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Design for Environmental Excellence: A Hybrid Reverse Osmosis

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Abstract: Design for Environment is an approach to design where most of the environmental impacts of a product are considered over the entire life cycle of a product. Aim of DfE is to address environmental impacts at all stages of the product life cycle by developing a methodology to analyse, design and develop a product with low environmental impact during its cradle-grave life cycle processes. A problem of Reverse Osmosis was considered and analysed using a complete life-cycle assessment tool called GaBi-ts. The life cycle assessment for the water treatment process using RO was modelled. The GaBi lifecycle assessment results showed us that the process cannot be modelled using GaBi. Based on the results of the GaBi, the experimental analysis was carried out for pre-summer, summer and post summer water samples treated using three different RO units. Water quality tests and quantity measurements were done to analyse the efficiency of the RO unit. An efficiency of 20-25% was observed initially with great drinking water quality. To improve the efficiency of the RO unit, a hollow fiber membrane was attached to two units and the water quality and quantity of the inlet and outlet was measured. A 30% increase in efficiency was observed with the same drinking water quality.

Keywords: Design for environment (DfE), Life Cycle Assessment (LCA), GaBi, Sustainability, Reverse Osmosis (RO)

I. INTRODUCTION

Design for Environment (DfE) is an approach to design where most of the environmental impacts of a product are considered over the entire life cycle of a product. Design for environment (DfE) is originally coined by the United States Environmental Protection Agency (EPA) in 1992. Current product design is leaned towards ensuring consistent performance life cycle of the product. Aim of DfE is to address environmental impacts at all the stages of the product life cycle. The ratio of product mass to waste mass, directly or indirectly produced as a result of the product during its life cycle is about one to twenty. There are many tools to support DfE. Most DfE tools are conceptual in nature, and there is little adoption of this in industry (Kota 2009) due to: Organizational inertia, corporate organization, Markets for recycled materials, Limited database, Resource limitation, Government regulations etc. Products make a substantial impact on environment. It is characteristic of the human nature to develop tools that help carry out daily activities in an easier and optimal way. It began with the invention of the wheel, and continues with the aid of computers (Bras 1997). Aim of DfE is to develop a methodology to analyze, design and to develop a product with low environmental impact during its 'Cradle- Grave' life cycle processes. In this study, a reverse osmosis process of treatment of water is considered. GaBi-ts, a complete life-cycle assessment tool was used for the study of the RO process and improving the quantity of the process by maintaining the quality.

II. RELATED WORK

There are no related work found. Literatures on design for environment has till now worked only on product life cycle assessment and not on process life cycle assessment. Literatures on reverse osmosis only talk about implementing a second stage reverse osmosis for increasing efficiency.

III. SCOPE OF RESEARCH

This research is carried out concentrating on the common problems faced by the general public while using the reverse osmosis process. This research may help the general public to implement the component and get purified water along with reduced water wastage.

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IV. METHODS AND METHODOLOGY

A. *Objectives of the project*

To improve the environmental friendliness of Reverse Osmosis process in terms of reduction in RO rejects along with removal of iron with respect to water or any wastewater.

B. *GaBi-think step: A complete life-cycle assessment module*

GaBi-ts — Complete Life cycle assessment software used to measure the environmental impacts due to the materials used in the production. Complete inputs for a product to be manufactured from its material extraction to the end of life. The GaBi think step is a complete life-cycle assessment module which helps us to evaluate our product at every step throughout its life-cycle phases. The GaBi-ts requires you to give the inputs like the material required, wastage every step, energy consumption etc., and outputs like expected emissions or wastage at every stage of the life-cycle phase. Once the flows are connected, the balances give you the environmental impacts caused due to the product. The GaBi workflow is attached in the supplementary information.

GaBi is the next generation product sustainability solution with a powerful Life Cycle Assessment engine to support the following business applications:

- •Life Cycle Assessment : Design for Environment, Eco- efficiency, Eco-design, Efficient value chains
- •Life Cycle Costing: Cost reduction
- •Life Cycle Reporting: Sustainable Product Marketing, Sustainability Reporting, LCA knowledge sharing
- •Life Cycle Working Environment: Responsible manufacturing

Using GaBi the flowchart of the RO process was modeled. The inputs like the materials used in the manufacturing of the RO unit, including the pumps and water and electricity usage were entered. A complete model from the extraction, usage, disposal and also the possible reuse and recycle options were also given.

C. *Testing and computing*

The second part consists of conducting the quality and drinking water qualities of the samples collected from 3 different RO units one being Aqua guard RO unit and two were assembled by taking the help of Benaka Solutions. Figure 1 shows the flowchart of the RO treatment process incorporated.

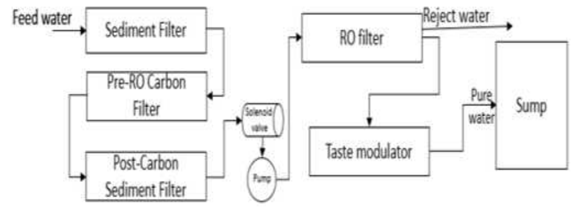

Fig. 1. Flowchart of the RO treatment process

Water Quality Testing: Water samples such as inlet, treated water and reject water were collected, measured. The tests were carried out for 3 different seasonal conditions, such as: Pre-Summer, summer and post-summer. As per the IS 10500, the following tests were carried out:

- •pH
- •Conductivity
- •Chlorides
- •Alkalinity
- •Hardness
- •Iron
- •Sulfates

A hollow fiber membrane was used in the next part of the experiment. This membrane was used to increase the efficiency of the RO unit. Tests were carried out to validate the same. Two membrane units were purchased and used. To one of the membrane the inlet was connected and the reject from the membrane was connected to the RO membrane. In the second case, the reject from the RO membrane was connected to the hollow fiber membrane. In both the cases the unit worked as two stage purification unit. Water quantities were measured. The water quality tests mentioned above were carried out. Figure 2 shows the flowchart of the RO treatment with hollow fiber membrane.

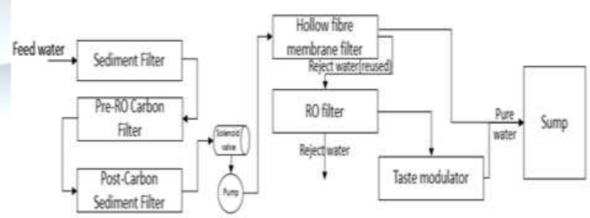

Fig. 2. RO treatment process with hollow fibre membrane

V. RESULTS AND DISCUSSION

GaBi-ts was used to determine the life cycle assessment of the RO process. Initially the basic RO process was modelled by providing the inputs like the average amount of plastic used in the unit, the type of membrane material used,

Water statistics before adding the membrane			
RO units	**Inlet**	**Pure water**	**Rejected water**
RO 1	1560	300ml	860ml
RO 2	1725	325ml	1050ml
RO 3	1640	340ml	800ml

water input, electricity input and the treated water as output. Inputs like plastic usage, membrane material, quantity of water used, electricity used were given in the flowchart. Expected output of the process were suggestion on reuse of plastic, amount of treated water and also the environmental impacts due to the different materials used, water wastage and electricity usage. The flowchart for the water treatment using reverse osmosis, was modelled as shown in the figure below.

Fig. 3. Flowchart of RO process in GaBi

The GaBi flowchart outcomes did not provide us the expected results. The study was to find the suitable process to reduce the reject water and increase the efficiency of the RO unit by maintaining the quality. As GaBi results were not as per out expectations, the primary study was considered as failure. GaBi-ts is more suitable for product lifecycle evaluation, rather than the process evaluation.

As we could not rely on the GaBi results, we planned to take up the experimental procedure. Three RO units- RO Aqua guard, and other two were assembled units. The samples from the three RO units were collected by running each unit for 2 minutes. The samples were collected using the water sample collecting cans of 1 and 2 litres. The RO unit consumes electricity and water as inputs. The initial water quality tests were conducted for pre-summer (series 1), summer (series 2) and post summer (series 3) seasons. It was observed that, when the unit was run for 2 minutes, there was about 75% of the input water was wasted as reject water. Some portion of water is held back in the membranes, which are considered as losses. The held up portion is retrieved when the next cycle of water treatment. The following table I shows the water statistics:

TABLE I
WATER STATISTICS BEFORE ADDING THE MEMBRANE

The following graphs show the results of the drinking water quality tests carried out for these samples:

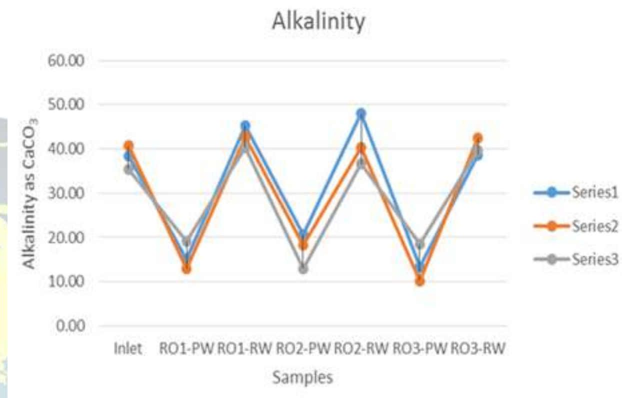

Fig. 4. A plot of Alkainity v/s Samples

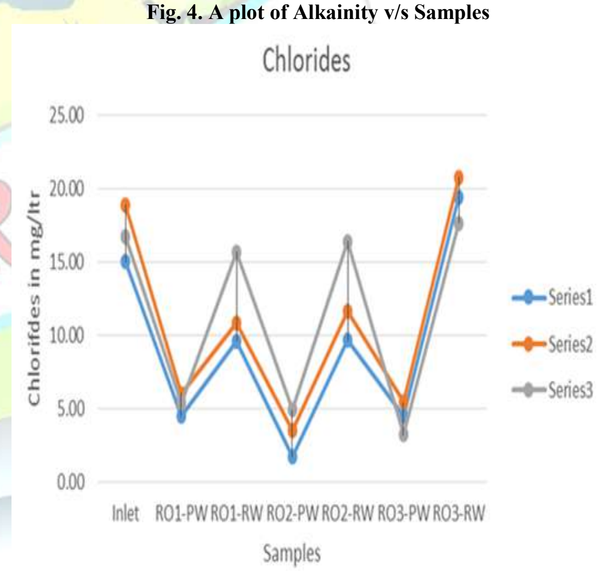

Fig. 5. A plot of Chloride content v/s Samples

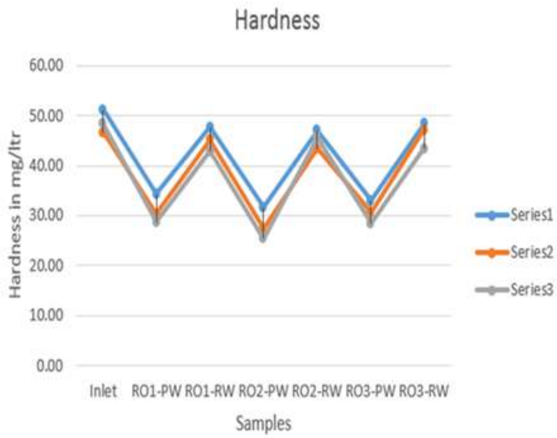

Fig. 6. A plot of Hardness v/s Samples

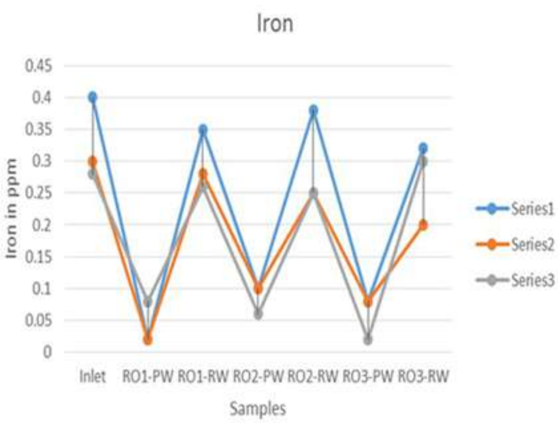

Fig. 7. A plot of Iron content v/s Samples

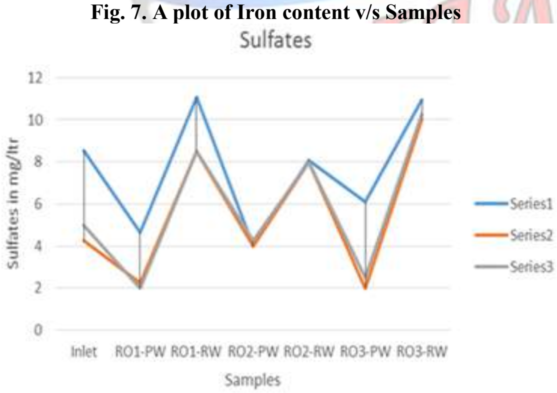

Fig. 8. A plot of Sulfate content v/s Samples

The hollow fibre membrane was added to the present RO Treatment process. The reject from the RO membrane is connected to the hollow fire membrane as the input. This acts as the recovery step. The following table II shows the water statistics after adding the membrane. It is observed that the reject water percentage has come down to 35% increasing the efficiency of the RO unit. Table III shows the water quality test results tested for the samples collected from the RO unit, namely: inlet, RO2-Membrane pure water (RO2 MPW), RO2 Pure water (RO2 PW), RO2 Reject water (RO2 RW), RO3 Membrane pure water (RO3 MPW), RO3 Pure water (RO3PW) and RO3 reject water (RO3RW).

TABLE II
WATER STATISTICS FOR THE RO UNIT AFTER ADDING THE HOLLOW FIBRE MEMBRANE

RO Units	Inlet	Pure Water	Reject Water
RO 2	2310	1110ml	800ml
RO 3	1890	970ml	470ml

TABLE III
WATER QUALITY TEST RESULTS FOR THE SAMPLES COLLECTED AFTER ADDING THE HOLLOW FIBRE MEMBRANE

Entries	pH	Conductivity	Chlorides	Alkalinity	Hardness	Iron
Inlet	7.04	17.31	17	44	43	0.23
RO2-MPW	6.86	17.70	13	34	35	0.01
RO2-PW	6.62	28.46	15	36	27	0.18
RO2-RW	6.45	6.99	16	60	45	0.07
RO3-MPW	6.90	21.15	11	38	24	0.21
RO3-PW	6.11	8.51	13	20	19	0.05
RO3-RW	5.98	25.61	16	52	40	0.17

The project was taken up with an interest towards saving water, as water is an important part of our life. The water wasted during the treatment of water using Reverse osmosis process is around 60-75 % of the inlet water. The efficiency of the RO unit is only 25-30%. The reject directly goes to the drains which is a total waste. To avoid this wastage a gentle effort towards saving the water is extended.

The AquaGuard RO initially, wasted around 75% of water. Other two units wasted around 70% of the inlet. The quality of the water treated were under limits as per IS10500.

A hollow fibre membrane was attached to two of the RO units. The reject water from the RO membrane was the input to the hollow fibre membrane. Pure water from RO membrane, pure water from hollow fibre membrane and reject from the hollow fibre membrane were the outputs. The hollow fibre membrane acted as the secondary treatment process. The quality of the water remained same with the increase in the efficiency. Efficiency increased by 25-30%.

VI. CONCLUSION

Literatures related to our study were not found or the related studies are very less which has also let us take interest in this topic.The results obtained from GaBi assessment were very minimal. Results for only electricity consumption were shown which was not as per our expectations. The results did not show the impact due to the materials used in the RO unit. The GaBi life-cycle assessment is suitable for the product life-cycle assessment but not for the process life-cycle assessment. The study was a failure when RO process was considered.

The working of different RO units for pre-summer, summer and post summer seasons was carried out. The study of quality and quantity of the treated and reject water for the different RO units was conducted and the positive results were obtained. An attempt to retreat the reject water is done in terms of increasing the efficiency of the RO unit. The addition of the hollow fiber membrane has reduced the reject water percentage from 75% to 45% while the drinking water quality is maintained.

The cost of the whole unit comes to around Rs 6000/- while the cost of other branded RO unit starts from Rs 8500/-. Hence, the unit also proves economical.

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REFERENCES

[1]. Arun Subramani, Joseph G Jacangelo, Treatment technologies for reverse osmosis concrete volume minimization: A review separation and purification technology, 472-489

[2]. Balasubramanian. P, A brief review on best available technologies for reject water (brine) management in industries, Centre for Energy & Environmental Science and Technology, Tiruchirappalli, International journal of environmental science, 2013, Volume3, No6.

[3]. Dr. Bertras, Incorporating environmental issues in product design and realization, Industry and Environment, Special issue on product design and the environment, United Nations Environment Programme Industry and Environment(UNEP/IE), Vol. 20, No. 1-2 (double issue), 1997 Invited contribution.

[4]. Fabrice Mathieus et al., Connecting CAD and PLM systems with eco-design software: Current experiences and future opportunities, International Conference on Engineering Design, ICED'07, Paris, France.

[5]. Heijungs, R. Int J Life Cycle Assess. (2017) 22: 1475. https://doi.org/10.1007/s11367-017-1358-z

[6]. How Do Reverse Osmosis Filter Systems Work & What Do They Do?- https://www.espwaterproducts.com/understanding-ro/ cited on March 2018

[7]. GaBi-ts, June 2017[online]- http://www.gabisoftware.com/international/index/

[8]. Herrmann IT, Moltesen A. (2015) Does it matter which life cycle assessment (LCA) tool you choose? A comparative assessment of SimaPro and GaBi. J Clean Prod 86:163–169

[9]. Seto KE, Panesar DK, Chuchill CJ (2017) Criteria for the evaluation of life cycle assessment software packages and life cycle inventory data with application to concrete. Int J Life Cycle Assess 22:694–70

BIOGRAPHY

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