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Water and Energy Footprint Assessment of Bottled Water Industries in India

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ABSTRACT

Assessment of water and energy footprint for eight bottled water industries was carried out. The investigation showed that one litre of bottled water has a water footprint of 17.41 litres and energy footprint of 7.08 MJ. Water consumption by the industry comprises 61% during material production, 17% in processes, 16% in energy and only 6% in the actual product. Hence, maximum consumption of water is in material production, while the processes required a smaller fraction of the total water and energy consumed. Therefore, water footprint can be reduced through optimization of water consumption in material production.

KEYWORDS

Bottled Water; Water Footprint; Energy Footprint; PET

1. Introduction

India is a developing country whose sustainable development and water usage are inextricably allied. Approximately 85% of the rural population of India is dependent on ground water. In the urban areas, though about 60% of the population is dependent on surface water sources, the quality is deteriorating. According to the studies carried out, the amount of annual utilizable water in India is 1100 Billion Cubic Meters (BCM). To meet food supply requirement for its fast growing population, India would require about 770 BCM by 2025, which is 70% of the total and the demand would be 1013 BCM which is very much close to the potential (www.whoindia.org). There is water scarcity during critical summer season. Ten percent of the population depends on unsafe water sources. The chemical and agrochemical contaminants are mostly responsible for polluting surface and ground water respectively.

The bottled water industries are flourishing in India especially in urban areas. The total annual consumption of bottled water has tripled in 2004 from 1999 (Chandra bhushan, 2006). There are more than 200 brands, nearly 80 per cent of which are local brands. The availability of water in PET (Polyethylene terephthalate) bottles with different capacities like 0.5 litre, 1 litre, and 20 litres becomes convenient to carry.

The water footprint is an indicator of direct and indirect uses of water. This includes Real Water Content (RWC) and Virtual Water Content (VWC), which is the water required for manufacturing the raw material, water used in processes and in energy generation for production purpose. Water footprint is also divided into Green water footprint (Rain Water), Blue water footprint (Ground or Surface water) and Grey water footprint. "Water Neutral" is a terminology which means reducing the water footprint of an activity as much as possible and offseting the negativity. Water Neutral does not mean that nullification of water is not possible in all cases but it means that water recycling and zero waste is quite possible in this particular industry.

LCA is an environmental tool to judge a material's performance as an ecofriendly option to its functional alternatives. Within an industry, LCA can be used for product development, future plans, making public policies, developing new marketing norms and a number of different applications [1]. The LCA of raw material or a

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final material is taken into account for the assessment of water requirement in the whole trade of this particular industry.

In the present investigation, the data of eight bottled water industries were analyzed from different regions of Maharashtra state of India with the functional unit of 1 litre. In Indian conditions, bottled water has become hygienic and safe option for drinking water. The experimental study was done with the surveyed industries for energy demand and water demand with respect to RWC and VWC. The study was also carried out with the annual bottled water demand in the country, water consumption and the energy required for the fulfillment of this demand.

2. Material and Methods

2.1. Primary Data

The primary data on water usage and energy utilization was collected for 8 bottled water industries in India through visits to the industries and questionnaires. The primary data includes water intake, water usage distribution and energy utilization in the actual water treatment.

2.2. Secondary Data

The secondary data was collected from the web sources, research papers, science magazines etc. The secondary data was used to calculate water and energy consumption for raw PET preparation, perform production, preparation of packing material like cardboard cartons along with the utilization in transportation and distribution to whole sellers, retailers or to direct consumers (in case of 20 litres jar).

3. Result and Discussion

3.1. Energy and Water Footprint of Bottled Water

The energy implication and water footprint of the bottled water are major issues of concern. Energy is required for PET resins formation and blowing of performs, water processing (Sand filtration, RO, Ozonation, bottling etc.), transportation and then for collection and recycling. Water footprint comprises production of raw polymer, carton material, processing, transportation.

3.1.1. Energy Footprint of the Bottled Water

Bottled water is sold in the Indian market in various convenient packs like half litre, 1-litre bottles and 20 litre jars. Polyethylene terephthalate (PET), the thermoplastic polymer is used for single use. As the container capacity increases manufacturers likely to toggle from PET to polycarbonate for rigidity and safety which required 40% more energy than PET bottles [2]. PET resin is a combination of the ethylene glycol and terephthalic acid. The resin pellets is then melted to form "Preforms" (Test tube shaped, cap threaded) which is then blown into final PET bottles. There are some plants which have blowing activities in their industries and some ready-made blown bottles.

Energy is required in the production of raw PET material and production of PET bottles, which is provided by various means like gas, petroleum and local electricity network. The life cycle assessment (LCA) of PET shows required energy of 77 $MJ \cdot kg^{-1}$ for virgin PET [3], manufacturing of perform and turning them into bottles required an additional 20 $MJ \cdot kg^{-1}$ [4]. Total raw PET required by 2015 to meet the demand of 45.65 billion litre will be approximately 1.09 metric ton. The energy required in the transport is totally dependent on how far the bottles have traveled. As present study mostly encompasses manufacturers dealing locally, the total energy required to manufacture the PET bottles and transport them to bottling plants is about 100 MJ. The average weight of the PET bottles studied was 24 gm with lid (Average 1.6 gm) weighed averages. So the energy required for production of single one litre capacity PET bottle is around 2.5 MJ. The packaging carton production requires 4.5 MJ of energy per case for 12 bottle capacity carton.

The energy required for diverse processes involved in pretreatment of water prior to filling in the bottles includes washing, sand filtration, reverse osmosis etc. (**Figure 1**). According to the present study the energy requirement in aforementioned treatments are ranging from 0.009 MJ to 0.20 MJ per litre of production. So the average energy consumption for treatment procedure is 0.08 MJ/litre. The water treatment involves sand filtration, reverse osmosis, UV treatment, Ozonation; in spite of extensive treatment processes it required only 0.0001 to 0.02 $MJ_{(th)}\ l^{-1}$ of energy [4].

3.1.2. Water Footprint of Bottled Water

Water foot print indicates direct and indirect use of water in the production of desired product. The water footprint of a business (BWF) can be defined as the total volume of freshwater that is used directly or indirectly to run and

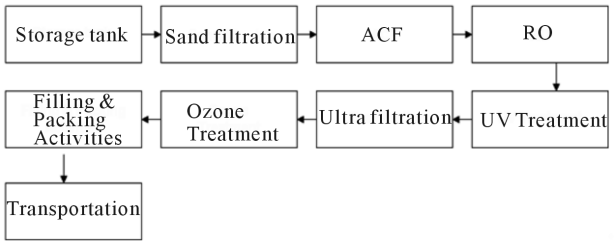

Figure 1. Flow diagram of bottled water treatment units (*figure caption*).

support a business. The water footprint of a business consists of two components: the operational water use (direct water use) and the water use in the supply chain (indirect water use) [5]. In this study, production included RWC of 1 litre (studied unit) and VWC which is the water required in the production processes, energy, material and transport of 1 litre of product (Bottled water). As most of the studied industries are distributing their products locally, here WF of transportation is omitted. As shown in **Figure 1** production includes filling and packaging of the product, which required PET bottles, paper cartons respectively and some cases include transportation of product at a distance, need water.

Table 1 showing variation in the ratio of RWC: VWC in the studied industries, BW1 and BW2 are having large production and wider distribution as compare to rest of the visited industries and also transported to varied area of Maharashtra state, India. BW3 showing largest production per annum amongst investigated industries but mostly having localized distribution. The rest of the industries BW4, BW5, BW6, BW7 and BW8 having smaller units with local distribution of a product. The total water footprint of the bottled water will be formulated as below;

$$\text{WATER FOOTPRINT}(\text{WF}) = (\text{RWC}) + (\text{VWC})$$
$$= (\text{RWC}) + (\text{VWC}_{(\text{material})} + \text{VWC}_{(\text{process})} + \text{VWC}_{(\text{Energy})}) \quad (1)$$

The materials used in the production of bottled water are mainly PET resin or PET bottle and the cardboard cartons used for packaging and delivering the bottles.

The energy required in the material production and in the processing has also been taken in account for WF calculation. The concept of conducting a detailed examination of the life cycle of a product or a process is a relatively recent one which emerged in response to increased environmental awareness on the part of the general public, industry and governments.

Table 1. Showing details of studied bottled water industries.

Sr. No.	Total Production (Per annum) in KL	RWC:VWC$_{(process)}$
BW1	11916	1:1.2
BW2	5098	1:3.0
BW3	1706960	1:3.9
BW4	975	1:4.1
BW5	1248	1:4.6
BW6	1440	1:2.5
BW7	3120	1:2.4
BW8	576	1:1.5

As per the LCA, production of 1 kg of virgin PET resin required 294.2 litres of water as the PET material is hygroscopic in nature [6]. As mention earlier the average weight of the PET bottle in these industries is 24 gm, so single bottle requires 7.35 litres of water. Then the filled bottles were packed in the cardboard cartons, a dozen bottles are normally packed in a carton for delivery, however now plastic packing material are also used. And some amount of water has been used up during transportation activity.

Environmental assessment of the cardboard by inferred that, one ton of the cardboards manufacturing required around 41.25 KL of water that is 41.25 litre of water for a kilogram [7]. One carton weighed about a kilogram, which means production of a single carton required 41.25 litres of water which means about 3.43 litres of water per bottle. As said earlier present study comprises industries which have local distribution of the packaged drinking water in various suitable sizes. So the water requirement in the transport sector is negligible.

The water consumption in the energy requirement for different processes also needs to be considered. Most of the power plants in the India are running on the coal *i.e.* thermal power plants providing energy to the country. Thermal power plants have mainly two types Subcritical Pulverized Coal and Supercritical Pulverized Coal which requires 520 and 450 gallons of water for production of one MWh of energy respectively. One kilogram of cardboard paper production required around 1.26 KWh or 4.5 MJ of energy. On an average 500 gallons of water is needed for production of 1 MWh of energy. The virtual water content$_{(material)}$ mainly comprises water consumption in PET bottle preparation and cartons manufacturing. As discussed earlier 1 bottle manufacturing required around 7.23 litres of water and single carton has a water footprint of 3.43 litres. Another 1.31 litres goes in the energy requirement for the PET bottle production. The energy required in this panoramic study encompasses energy in PET bottle production, carton production and energy required in water treatment processes which will give virtual water content$_{(energy)}$. So the total energy requirement for sampling unit that is for litre is 2.95 MJ inferred that 1.54 litre.

The production of bottled water gives a footprint of 17.41 litres for the production of one litre bottle (**Table 2**). The percentage ditribution of water usage in this industry are 61% in the material, 16% in processes, 17% in energy and only 6% in actual product (**Figure 2**). The overwhelming bottled water demand and simultaneous increase in the water usage to meet demand in successive years. As it can be seen from **Figure 3** that water demand is increasing with 25 percent but the water in the production touches the frontier.

3.2. Bottled Water Demand Projection

Table 3 shows that the current total bottled water consumption is around 210 billion litre/year, as India showing total consumption is around 14 billion litre/year. The consumption growth rate in India is continuously increasing by around 22 - 25 percent (Figure 4). India is the tenth largest consumer in the world, but the per capita consumption of India was 4.8 litres in 2004, which is way behind Italy, has 184 litres [8].

4. Conclusion

In India, bottled water industries are growing rapidly in current years and would follow the same trend in the recent future. The energy and water footprint calculation of

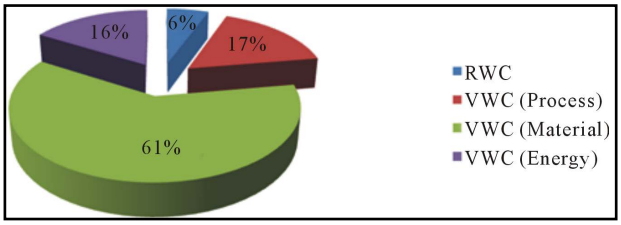

Figure 2. Percent distribution of the water in the package drinking water.

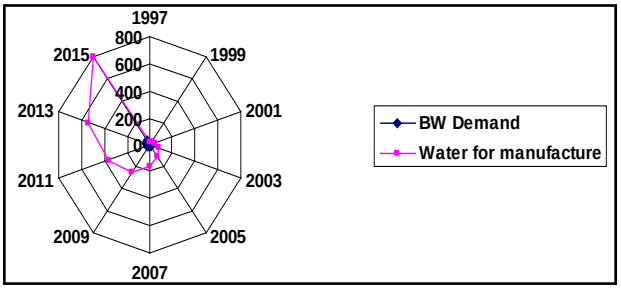

Figure 3. Bottled Water demand and water usage in manufracturing in India (In billion litres).

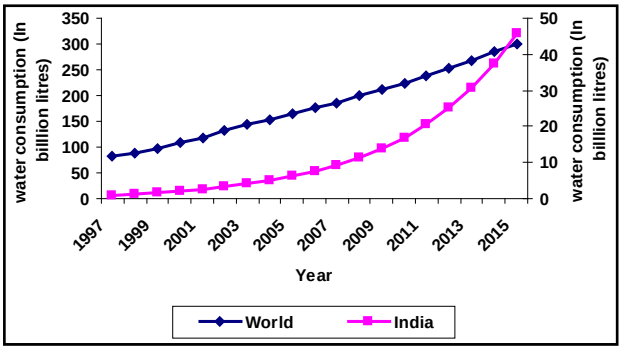

Figure 4. World and Indian scenario: growth in consumption.

Table 2. Showing water footprint of the studied industries.

Industry	RWC	$VWC_{(Material)}$	$VWC_{(Process)}$	$VWC_{(Energyl)}$	Water Footprint
BW 1	1	10.66	1.2	2.85	15.71
BW 2	1	10.66	3	2.85	17.51
BW 3	1	10.66	3.9	2.85	18.41
BW 4	1	10.66	4.1	2.85	18.61
BW 5	1	10.66	4.6	2.85	19.11
BW 6	1	10.66	2.5	2.85	17.01
BW 7	1	10.66	2.4	2.85	16.91
BW 8	1	10.66	1.5	2.85	16.01
Average	**1**	**10.66**	**2.9**	**2.85**	**17.41**

Table 3. Bottled water consumption scenario: World and India (2005-2015 is projected).

Year	**1997**	**1999**	**2001**	**2003**	**2005**	**2007**	**2009**
World	81	98	119	145	164	186	212
India	1.04	1.68	2.66	4.2	6.25	9.3	13.84
2011	**2013**	**2015**	**2011**	**2013**	**2015**		
239	268	301	239	268	301		
20.61	30.67	45.65	20.61	30.67	45.65		

this particular industry gives an idea about environmental threats caused by this industry with respect to energy and water requirement. This particular investigation gives water footprint of 1 litre bottle as 17.41 litres. Along with the water footprint, energy demand in the bottled water manufacturing is around 7.08 MJ/litre. Hence, it can be said that this particular industry will impact on the environment with respect to energy and water demand. India is facing shortfall of both, as the supply is much lesser than the demand.

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