to oxidize than the fluid having lower oxidation potential.

4.4 O.R.P

The standard unit that is used to measure oxidation reduction potential (ORP) is millivolts. ORP is used to check whether the water is dead or alive. The ORP rating must be of 30 to 45mV.

5. MEASUREMENT OF IONIC CONCENTRATION OF INLET, RO AND REJECTED WATER

There are many methods available to determine the concentration of ions in the water. But the easy and best way to determine the ionic concentration of water is to find the capacitance and conductance of the water. Since, the capacitive and conductive values differ largely with the slight deviation in the ionic concentration of water. The reverse osmosis water has very low ionic concentration compared with inlet and rejected water since the most of ions from the inlet water is removed by reverse osmosis membrane. While, the rejected water has high ionic concentration compared with inlet and RO water, since all the removed ions are accumulated in the rejected water. The ionic concentration of inlet water is greater than the RO water and less than the rejected water.

5.1 DETERMINATION OF CAPACITANCE

LCR meter is used to determine the capacitance of inlet, Ro and rejected water. The LCR meter is electronic equipment that is used for the determination of inductance (L), capacitance (c) and resistance (R). LCR meter has various ranges of test frequencies like 50Hz, 60Hz, 100Hz, 120Hz, 1kHz, 100kHz and 1 MHz. These variations in the frequencies are very helpful in the R & D works. Here the test frequencies of 100Hz and 1kHz are taken. Here the parallel plate capacitor is used to measure the capacitance of the water.

$$C = \frac{\varepsilon A}{d}$$

- Since A and d are constant here.

$$C \propto \varepsilon$$

- The medium doesn't change here. Only the ionic concentration of the water changes, hence ε value also changes.
- Area of the plates of parallel plate capacitor is, **A=8.6cm.**
- Distance between the two plates is**, d=0.6cm.**
- The ionic concentration of rejected water is more hence the movement of ions between the plates is high.
- Thus, the value of capacitance is also high. The rejected water will have average value of capacitance and the Ro water will have low value of capacitance.

Table -1: Water Sample measurement using capacitance (at 1 kHz)

CAPACITANCE 1 kHz (µF)			
	Inlet water	**RO water**	**Rejected water**
Day 1	0.1038	0.0225	0.1755
Day 2	0.1141	0.00613	0.5863
Day 3	0.1407	0.00393	0.7133
Day 4	0.1025	0.00509	0.5225
Day 5	0.05257	0.00272	0.1036
Day 6	0.04877	0.0027	0.1927
Day 7	0.0526	0.00285	0.0749
Day 8	0.0591	0.00174	0.1813

Day 9	0.04503	0.001303	0.2214
Day 10	0.03885	0.001225	0.2075

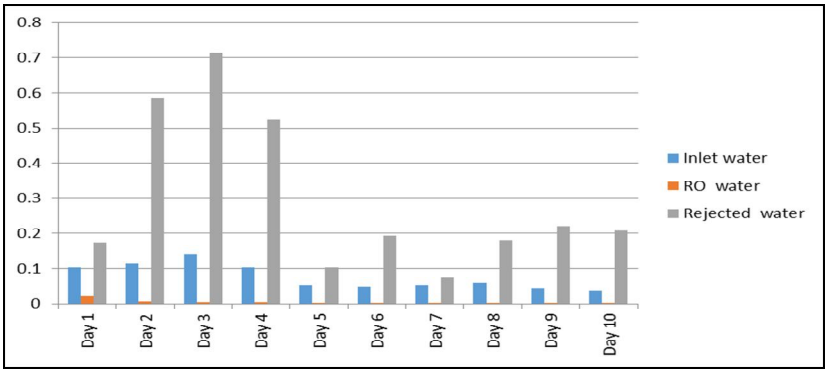

Fig -7: Graph for Water Sample measurement using capacitance (at 1 kHz)

Table -2: Water Sample measurement using capacitance (at 100 Hz)

CAPACITANCE 100Hz (µF)			
	Inlet water	**RO water**	**Rejected water**
Day 1	3.7	0.8131	5.42
Day 2	3.748	0.1858	12.69
Day 3	4.23	0.119	13.62
Day 4	3.18	0.152	10.81
Day 5	1.69	0.782	3.28
Day 6	1.65	0.065	5.38
Day 7	1.785	0.083	2.33
Day 8	1.973	0.06063	5.187
Day 9	1.45	0.004184	6.27
Day 10	1.25	0.03842	5.52

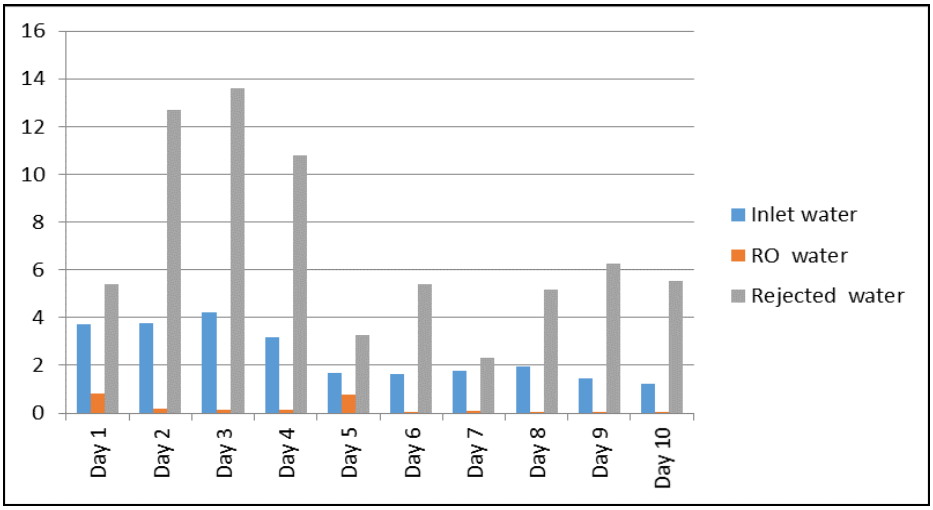

Fig -8: Graph for Water Sample measurement using capacitance (at 100 Hz)

5.2 DETERMINATION OF CONDUCTANCE

The conductance of the water is determined by the means of conductivity meter. The conductivity meter consists of two electrodes anode and cathode. Normally the electrodes are made up of platinum. The electrodes are connected to the electrical supply. The rod of the conductivity meter consisting of anode and cathode is dipped into the water whose conductance is to be measured. The negative ions in the water moves towards anode and the positive ions move towards cathode. Thus current flows between two electrodes. The electrical conductance will be more in the rejected water as it has more ions in it followed by inlet water and then Ro water.

Table -3: Water Sample measurement using conductance

CONDUCTANCE 1000 µs			
Inlet water	**Inlet water**	**Inlet water**	**Inlet water**
1.72	1.72	1.72	1.72
1.6	1.6	1.6	1.6
1.43	1.43	1.43	1.43
1.21	1.21	1.21	1.21
3.71	3.71	3.71	3.71
0.73	0.73	0.73	0.73
0.6	0.6	0.6	0.6
0.61	0.61	0.61	0.61
0.52	0.52	0.52	0.52
0.5	0.5	0.5	0.5

Fig -9: Conductance probe

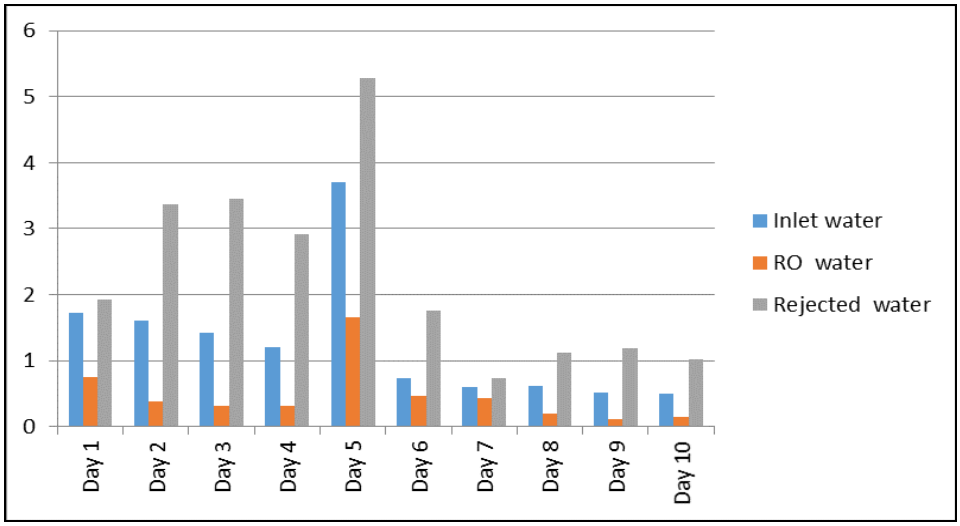

Fig -10: Graph for Water Sample measurement using conductance

6. RESULT

It is identified that the contaminants, chemicals, suspended particles and some minerals are removed from the inlet water as the inlet water is treated at various stages. RO water has light weight as it has less ionic concentration, i.e.… the above mentioned compounds are removed from and made the water fit for drinking. The rejected water high concentration of ions as it has the above mentioned compounds. It is seen that the ionic concentration of the Ro water and the rejected varies with respect to the concentration of the inlet water. This capacitance and conductance test can be used to determine the performance of the RO plant. The parameters which were discussed previously must be kept in the given limit and the filters must be changed or cleaned frequently to yield a good quality of water.

7. CONCLUSION

Thus the RO process is studied in detail. It is seen that all the parameters must be monitored carefully and clearly, since water losses all the minerals if the raw water is purified to the extent. Sometimes the bacteria which are useful for humans may also be destroyed and chlorine may react with organic compounds and forms carcinogenic substances like trihalomethane (THMs). This leads to disorders and diseases to the person who is drinking the RO water. This may be acceptable to some extent since all the technology has its own pros and cons. But this must be eliminated by monitoring the RO plant continuously.

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