Treatment and Reuse of Wastewater from Beverage Industry

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Summary: Water is used in most process industries for a wide range of applications. Processes and systems using water today are being subjected to increasingly stringent environmental regulations on effluents and there is growing demand for fresh water. These changes have increased the need for better water management and wastewater minimization. The combination of water demand management and cleaner production concepts have resulted in both economical and ecological benefits. Beverage industry requires huge amount of fresh water, generating considerable amount of polluted waste water during different processes including drink production, washing bottles, plant washdown as well as washing the floors and the general work area. Most of the industries do not reuse the waste water and consuming bulk of fresh water. The beverage industry is one of the major industries in Pakistan and the present study was conducted on the beverage/soft drink industry at Hattar Industrial Estate, Hattar, Pakistan to assess the feasibility of reuse of wastewater form bottle washing plant by conducting treatment test, like dilution of the waste water in different ratios, reverse osmosis and ion exchange.

Keywords: Beverage industry, soft drinks, wastewater reuse, bottle washing, ion exchange, reverse osmosis, Pakistan.

Introduction

Freshwater sources, while renewable in the long term, have finite withdrawal limits. Pakistan has reached the withdrawal limits of its surface and groundwater sources. The per capita availability of water has decreased from 5,300 m^3 per person per year in 1951 to less than 1,100 m^3 per person per year in 2007 owing to population growth. It is projected that water availability will be less than 700 m^3 per capita by 2025 [1]. Pakistan is heading inevitably into the category of water-stressed countries, defined as having less than 1,000 m^3 per person per year [2].

Across Pakistan, surface and groundwater sources continue to be polluted by raw sewage, industrial waste, and agricultural runoff. Most of the rural population defecates in or near cultivated fields. Less than half the urban sewage is drained off through sewers and covered drains, and only a small fraction of that is treated before being disposed off into water bodies [3-5]. An immediate consequence of these practices is that the majority of Pakistan's population does not have access to potable water. The lack of sanitation facilities and poor hygiene is one of the main causes of Pakistan's high burden of disease. Poor sanitation and hygiene and the lack of access to a safe drinking water supply are considered key contributing factors to the high rate of disease (such as diarrhea) in the country [6, 7].

The pressures on water resources due to industrial growth are quite significant and have increased water pollution problems. According to the State of the Environment Report, only a marginal number of industries conduct environmental assessments (about 5% of national industries). The national quality standards specifying permissible limits of wastewater are seldom adhered to. Most industries in the country are located in or around major cities and are recognized as key sources of increasing pollution in natural streams, rivers, as well as the Arabian Sea to which the toxic effluents are discharged. In Pakistan, only 1% of wastewater is treated by industries before being discharged directly into rivers and drains. For example in KPK Province, 80,000 m^3 of industrial effluents containing a very high level of pollutants are discharged every day into the river causing observable incidence of skin diseases, decrease in agricultural productivity and decrease in fish population [8].

Processes and systems using water today are being subjected to increasingly stringent environmental regulations on effluents and there is growing demand for fresh water. These changes have increased the need for better water management and wastewater minimization. The combination of water demand supervision and cleaner production concepts have resulted in both economical and ecological

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benefits. The biggest challenge for developing countries is how to upgrade the industrial processes, which at times are based on outdated technology, within financial, institutional and legal constraints. Processes in closed circuits can reduce water intake significantly and minimize resource input and the subsequent waste thereby reducing pollution of finite fresh water resources.

The beverage industry is one of the major industries in Pakistan. An estimates per capita soft drinks consumption in Pakistan to stand at about 20 liters per annum, which leaves significant room for further growth [8]. Beverage industry requires huge amount of fresh water, generating considerable amount of polluted waste water during different processes including drink production, washing bottles, Plant washdown as well as washing the floors and the general work area. Approximately 3 to 4 liters of fresh water is required to produce 1 liter of soft drink [9]. Most of the industries do not reuse the waste water and consuming bulk of fresh water for each cycle. Beverages are sold in bottles or packages, specifically the soft drink bottles are being reused as they are inexpensive (single serving 250-300mL) compared to PET disposable bottles (50–60% expensive) or aluminum canes (>100% expensive). The industry is encouraged to reuse the bottles by the government. Normally, a deposit system is used by the manufacturers to ensure that the bottles are returned for reuse.

It is estimated that almost 50% of waste water produced during the beverage production comes from the process of bottle washing [10]. Caustic soda and sugar are also released along with water as major pollutants [11]. Beverages industries require large quantities of fresh water for cleansing and rinsing operations. Wasting such a huge quantity of fresh water in the beverage industry has been a debate since many decades. One basic cause of fresh water wastage is the reuse of glass bottles which requires a huge expense of water as a rinsing and cleansing agent before they are refilled [12].

Bottle washing is usually conducted for two purposes i.e. to remove microorganisms and other chemicals to render the bottles safe for the human health and to clean the bottles for a good presentation of the product by removing the debris, solids and other contaminants from its surfaces. Different chemicals used for washing of bottles may include sodium hydroxide, detergent, chlorine solution. Washing of bottles is usually done in different stages, Pre-rinse, pre-wash, caustic wash and final rinsing. The bottles are first washed or pre rinse with hot water and are then entered in a compartments containing 2-3% sodium hydroxide solution at 60–70 ºC for 5–20 minutes. The present study was conducted on the beverage/soft drink industry at Hattar Industrial Estate, Hattar, Pakistan to assess the feasibility of reuse of wastewater form bottle washing plant by conducting treatment test, like dilution of the waste water in different ratios, reverse osmosis and ion exchange.

Results and Discussion

Water Use

Beverage Industry normally uses large quantity of water. The bottling plant in study uses large quantity of fresh water, the water consumption ranges from 15000 m^3 to 22000 m^3 per month. During 12 months of the year, five months coincide with the high season of production (April to August), and the seven remaining months with low season. During the first season, the plant uses an average of 600 m^3/day. The water losses by the networks vary between 60 % and 70 % of water consumed. The ratio of the plant m^3 of water / m^3 of product varies between 3 to 4, with a minimum of 2.9. However the average over the hot spell of month of (April to August) was 3.9. This indicates that a major proportion of the water supplied does not end up in the product and goes to waste untreated. According to research carried out, the average ratio for soft drinks manufacturing industries should be set at 2.3 m^3 of water/m^3 of soft drink produced [13,14].

Water Used in Bottle Washing

The bottle washing causes most of the water consumption. Modern bottle-washers needs 150-200 ml per bottle; where as an older one consumes up to 600 ml [10]. This corresponds to the consumption of 20000-30000 m^3/y for a medium-sized company and much more than 250000 m^3/y for a large one [15]. The industry in present study, the bottle washing plant uses approximately 50–60 % of water daily used. Soaker type water washing unit is being used in the process of a bottle-cleaning machine is shown in Fig 1. At the beginning pre-cleaning takes place; normally this zone consists of several soak and rinse baths, which is followed by the main cleaning in a caustic soda bath which contains 2–3% NaOH with a temperature of about 60-80°C. To that a pre-final rinse bath is connected. After leaving the caustic soda and pre-rinse zone, the bottles are washed in final rinse with plenty of cool water (28°C) finally before filling. After leaving the cool water bath the water goes to the sewage without any recycling. In bottle washing unit most of the fresh water is used so that a recycling system in this zone could reduce the amount of fresh and wastewater most effectively. The recycling system in this unit strives to save water by 50% and it is not possible to replace all the fresh water by recycled water because the law demands to use drinking water for the very last step in the cleaning processes for the food industry.

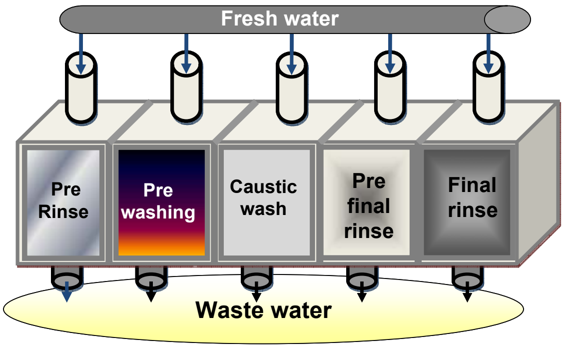

Fig. 1: Schematic diagram of bottle washing Unit.

Waste Water Characterization of Bottle Washing Plant

Initial waste water characterization of bottle washing plant has been shown in Table 1, along with the NEQS-Pak standards for Industrial effluents to sewage [16]. Waste water obtained from the final bottle washing has a light gray color with an average pH of 10 due to the presence of caustic soda in the washing solution. The average (12 months) characteristics were as follows: DO, 3.6 mg/L, Turbidity 16 NTU, COD 85 mg/L, TDS, 850 mg/L, TSS, 45 mg/L, EC, 2105 µs/cm, total hardness, 180 mg/L, total iron 1.1 mg/L, sulfate 195 mg/L, nitrate 9.0 mg/L, chloride 512 mg/L, MBAS 0.9 mg/L, and silica 60 mg/L.

Table-1: Characteristics of bottle wash wastewater, NEQS-Pak standard for wastewater effluent and the quality of fresh water supplied to industry.

Parameters	NEQS [16]	Fresh Water supplied to industry	Bottle wash Wastewater
pH	6.0–9.0	7.3	9–11
DO (mg/L)	–	5.8	3.1–4.1
Turbidity (NTU)	–	2.5	12–25
Iron (mg/L)	2	0.8	1–2
MBAS (mg/L)	–	–	0.5–1.5
Nitrate (mg/L)	–	2	3.0-15
Temperature (°C)	40	25	45–60
COD (mg/L)	150	–	25–125
TSS (mg/L)	200	–	26–90
Hardness (mg/L as CaCO3)	–	51	150–250
Silica (mg/L)	–	–	30–90
sulfate (mg/L)	600	51	112–280
Chloride (mg/L)	1000	–	412–615
Conductivity (µs/cm)	–	560	1050–3200
TDS (mg/L)	3500	341	750–1200

Waste Water Treatment of Bottle Washing Plant

The low-cost options for water treatment and its reuse aiming at water and energy conservation were investigated. Treatment of water is not mystery anymore since the development of many other water treatment technologies, and important thing is to choose right technology at right time to reduce the waste water discharge. Low-cost chemical and physical treatment systems can be right treatment technologies for water to be used for steam generation in boilers or for rinsing purposes. Different physico-chemical characteristics of water such as pH, hardness, TDS, conductivity, and silica are important considerations to achieve safe drinking water quality. This study is focused on treatment of wastewater, produced after final bottle rinser, to make it suitable for boiler feed water or pre-final rinse. As the temperature of this effluent is higher than 50 ºC, so it is beneficial in terms of saving energy by providing less energy to raise its temperature in order to remove latent heat for the steam production. Target values for boiler feed water are given as; total hardness of 0.3 mg/L (as $CaCO_3$), pH of 7.5–10, total iron 0.1 mg/L, silica 150 mg/L, TDS of 3000 mg/L. TSS of 300 mg/L [17]

Dilution with Fresh Water

Wastewater from bottle washer was diluted with 25% to 50% with fresh water to assess the feasibility of reuse after simple dilution. It was found that most of the parameters shown a decreasing trends (Fig. 2, 3 and 4), water from dilution up to 50% with fresh water could be used for first three stages of bottle washing. However this water cannot be used in boiler feeding as the hardness is main concern which is not dropped to the level required for water feeding in boiler.

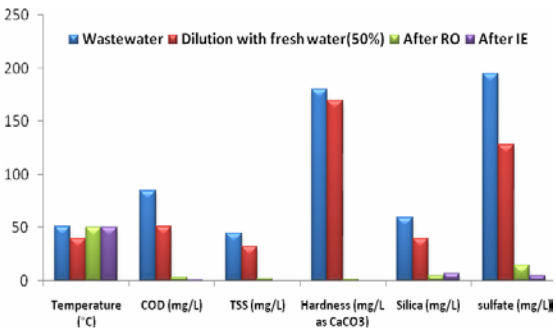

Fig. 2: characteristics of waste water before and treatment with respect to Temp, COD, TSS, Hardness, Silica and Sulfate.

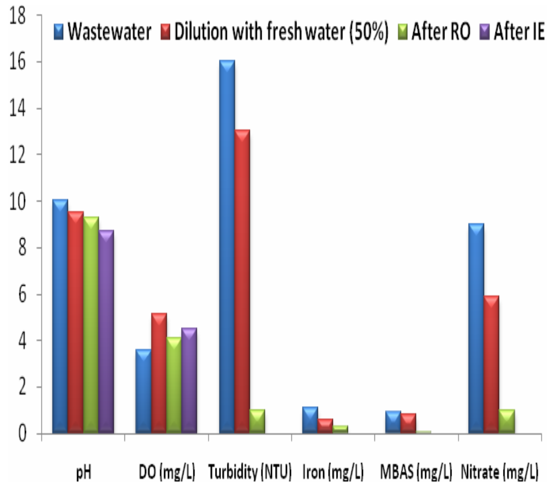

Fig. 3 Characteristics of waste water before and treatment with respect to pH, DO, Turbidity, Iron, MBAS and Nitrate.

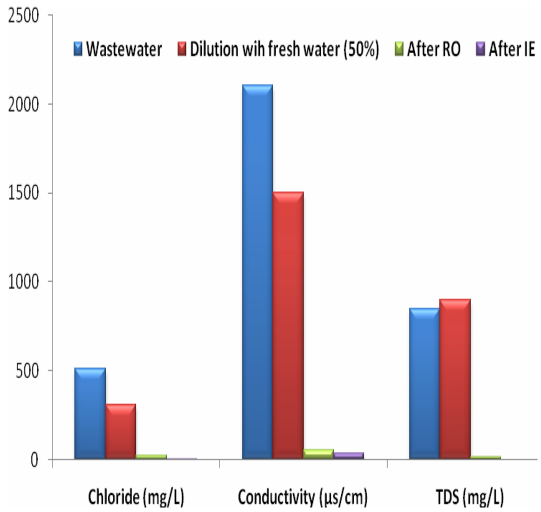

Fig. 4: characteristics of waste water before and treatment with respect to chloride, EC and TDS.

Filtration

Simple filter cartridge of 0.45 um was used for wastewater treatment; which is commercially available and is used for potable water treatment. Water is passed through the filter under the effect of gravity and is collected. Treatability with filtration only removed the TSS to a level of 20 mg/L; however other parameter does not show any significant decrease.

Reverse Osmosis (RO)

The reverse osmosis process pilot plant consisted of a storage tank, a large pore (<50 microns) cartridge filter and a reverse osmosis unit. The experimental arrangement is shown in Fig. 5. A single run with influent temperature at 40-50 °C were conducted. The membrane was washed with 0.5% EDTA solution, 0.3% nitric acid solution and 0.5% EDTA solution in succession [18]. The results of the pilot study with the reverse osmosis process pilot plant are shown in Fig. 2, 3 and 4. It was observed that better recovery rates occur at higher operational temperatures. Table-1 indicates that RO system removed more than 99% of the impurities from the wastewater. The quality of treated effluent is better than potable water.

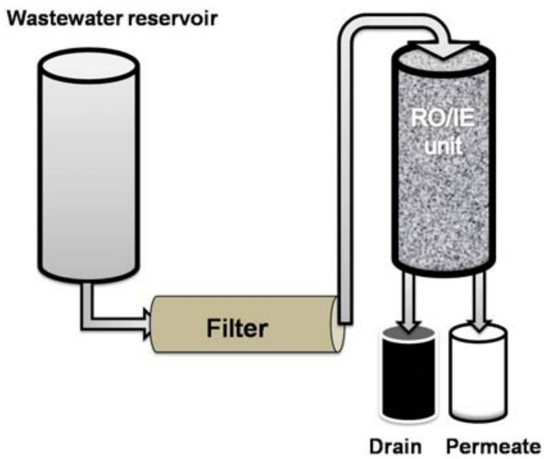

Fig. 5: Schematic diagram of wastewater treatment plan.

Ion Exchange (IE)

The ionic exchange unit can be formed by replacing RO unit by IE unit in Fig. 2. A single column was packed with commercially available ion exchange resin for cations and anions removal. The result shown in Fig. 2, 3 and 4. indicates that most of (>99%) materials have been removed successfully using IE. Especially the hardness removal to the value required for the boiler feed water. The effluents treated by either of the last two process combinations were adequate for recycling in all processes of bottle washing to boiler feed water, except the final bottle wash, since they obtain water that complies with the industrial water quality requirements. Both treatment alternatives for water reuse are economically feasible because they allow 50% water saving at unit cost 60% lower than the soft water cost needed for bottle washing [10].

Experimental

Study Area

Beverage/soft drink industry located at Hattar Industrial Estate, Hattar, Pakistan. According to Sarhad Development Authority, Pakistan, the "Hattar Industrial Estate (HIE)" housed 180 operational units. The estate, spread over an area of 1063 acres, can be divided into six main domains namely, Textile, Marble, Heavy Electrical Engineering, Chemicals, Ghee & Cooking Oil, Food & Beverages. The Beverage industry under present study produces a wide variety of energy drinks, juices, soft drinks, syrups, squashes, sauces, jams, pickles preserves from fruits and vegetables. Daily demand of fresh water is accomplished by pumping fresh water either from underground wells or from natural resources. The water once used is discarded in the nearby drain causing environmental hazard to natural flora and fauna. This waste water is also a health risk to various livestock and human being downstream.

Characterization of Wastewater

Characterizations of water and wastewater samples were performed according to *Standard Methods* [19]. Parameters investigated are COD, pH, temperature, electrical conductivity (EC), turbidity, total dissolved solids (TDS), total suspended solids (TSS), dissolve oxygen (DO), methylene blue active substances (MBAS), silica, iron, sulfate, nitrate, chloride, and total hardness. The instruments used are turbidity meter (Lovibond Tintometer Gmbh, Dortmund). The pH, DO, Temperature, EC, and TDS were measured by using HANNA, USA,). For reverse osmosis (RO) treatment; membrane used was TMF-50 Model (USA), For Ion exchange, Amberlite IR120 strong acid cation and IRA96 strong base anion, H and OH forms were used respectively.

Sampling

Fresh water and waste water samples were collected from different sources, like fresh water from underground tube well (major source of fresh water); various batches of waste water from bottle washing plant. Sampling was conducted during the plant operation during one year period of study.

Conclusion and Recommendations

Water is important necessity of life and availability of fresh and clean drinking water reached towards its alarming condition, so there is a need for treatment of wastewater from houses and industries to save the natural fresh water for future generation. As soft drink industries are using large amount of fresh water especially in bottling plants where used bottles are washed with caustic solutions to make them ready for reuse; however, large amount of fresh water is used in this process, so it is suggested that wastewater of soft drink industry can be treated and reused to save burden on fresh natural water resources and energy. It is recommended that wastewater of beverage/soft drink industry if treated through a combination RO and IE, can be reused in bottle washing plant and in boiler etc and limited the use of natural water resources and energy. Furthermore dilution of waste water samples with fresh water up to 50% could be reused for first three stages of bottle washing.

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