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# Life cycle assessment of filtration systems of reverse osmosis units: a case study of a university campus

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**Abstract**

Environmental concerns are gaining importance in ground water resource management. Reverse osmosis (RO) systems are commonly used for filtration of surface and ground water for domestic and commercial purposes. This study aims to analyze the environmental impacts of electricity, fresh water and material consumption in various types of RO systems. The evaluation tool used for this study is life cycle assessment (LCA) and for this purpose Umberto NXT Universal software with Eco-invent version 3.0 database has been utilized. The inventory analysis has been done for RO systems of four different capacities, viz 25, 50, 250, and 500 liters per hour (LPH). This research also provides comparison of quantitative impacts of different capacity RO systems. All inclusive, the study presents an insight into the environmental impacts of various RO systems used in India and also discuss the alternative technologies for filtration of surface and ground water.



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Keywords: Reverse osmosis; Life cycle assessment; Environmental impacts; Water resource;

## 1. Introduction

Water is a crucial element for maintaining environment and ecosystem conducive to sustain all forms of life. It plays a vital role in fulfilling basic human needs for life and health as well as in socio-economic development. The demand for drinking, domestic activities, livestock, agriculture, industries, power generation, and other uses are all increasing to meet the requirements of increasing population and also to cater for the enhanced per capita requirement due to rise in living standard [1]. The available surface and ground water resources, which are the part of a larger ecological system, are renewable but limited and India has 16% of the world population where as the water resources are only 4% [1]. The arid regions are solely dependent on ground water for their domestic usage. Hence the quality of ground water is important, especially for drinking purposes. The ground water contains impurities such as suspended solids, dissolved solids, and other impurities [2] Hence, water needs to be treated before it reaches to the households. One such well known treatment methodology is reverse osmosis (RO). Reverse osmosis uses a membrane for the removal of contaminants from polluted water [3]. The process takes place when a pressure is applied to the concentrated side of the membrane forcing purified water into the dilute side. The rejected impurities from the concentrated side are being washed away in the reject water. This rejected water is one of the major wastage and hence this gives a scope for estimating the amount of water which gets treated using RO system and also for estimating the reject water. It is a social obligation to provide the population with the sufficient quantity of drinkable water and at the same time it is also necessary to prevent environment impact by reducing wastage and recycling the water [4].

The drinking water requirement of university campus is also fulfilled by RO systems. The aim of this study is to analyze and visualize the environmental impacts of electricity, fresh water and material consumption in RO systems of various capacities to produce potable drinking water.


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## 2. Case study

At university campus the main source of water is ground water. However, for irrigation purpose a small amount of harvested rainwater is used. The groundwater is extracted, using submersible electric pumps, from nine tube-wells providing 2,010 Kiloliters of water per day. The depth of these wells varies between 310 to 800 feet. Rainwater harvesting is implemented in newly constructed buildings to collect water. In 2013, the total amount of water harvested is estimated to be approximately 2,396,284 litres [4]. The groundwater is tested and it is found that the deep tube-well water is within the desirable limit of the Indian Standards and hence distributed without treatment. However, for drinking purposes the university has installed reverse osmosis (RO) treatment devices in the campus.

However the water supply system is a combination of gravity and pumping system. First the water extracted from the wells is stored at the reservoirs near to wells. Afterwards, the water in the reservoirs is transported with booster pumps through the pipeline system to tanks on the rooftops or inside the buildings. They are refilled automatically in all buildings for a 24 hours continuous supply. The staff quarters of campus are exceptions with an intermittent supply. The tanks in the buildings are only filled in the morning and evening. In addition, there is a refilling time in the night for the staff houses with two floors to provide sufficient water pressure to reach the tanks on the roof top.

The tap water is treated for drinking purpose using RO (reverse osmosis) systems installed at different locations in the campus. Anyhow; tap water can also be consumed without treatment due to good groundwater quality as described earlier.

A total of 6191 residents live on the campus including students, research scholars, faculty, staff and family members, guests and workers [5]. In the university campus the capacity of RO systems employed is approx. 33000 litres of ultrapure water, which is sufficient to meet the drinking water requirement for the residents. It is assumed that an average person needs 5 liters/day (The Hindu, 2013)of water for drinking purpose.

Table 1. Overview over water demand [4]

| Consumer | Water demand in l/d |
|---|---|
| Domestic | 829,980 |
| Businesses | 39,650 |
| Institutional | 198,270 |
| Public | 544,602 |
| Losses in distribution | 302,400 |
| Wastage | 123,820 |
| Total water demand | 2,038,722 |
| Water demand per capita | 329 |

## 3. Materials and method

LCA is an evaluation technique used for analyzing the energy and material flow throughout the life cycle of a product or a process. LCA has been widely used nowadays in various treatment processes [7] [8]in process industries as well as in manufacturing industries [9],[10]. In this study material and energy flow of drinking water, its purification and rejected water treatment was included. In this study a simple LCA has been performed using ISO 14040/44 (ISO, 2006), which comprises of four stages: goal and scope definition, inventory analysis, impact assessment, and interpretation. For this the collected data of water supply, demand and energy consumed was evaluated and visualized. The outputs were allocated to impact categories which resulted in a more vivid presentation. As a consequence, the awareness for negative effects has been increased.

To carry out this assessment, the whole life cycle of the product (including groundwater catchment, storage, distribution, purification, consumption, disposal, and recycling), the required energy, and material production is taken into account. In this study one important point to be mentioned is that during the purification process approximately 75% of the supplied water is wasted and 25% of the supplied water is purified. This waste water is directly supplied to the sewage treatment plant for further treatment and re-distribution. The energy and material required for sewage treatment of both used and wastewater is also considered. This provides better understanding of the environmental impacts of the drinking water supply system.

The inventory analysis and the impact assessment of both models were conducted in the Umberto NXT LCA software. The used assessment method was ReCiPe 2008 which combines midpoint and endpoint approaches.

In this study two models have been considered to find out the most efficient RO system for the institutional purpose. The results of both models were analysed to determine the intensity of the reduction of environmental impacts due to the related optimization ideas. The scope of this method is to find a base for developing efficient optimization methods.

### *3.1. Goal and scope definition*

The main objective of the study was to identify most environmentally efficient RO systems used in the campus for drinking water supply. According to the data provided by RO system distributors, most commonly used RO systems for institutional purpose are 25 LPH, 50 LPH, 250 LPH and 500 LPH. Thus these four RO systems were chosen for analysis. The energy and material requirement for all these RO systems were significantly different from each either and resulted in different environmental impacts. Thus for conducting LCA of these RO system including all pre-chain of water supply