Quantitative assessment of water consumption for manufacturing packaged drinking water at Rail Neer Plant – A case study

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Case study is based on total production and cumulative water consumption of various water treatment units used in water treatment at Rail Neer Plant, Nangloi, Delhi to meet Bureau of Indian Standards specification for packaged drinking water (IS:14543: 2004) and various amendments incorporated till February 2006. The treatment system comprises of chlorination, activated carbon filtration, pesticide removing system, softener, ultrafiltration, reverse osmosis, marble chip filtration unit, micron filtration, UV disinfection and ozonation. Study was carried-out following Good Manufacturing Practices (GMP) & Good Laboratory Practices (GLP). It was found that for manufacturing one litre of Rail Neer packaged drinking water 1.64 litre water was consumed.

Keywords: Backwashing, Chlorination, Permeate, Ultrafiltration

Introduction

In USA, groundwater extracted for bottled water industry is well studied[1]. This study might help in finding out a practical ratio formulation for water conservation system in packaged drinking water plant and will save a precious natural resource. To meet the increasing demand of providing pure drinking water to passengers traveling in Indian Railway, Indian Railway Catering & Tourism Corporation Ltd (IRCTCL), New Delhi has commissioned, on 6 May 2003, a packaged drinking water plant (capacity, 72,000 l/day) with brand name “Rail Neer” in Nangloi, New Delhi.

Methodology

The Bureau of Indian Standards (BIS) specifications for drinking water[2] & packaged drinking water[3] was thoroughly referred in the study considering that Good Manufacturing Practices (GMP) & Good Laboratory practices (GLP) are followed in Rail Neer Plant in India. GMP involves zero leakage of water in pipelines. GLP includes precise calibration of lab instruments, using recently prepared reagents, complete microbiological and chemical analysis of water, and compliance of sanitation conditions for various units. To assess consumption of water for manufacturing packaged drinking water, quantitative estimation was evaluated based on 24 h production (Batch No. 29/12) and the minimum time required to run ultrafiltration, reverse osmosis and softener to produce one day production. Water treatment unit at Rail Neer Plant, Nangloi, New Delhi, uses following steps (Fig 1):

Step 1: Chlorination

Raw water is chlorinated with sodium hypochlorite (8-10 ppm) solution primarily to destroy disease-producing microorganisms[4]. Chlorination also helps in oxidizing some of the metal impurities like iron and manganese and in removing colour and odour from raw water.

Step 2: Activated Carbon Filtration (ACF) Unit

Chlorinated water is then passed through ACF system in order to remove free residual chlorine, organic compounds, dissolved gases and suspended solids. After a preset volume of water is passed through ACF unit, backwashing of the system is done to regenerate activated carbon. The complete backwash sequences takes 15 min to complete and in case of extended backwash, it takes 40 min or till water is clear (Table 1).

Step 3: Pesticide Treatment Unit

Rail Neer Plant is the first plant in India using pesticide removing filtration system right from the...
beginning. As per BIS specifications, maximum permissible limit in packaged drinking water for individual pesticide residue is 0.0001mg/l and for total pesticide residue is 0.0005 mg/l. Pesticide treatment unit consists specific grade fine Norit carbon imported from Netherlands. Water consumption in pesticide filtration unit is shown in Table 1.

**Step 4: Softener**

Since treatment process in Rail Neer is reverse osmosis (RO) based, it is necessary to remove hardness from raw water prior to RO unit, as high hardness will result in scale formation in RO. Hardness of water is due to calcium and magnesium salts (chloride, carbonate, bicarbonate & sulphate). Iron-III also contributes in hardness but its contribution is relatively negligible as compared to Ca and Mg. The softening process consists of cation resin to remove hardness impurities of Ca and Mg. The resin used in Rail Neer plant is a synthetic organic copolymer of styrene in the physical form of small beads (0.5 mm diam). When the plant is on production mode for continuous 24 h, softening unit needs regeneration for approx every 12 h since Ca and Mg replace sodium ions. It was found that 9667 l water is consumed in softening unit (Table 1). Since regeneration is needed twice in a day in Rail Neer Plant, the consumption for 24 h production is $9667 \times 2 = 19,334$ l.

**Step 5: Cooling Tower**

Rail Neer plant has one blowing unit for manufacturing PET bottles (1 l). The blowing unit has the capacity to produce 3,000 PET bottles/h from preforms, which is heated uniformly and then put in moulds designed for producing 1 l bottle. The compressors need water for operation, for which cooling tower is installed. Water consumption in cooling tower has been found out approx 250 l/h. The total consumption of water in cooling tower for 24 h production is therefore 6,000 l.

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**Table 1—Water consumption in different treatment systems**

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Types of process</th>
<th>Time required in min</th>
<th>Water inflow in l/h</th>
<th>Water requirement in l</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACF</td>
<td>Backwash</td>
<td>15</td>
<td>20,000</td>
<td>5,000</td>
</tr>
<tr>
<td></td>
<td>Rinsing</td>
<td>10</td>
<td>10,000</td>
<td>1,660</td>
</tr>
<tr>
<td>Pesticide Treatment System</td>
<td>Backwash</td>
<td>15</td>
<td>31,400</td>
<td>7,850</td>
</tr>
<tr>
<td></td>
<td>Rinsing</td>
<td>10</td>
<td>10,000</td>
<td>1,660</td>
</tr>
<tr>
<td>Softener</td>
<td>Backwash</td>
<td>20</td>
<td>20,000</td>
<td>6,667</td>
</tr>
<tr>
<td></td>
<td>Slow rinsing</td>
<td>50</td>
<td>1,000</td>
<td>833</td>
</tr>
<tr>
<td></td>
<td>Fast rinsing</td>
<td>10</td>
<td>10,000</td>
<td>1,667</td>
</tr>
<tr>
<td></td>
<td>salt injection</td>
<td>30</td>
<td>1,000</td>
<td>500</td>
</tr>
</tbody>
</table>
Step 6: Ultrafiltration

Pore diam of ultrafiltration (UF) membranes in Rail Neer plant are in the range of 1,000 to 1,000,000 mol wt cut off (0.001-0.02 µ). UF system of Rail Neer consists two long hollow fiber module (each cartridge of 480 sq inch and 100,000 mol wt cut off) designed to produce 9000 l/h, stainless steel centrifugal pumps which is used for recirculation and backflush operation, one prefilter-basket strainer filter, and recirculation/CIP tank & pressure gauges with various sets of pipes/fitting. The membrane productivity is 32m³/h @ 3.5 kg/cm².

During operation of UF unit, valve of fast flush mode operation starts automatically providing shear sweep along the UF membrane cartridge. Feed water at a high flow velocity is pumped through the cartridge. Fast flush (5-15 min) serves to remove highly concentrated material from hollow fiber. Cartridge productivity is restored with a backflush cycle using permeate water. Backflushing (60 sec) serves to remove accumulated particles from the surface of hollow fiber membrane and then pushes particles out of the lumen to feed manifolds. Out of an inflow of 10,000 l/h of soft water, 9,000 l comes out as permeate and 1,000 l is drained out as reject. To make 1,15,400 l (72,000 l for filling, 43,200 l for PET bottle rinsing & 200 l for cap washing for 24 h production), UF system needs to be run for 12.8 h. Therefore, rejection per day will be 12.8 × 1000 = 12,800 l.

Step 7: Reverse Osmosis (RO) Unit

RO7,8 system in Rail Neer Plant consists of reverse osmosis membranes(model 8040CPA) pressure vessels, and piping for feed, reject and product with necessary instruments. RO system consists of two stages, of which first stage contains three membranes and second stage two with one dummy (distance piece). A high-pressure pump is provided to generate high pressure in the system. A micron filter has also been provided before RO inlet. Total dissolved solids at RO inlet are 1200-2000 mg/l. The flow at inlet is 9000 l/h, out of which 5000 l/h is received as permeate, 2750 l/h is recirculated to the system to maximize the recovery and 1350 l/h is rejected as a concentrate. To produce 72,000 l/day, RO system needs to run for 14 h 25 min. Hence, total rejection in RO unit for a day production is 19,440 l.

Step 8: Marble Chip Filtration Unit

After RO treatment, pH of the water becomes low. Marble chips filter (MCF) contains marble chips as media, which is used to boost pH and also picks-up calcium from the marble chips. MCF consists of a glass reinforced plastic pressure vessel, which holds the media together with a pipe work, PVC valve enables to control the plant to produce high quality water and backwash the marble chips media when required. The components are all mounted on a pressure vessel or on proper mounting brackets.

Step 9: Filler

It is important from quality aspect to sanitize2 the filling section before starting the production. Sanitation of filler is done daily with 10% sodium hypochlorite (25 ppm). The filling section tank is filled with chlorinated water and left for some time. It is then freed from the residual chlorine by providing ultra filtered water continuously until the traces of chlorine are removed completely as evident in chemical analysis. The consumption of water in filling section sanitization is found approx 1,000 l/day.

Step 10: Pet Bottle & Cap Washing

For measurement of water consumption in bottles & caps washing, water coming out from drain pipeline in filler was collected and measured. The washing of PET (polyethylene tetrathalate) bottles and caps is done automatically by ultrafiltered water. PET bottles are made to pass through rinsing assembly. Rinsing/washing of the bottle continues until bottles pass through the assembly. Water used in washing PET bottles was found to be 600 ml for 1 l. Since production in 24 h is 72,000 l, total volume of UF water consumed for PET bottle washing is 43,200 l. Cap, used for sealing of the bottle, is also washed with UF water. The water consumption for washing of 72,000 caps was found 200 l after measurement.

Results and Discussion

Water consumption in each treatment unit in Rail Neer Plant, Nangloi, New Delhi for manufacturing 72,000 l/day (Table 2) shows that for manufacturing 1 l of Rail Neer packaged drinking water, approx 1.64 l of water is required following GMP and GLP.

Water consumption is maximum in case of backwashing as high inflow of water with high pressure from bottom to top is provided. This is entirely due to consumption of water in getting the system free from the chemical (sodium hypochlorite) added in raw water. After a certain volume of
chlorinated water is passed through activated carbon, chlorine and other impurities are adsorbed continuously upon the surface of granulated activated carbon. Water with high pressure is applied to the activated carbon unit from bottom to top so that chlorine adsorbed on the surface of carbon gets free. The consumption of water further depends upon the strength of the hypochlorite solution added to the raw water.

In case of rinsing (ACF I), rejection is low as the volume of water required is low and the direction of flow is from top to bottom. Further, rejection in backwashing of ACF II is maximum since the quantity of carbon in this vessel is more (for pesticide adsorption) as compared to the ACF I, which contains carbon primarily to adsorb free residual chlorine as well as to remove colour, odour and turbidity. The volume of water consumption depends upon the purpose of each unit. When UF unit, RO unit and filling unit is in operation, a certain volume of water is rejected as process requirement. In this case, there is no rejection from ACF, pesticide filtration unit and softener. In case of backwashing and rinsing of ACF I, ACF II (pesticide filtration unit) and Softener, UF unit is stopped and during this operation there is no rejection from UF unit. Rejection from UF and RO unit will continue only as long as they are under operation. As soon as they are stopped, rejection will stop automatically.

The study covers consumption of water during online production and sanitation before starting production. It does not cover monthly sanitation, which is carried out once in a month to sanitize the whole units wherein sanitizations of different units are undertaken with specific chemicals compatible for specific unit. The study also excludes water consumption for lab activities like making distilled & double distilled water, glassware washing, chemical & microbiological analysis as well as water consumption for personal use for the personnel involved in production.

**Conclusions**

The case study addresses water consumption of various water treatment units used in packaged drinking water plant following GMP and GLP. More research on various capacities needs to be undertaken and justifications on their inclusion in water treatment plants needs to be done based on cumulative water consumption.

**Acknowledgement**

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**References**