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An Investigation of Water Resource Management in the Beverage Industry

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Abstract

According to studies, industrial water use comprises production processes, auxiliary processes, kitchen use, and outdoor use. Reducing industrial water use is dependent on the implementation of administrative, engineering, mechanical, and human controls. The objectives of this research were to assess the water use of a Soft Drink Plant; determine the water use ratio for a two-year period; and determine the plant's compliance with local and international regulations for wastewater discharge. We also determined the level of success of implementing a water minimisation plan, whether there was an improvement in the Water Use Ratio, and compliance of the industry with local and international discharge regulations. The sequential transformative strategy was used to collect and analyse data so as to ascertain water usage and disposal, and a semi-structured interview was conducted to validate the non-existence of heavy metals in the wastewater discharged from the soft drink plant. The Soft Drink Plant's Water Minimisation Plan 2013-2016 achieved a high level of success overall, with 74.42% of the activities implemented by the assigned completion dates. However, three of the five measures implemented recorded low levels of success. Paired sample t-tests revealed statistically significant differences in the water use ratio obtained for the periods 2013-2014, 2014-2015, and 2013-2015, although the differences were relatively small (t (df)=2.242, p=0.047; t (df)=2.592, p=0.025; and t (df)=6.250, p=0.000) for the respective periods. Six of the eleven tested parameters were statistically different when compared to the Coca-Cola Operating Requirements and Environmental Protection Agency standards, indicating a high variation in effluent discharge.

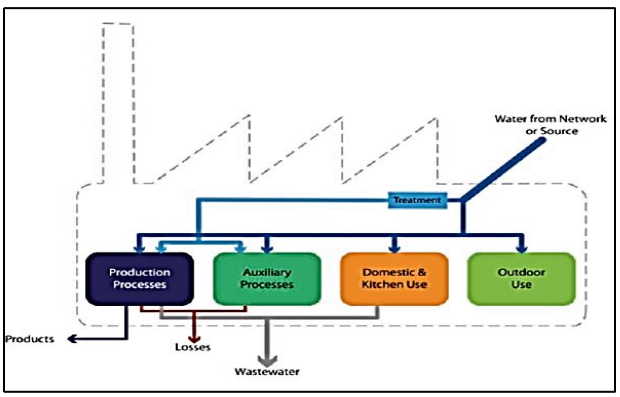
Keywords: Water use ratio, Water minimisation plan, Effluent

1. Introduction

The need for monitoring Guyana's water resources is becoming increasingly important in the context of a changing climate. While Guyana is not in a water scarce region, shifting climatic and weather conditions are causing unprecedented environmental changes coupled with increases in industrial water use. The demand for water will continue to rise with environmental and demographic shifts. Therefore, managers in both public and private sectors must agree on measures that can be taken to apportion the supplies between the demanding agencies, with industries being the second largest water consumer (Mirata & Emtairah, 2014).

Studies have shown evidence that water use associated with industrial processes contribute to the degradation of water tables, over-extraction of wells, increased pollution, and greater energy use (Beverage Environmental Industrial Roundtable [BIER], 2011). In response, governments have incentivised the use of technologies to reduce water use – an instrument for environmental protection to counteract water wastage in industries (World Water Assessment Programme, 2009, p. 14). According to the World Health Organisation [WHO] (2012), "water shortages are likely to be more common within a changing biosphere". Industrial processes account for more than 10% of the global water usage and studies have shown that in order produce one litre of some beverages, more than ten litres of water are used in the production and operational stages. The improper disposal of industrial waste water and continuous extraction of fresh water to meet a growing demand increases environmental cost.

Figure 1
Water use in a typical industry



From Water use efficiency in industrial facilities, by M. Mirata & T. Emtairah, 2014, in *Water efficiency handbook* (pp. 43), Arab Forum for Environment & Development.

Mirata and Emtairah (2014) have shown that when a systematic approach to water efficiency is adopted by an industry, water consumption is generally reduced by 20-50%; in some cases, a 90% reduction is achieved when measures like closed loop reuse are implemented. Common measures to improve water efficiency within an industry include: improved housekeeping, modifying the processes or equipment, changing products or materials, and replacing equipment and technology when required. Water efficiency is monitored by calculating the water use ratio (WUR), which indicates the amount of water needed to produce one litre of final product with minimal environmental impact.

The water use ratio is calculated using the equation:

$$\mathrm{WUR} = \frac{\text{Total Water Used (kL)}}{\text{Total Beverage Production (kL)}}$$

Table 1
Comparison of local and international allowable ranges of effluent

Parameter	Local	KORE
Aluminum	<5mg/L	<0.1mg/L
Chemical Oxygen Demand (COD)	250ml/L	_____
Colour	_____	100[7](Pt/Co units)
Dissolved Oxygen (DO)	3.5 – 5.0mg/L	>4.0mg/L
Free Chlorine (Cl^-)	<0.005mg/L	0.001mg/L
Iron (Fe)	<0.3mg/L	<0.1mg/L
Nitrogen (mg/L)	____	<5mg/L
pH	4.0 – 5.0	6.5 – 8.0
Phosphorus	<2.0mg/L	<2.0mg/L
Temperature	25 - 27°C	28°C

Requirements for water discharge into the environment are set by third parties; from local standards and international regulations such as the ISO 14001 which focuses on environmental management, and local regulations. Global Water Stewardship however, which focuses on the implementation of effective wastewater treatment and conservation processes, is one of the key areas having the most impact (Coca Cola Company, 2010). Water optimisation strategies used by industries is important because they can lower water withdrawals from water sources, increase water availability, improve community relations, increase productivity per water input, lower wastewater discharges, reduce thermal energy consumption, and reduce processing cost.

2. Methodology

An investigation was conducted on water usage at a soft drink plant, which assessed: strategies to reduce water use (Table 2), water use ratio (WUR), and compliance with local and international regulations for wastewater discharge. The study used primary qualitative data (semi-structured interview), primary quantitative data (wastewater samples), and secondary quantitative data (wastewater records).

Water Minimisation Plan – This study used a simple modified impact matrix from the Brewers Association (2015). The matrix used a weighted scale of high, medium, and low success based on the calculated percent ranges and the dates assigned for the completion of activities. A high rating indicated that 100-70% of the activities were completed by the assigned date; a medium rating indicated that 69-40% of activities were completed by the assigned date; and a low rating indicated that 39-0% of activities were completed by the assigned date. The following formulas were used to determine the percentage of activities completed and the overall percentage of activities conducted:

$$\text{Percent of Activities Completed (\%)} = \frac{\text{No. of Activities Completed}}{\text{Total No. of ACtivities Outlined}} \text{ x } 100$$

$$\text{Overall Percent of Activities Completed (\%)} = \frac{\text{Total of No. of Activities Completed}}{\text{Sum of Total No. of Activities Outlined}} \text{ x } 100$$

Water Use Ratio – Data from the soft drink plant in relation to the water use ratio was obtained for the period 2013-2015. The percentage of improvement was calculated using the following formula, expressed as a percentage:

$$\text{Percent Improvement (\%)} = \frac{\text{Previous Year Water Use Ratio in L/L} - \text{Current Year Water Use Ratio in L/L}}{\text{Previous Year Water Use Ratio in L/L}} \text{ X } 100$$

Compliance with local and international regulations – To determine level of compliance, wastewater discharge produced by the production of soft drinks underwent water quality testing. All water quality tests followed the standard testing protocols for Hach equipment. Results were compared against the national standard set by the EPA Guyana, and the Coca Cola Operating Requirements (KORE) standard. The paired sample t-test was used to compare the influent and effluent of the treatment plant over a two-year period. A semi-structured interview with the wastewater treatment facility operator provided insight on wastewater quality, fluctuation of pollutant levels, and heavy metal contamination.

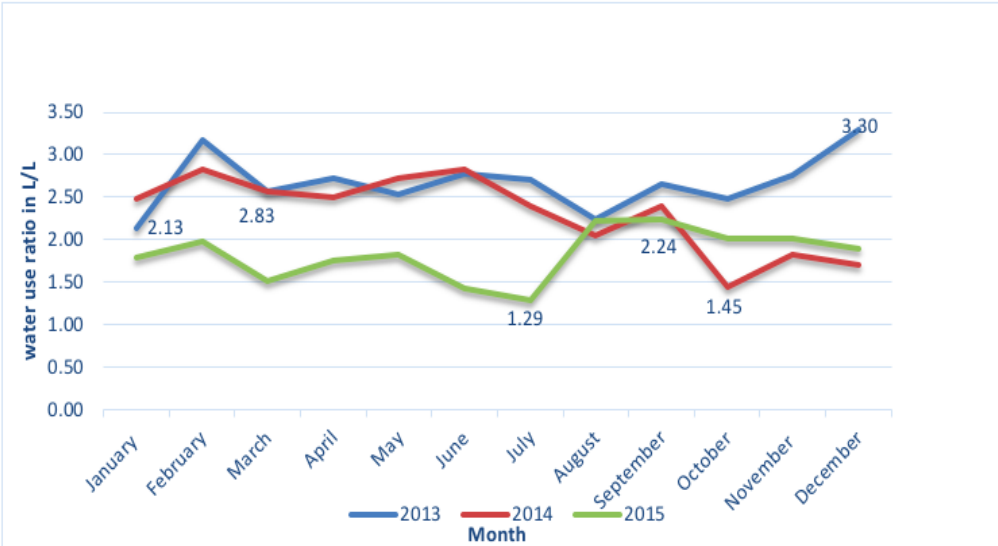
3. Results

Table 2
Level of success assigned to the measures implemented

	MEASURES					
	Repair All Leaks at Soft Drink Plant	Installation of PET Water Recycling System	Installation of Water Meters to all External Areas being Supplied Water by Soft Drink Plant	Installation of Spray Nozzles in Wash Hoses	Installation of Closed Loop CIP System for Syrup Room	Accurately Measure Water Usage at the Soft Drink Plant
SUCCESS	*High (100%)*	*Low (37.50%)*	*High (100%)*	*High (100%)*	*Low (28.57%)*	*Low (0.00%)*

Table 2 indicates that three measures used by the soft drink plant to reduce water use showed high (100%) levels of success (repairing all leaks, installing water metres to external areas, and installing spray nozzles in wash hoses), while the remaining three showed a low degree of success (installing PET water recycling system, installing closed loop system, and accurately measuring water use). Importantly, prior to 2016 the total water use by the soft drink plant was not accurately measured as a result of a delay in the implementation of the plan. Repairing of leaks, installing water meters as well as spray nozzles were 100% completed by the assigned date. Installation of the polyethylene terephthalate (PET) water recycling system and the closed loop clean-in-place (CIP) system for the Syrup Room were 37.50%, and 28.57% completed respectively; while no activity was completed for accurately measuring water use.

Figure 2
Water use ratio for the years 2013-2015



In 2013, the highest WUR was seen in December and the lowest in January; whilst in 2014, the highest was obtained in February and the lowest in October. For 2015, the highest value was recorded in September and the lowest in July. The difference in WUR for the years 2013 (M=2.6725, SD=0.33284), and 2014 (M=2.3100, SD=0.45373) was statistically significant (t (11) =2.242, p=0.047) (Tables 3 and 4). Similarly, WUR comparisons between 2014 and 2015 and 2013 and 2015 showed that both pairs were statistically significant (i.e. different) for the year 2014 (M=2.3100, SD=0.45373), and 2015 (M=1.8300, SD=0.29802); t(11)=2.592, p=0.025; and 2013 (M=2.6725, SD=0.33284), 2015 (M=1.8300, SD=0.29802); t(11)=6.250, p=0.000 (Tables 3 and 4). Additionally, the average water use ratio for 2013 was 0.3625L/L higher than 2014 (95% CI [0.00670, 0.71830] L/L). A higher mean WUR was also noted in 2014 compared to 2015 (0.48000L/L higher) (95% CI [0.07241, 0.88759] L/L), while a 0.8425L/L increase was evident when the years 2013 and 2015 were compared (95 %CI [0.54579, 1.13921] L/L).

Table 3
Pair Sample Statistics of WUR

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Year2013	2.6725	12	.33284	.09608
	Year2014	2.3100	12	.45373	.13098
Pair 2	Year2014	2.3100	12	.45373	.13098
	Year2015	1.8300	12	.29802	.08603
Pair 3	Year2013	2.6725	12	.33284	.09608
	Year2015	1.8300	12	.29802	.08603

Note. N= number of samples

Table 4
Paired Differences in WUR

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Year2013 - Year2014	.36250	.55999	.16165	.00670	.71830	2.242	11	.047
Pair 2	Year2014 - Year2015	.48000	.64150	.18519	.07241	.88759	2.592	11	.025
Pair 3	Year2013 - Year2015	.84250	.46699	.13481	.54579	1.13921	6.250	11	.000

Table 5
Comparison of EPA standard, KORE standard and researchers' mean effluent

Parameter	Effluent Mean for 2015 and 2016	LOCAL BODY STANDARD (EPA)	KORE (INTERNATIONAL)	Researchers' Mean results for WOT (Effluent)
PH	8.043	4.0 – 5.0	6.5 – 8.0	7.315
Temperature	30.176	25 - 27°C	28°C	29.05
Chemical Oxygen Demand	83.007	250mg/L	none	96
Dissolved Oxygen	3.425	3.5 – 5.0mg/L	>4.0mg/L	4.25
Chlorine	0.181	<0.005mg/L	0.15mg/L	0.2
Aluminium	0.173	<5mg/L	<0.1mg/L	0.005
Turbidity	93.233	<15	<2000 [9] NTU	73.6
Phosphorous	0.612	<2.0mg/L	<2[9]	0.085
Nitrogen	0.582	none	<5 [9] mg/L	0.17
Iron	0.197	<0.3mg/L	<0.1mg/L	0.05
Colour	108.91	none	100 [7](Pt/Co Units)	92.6

Note: KORE is the acronym for Coca Cola Operating Requirements.

The pH, temperature, chlorine, and turbidity were not statistically different among the effluents for January 2015 to January 2016 when compared to those sampled by the researcher. However, differences in chemical oxygen demand (COD), dissolved oxygen (DO), aluminium, iron, phosphorus, colour and nitrogen were statistically significant when the effluents for January 2014 and January 2016 were compared with those sampled by the researcher. Notably, the pH values of wastewater samples was within the optimal range but was closer to the upper limit.

4. Discussion

The WMP for the years 2013-2016 showed a high level of overall success – 74.42% of the activities implemented. The measures and underlying activities outlined in the WMP are used in soft drink facilities worldwide. For example, a soft drink facility in Dongen, the Netherlands in 2012 reduced its water consumption levels by implementing monitoring systems that notified operators when limits were approached (BEIR, 2012). In Dunkerque, France a facility re-uses water to regenerate and rinse resin granules used to purify the water for making beverages (Coca Cola Enterprises, 2015). Moreover, the Pepsi Company has identified monitoring techniques; ensuring the fixture of leaks, recycling and reusing water as some of the ways accredited to saving US$15 million, and over 14 billion litres of water in 2013 when compared to a 2006 baseline (Pepsi Company, n. d.). Therefore, the measures implemented were dependent on the areas where high water consumption rates occur, and the level of concern by management. Though a high level of success was assigned to the WMP for the years 2013-2016 under review, three of the six measures implemented that had low levels of success require more attention: the installation of PET recycling system (37.50%); the installation of the closed loop CIP system for the Syrup Room (28.57%); and accurately measuring water usage for the soft drink plant (0.00%).

BIER (2012) and BIER (2014) reported an overall improvement of 9% and 2% respectively in the water use ratio when a study was conducted on a number of carbonated soft drink bottling locations during the periods 2009-2011 and 2010-2013. Moreover, a decrease in facilities' improvement of WUR was observed from 74% during the years 2009-2011 to 69% for the years 2010-2013. A similar decline in the overall WUR improvement of the soft drink plant was recorded for the periods 2013-2014 (21.35%) and 2014-2015 (11.90%). A detailed breakdown of the activities and relative percentage of water used for the resultant total water use was inaccessible.

It is important to note that this beverage industry uses a closed looped system. These systems reduce the amount of water and energy as they return water and steam to the boiler for reuse. However, the closed looped CIP system had a low level of success since only 28.57% of the activities were completed at the time of analysis.[1] Similarly, the PET water recycling system also had a low success rate (37.50%). Through interviews, it was determined that a myriad of factors may be responsible for the annual fluctuation of WUR; for instance, increases in local demand for beverages around religious and national holidays, errors in soft drink blends, spillages, non-conforming products can affect the annual WUR of the soft drink plant.

The Environmental Protection Agency (EPA) was mandated to establish disposal limits for wastewater in order to protect the integrity of the environment (Environmental Protection Act, 1996). Should limits be exceeded over time, there may be social, economic, and environmental implications. Four of the eleven tested parameters (pH, temperature, turbidity and chlorine) did not show any statistically significant difference when compared to the researcher's results and the specified disposal limit (one-way ANOVA $F=0.727$, $p=0.736$; $F=1.284$, $p=0.162$; $F=1.557$, $p=0.097$; and $F=0.292$, $p=0.993$). Therefore, these parameters were generally in keeping with the discharge regulations for the 2015 to 2016 period. The optimal range of water pH for most of the aquatic species is from 6.5 to 8.5 (Guyana National Bureau of Standards [GNBS], 2015). According to the Waste Water Treatment Plant Supervisor, the pH level of the wastewater is one of the more important parameters since a deviation in optimal pH can result in a chain reaction of biological and chemical changes and has a direct influence on wastewater treatability, regardless of whether the treatment is physical, chemical, or biological (Coca Cola Company, 2010). The maximum acceptable concentration of iron in water for discharging as waste is 1.0 mg/l (Coca Cola Company, 2010). It was found that wastewater from beverage industries was not a significant source of iron that may impact the environment. According to the Coca Cola Company (2010), DO concentrations within >4.0-8.0 mg/l is fair for aquatic environments. The mean DO concentrations in each sample (4.5mg/L, 4.0mg/L and 4.2mg/L) indicated that a fair concentration of oxygen was dissolved in the water at the moment of discharge. The GNBS (2015) stated that COD of any trade effluent to be discharged into watercourses should not be

[1] Completion dates for five of the nine activities under observation for the closed loop CIP system had passed at the time of analysis.

greater than 100 mg/l. Two of the three mean COD values (93mg/L, 99mg/L and 110mg/L) were below that local standard. However, all were well above the standard set by the EPA (Table 5).

Subsequently, six of eleven water quality parameters that were tested were statistically different when compared to the authoritative body's specification and researchers' results, representing a wide variation in results. A statistically significant difference can indicate that the variation is so great that a 95% level of accuracy is not achieved, creating a refutable scenario. However, the local and KORE bodies have different ranges of disposal for the wastewater parameters. The mean values of four of the eleven parameters (pH, temperature, chlorine and turbidity) were above the local standards, while two parameters (temperature and chlorine) were above the standards set by KORE (Table 5). No standard was set for nitrogen by the EPA, or for COD by KORE.

According to the plant supervisor, heavy metal contamination is unlikely to occur in the production phase because of the closed loop system used by the bottling plant which uses 'online' automatic verifications. Kaztel (1994) listed leached wastewater with high heavy metal concentrations into surrounding freshwater bodies as one of the most destructive industrial biological threat. The soft drink plant sends samples to Puerto Rico annually to test for the presence of heavy metals, and no other heavy metal was detected other than aluminium. Lowering the environmental impact has created scope for revenue-generating ventures such as a fish harvesting facility on the waste water treatment plant, demonstrating the ability of aquatic organisms to survive and flourish in the wastewater.

5. Conclusion

The success of the WMP was largely dependent on the timely implementation of the stated activities. The plan received an overall success rate of 74.42% when assessed based on the activities completed at the time of analysis. One major activity to be completed is measuring the overall water use of the plant as a result of the 'Closed Looped System' installed at the time the research was conducted. The Closed Loop System does not allow for the measurement of water for auxiliary processes that are not directly a part of the loop. Installation of water metres at strategic points will be useful in completing this activity. Improvements are likely should the soft drink plant focus on the measures garnering low levels of success, since soft drink facilities worldwide have successfully implemented such targeted measures and underlying activities and reduced water usage, for instance. However, adequate human and machinery resources are vital to attaining success. Although there were parameters above the local and international standards, it was evident that this was not detrimental to aquatic life as a fish harvesting facility was developed at the waste water treatment plant. Thus, the soft drink plant should continue to improve on adhering to the standards set for the effluent discharged by both the local and international bodies to reap the associated social, economic and environmental benefits.

Conflicts of Interest

The authors declare no conflict of interest.

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