Water quantity auditing of a Ghanaian beverage plant

Emmanuel Okoh Agyemang, Esi Awuah, Lawrence Darkwah, Richard Arthur and Gabriel Osei

ABSTRACT

The study aimed at conducting a water quantity audit in a Ghanaian beverage plant. Primary data on the daily volumes of input water from the main reservoirs of the plant, daily volumes of beverage produced and the water consumed at the 8 metered stages of the plant out of a total of 12 stages were recorded over a period of four months. Secondary data on the plant's monthly water consumption was obtained from Ghana Water Company Limited billing records for the period January 2005 to December 2009. The study revealed that, the average monthly water consumption was 9,825 m^3 with a standard deviation of (±1,399) in the past five years (2005–2009). Stages with high water usage in the plant were the Syrup and Beverage Preparation stage (55%) and the Bottle Washer Equipment stage (34%). Furthermore, the plant's specific water consumption determined was 3.5 : 1 which is better than the company's target of 4 : 1. This indicates that the plant's current water use efficiency is good and therefore encouraging.

Key words | beverage, environment, resource, specific water consumption, stages

Emmanuel Okoh Agyemang (corresponding author)
Richard Arthur
Department of Energy Systems Engineering,
Koforidua Polytechnic,
P.O. Box KF981, Koforidua,
Ghana
E-mail: *doc.okohmet@yahoo.com*

Esi Awuah
Department of Civil Engineering,
KNUST, PMB, Kumasi,
Ghana

Lawrence Darkwah
Department of Chemical Engineering,
KNUST, PMB, Kumasi,
Ghana

Gabriel Osei
Department of Mechanical Engineering,
Koforidua Polytechnic,
P. O. Box KF 981, Koforidua,
Ghana

INTRODUCTION

Water is vital for survival, health and dignity and is a fundamental resource for human development (Rangwala *et al.* 2007). It is a cross-cutting element in the Growth and Poverty Reduction Strategy (GPRS II) of the Republic of Ghana and is linked to all eight Millennium Development Goals (MDGs) (Ghana National Water Policy Document 2007). Most of the world's freshwater resources have been explored, yet many people lack access to adequate water supply for their basic needs (Odoyo 1998). Growth in population, increased economic activity and improved standard of living has led to increased competition for the limited freshwater resources.

The increasing cost of supply, scarcity of an untapped source of surface water, limitation of groundwater because it's a finite resource and due to the possibility of its contamination, as well as the growing concern on environmental issues in relation to waste water released into the environment, lead many countries and water utilities to explore alternatives such as water conservation and water use efficiency, to manage municipal water systems (Odoyo 1998). With the increasing demand on the limited freshwater resources, water conservation and efficiency improvement methods need to be assessed as long-term measures and consequently implemented to reduce municipal water use (Andren 2004).

Although most industries have made significant improvements in reducing their operational and process consumption of water of which the brewery and beverage industries are no exception, an opportunity still exists to engage beyond the fence line and work with respective supply chains to improve water use efficiency in order to reduce the total cost of production, maximise profits and consequently mitigate the risk of disruption to businesses (Agyemang 2010). The company under study is a large beverage producer which uses water as the main ingredient in all of its products and therefore water use efficiency represents one of the major requirements for the success of the business.

doi: 10.2166/washdev.2013.030

The beverage industry uses nearly 40% of the potable water produced for the metropolis where it is located. The industry records high costs of production with regard to the quantity of water used for production, which amounts to about 15% of the annual cost of production. The annual production reports indicates that there is a substantial water wastage at three out of the eight metered stages of the production- syrup and beverage preparation, bottle washing, and CO_2 production. To improve upon the efficiency of water usage on the plant, this study was carried out to identify factors that affect the specific water consumption. Further, the study was carried out to quantify the water consumption at the metered stages of the plant.

METHODOLOGY

Four meters that record the input water to all 12 stages of the plant were identified. Eight out of the 12 stages were metered while the other four stages could not be metered due to logistical reasons. The metered stages include the Bottle Washer Equipment, Boiler House, Production Floor Area one, Fleet Maintenance Yard, Syrup and Beverage Preparation Units, Workshop and Bath House, Carbon Dioxide Plant and the Canteen. The unmetered stages include the Laboratory, the Production Floor Area two, Lubricating Water and the Administration and Sales Office. Input water to all the stages of the plant and water used at the eight metered stages were recorded each day at 0600 h from 1 August – 30 November 2009. Also the beverage produced within that same period was also recorded against each day. Furthermore, data on the monthly water consumption for the period between January 2005 and December 2009 were collected from Ghana Water Company Limited billings and tabulated.

RESULTS AND DISCUSSION

Water consumption pattern for the period 2005–2009

The results in Figure 1 depict similar trends of monthly water consumption for the period 2005–2009. Even though 2005 was expected to register the highest average yearly water consumption for the study period, the case was not so. This was attributed to the low demands and production of beverage arising from frequent cuts of water supply from the Barekese Water Treatment Plant due to an expansion exercise, frequent power outages and the high cost of production in that year. The highest yearly

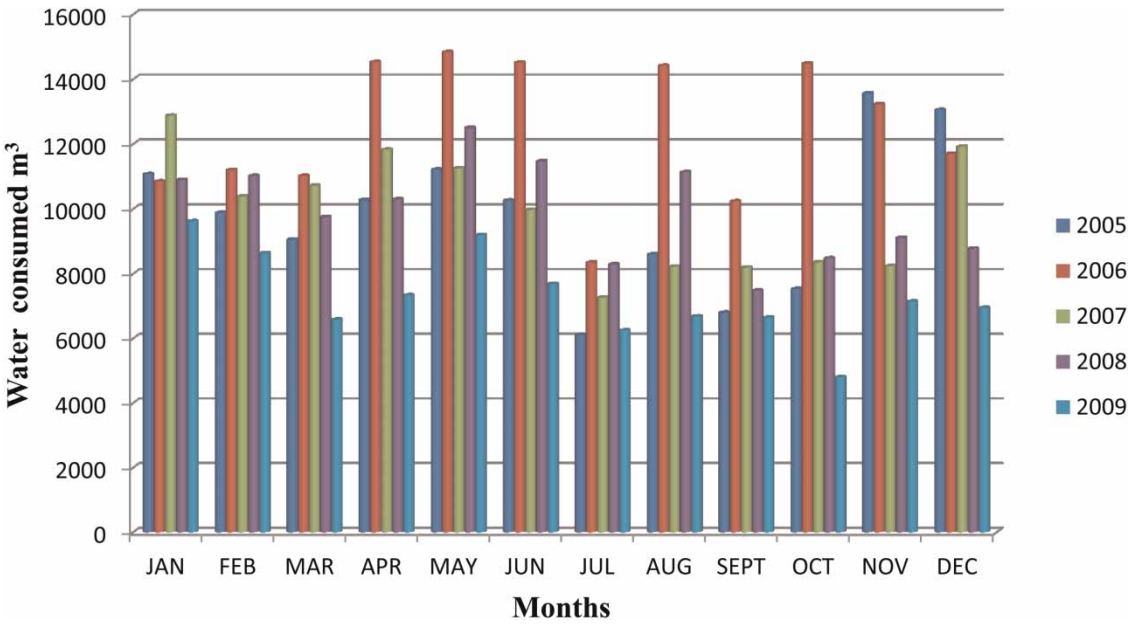

Figure 1 | Monthly water consumption pattern for the period 2005–2009.

average water consumption for the study occurred in 2006 followed by 2007 and 2008 in that order with the lowest yearly average water consumption registered in 2009. The decreasing trends in water consumption for the period from 2006 to 2009 were consistent with a corresponding decrease in beverage produced in those years. This trend could be due to a decrease in the demand for beverage produced from the plant resulting from competition from similar beverage products on the market.

Figure 2 is a plot of the average water consumption for the various months of the years 2005–2009. Evidently from the month of January, the water consumption of the plant declines until March where it eventually increases from April to May. From the month of May water consumption declines once again registering the lowest monthly water consumption in the month of July. From the month of September water consumption increases once again. The maximum, minimum and average monthly consumption established for the plant is 11,801, 7,251 and 9,825 m^3 registering a standard deviation of (±1,399). The variation from the average water consumption could be attributed to several factors such as special events including Christmas, New Year and Easter celebrations, naming ceremonies, weddings, workshops, seminars and conferences where people are mostly served with beverages. Frequent shut down of process equipment due to minor and major maintenance work in the plant as well as sudden cut-offs in water supply to the plant from Barekese Water Treatment Plant, resulting from factors such as frequent power outages, expansion of water treatment facilities and sudden breakdown of various treatment units at several periods of the year, were identified as factors that could explain the variation in water consumption. Also pertinent, among other factors that explain the variation, is the fact that in Ghana where temperatures are relatively higher (30 °C to 42 °C) during the harmattan period people tend to take in more beverage products to quench their thirst. The large standard deviation confirms the large range of variation in water consumption at different periods of the year from the average monthly consumption as explained.

Water usage at the metered stages of the plant

In Figure 3, the highest average water consumption for all the months was registered at the Syrup and Beverage Preparation Units (55.47%), followed by the Bottle Washer Equipment (33.96%), Production Floor cleaning (1.59%), Fleet Maintenance Yard (0.21%), Boiler House (3.40%), Workshop and Bath House (0.77%), Carbon Dioxide Plant (3.78%) and finally the Canteen (0.81%).

Generally the water consumption pattern at the various stages of the plant showed similar trends for each of the month (August, September, October and November) under study. Figure 4 is a plot of the water consumption for the months of August, September, October and November under study.

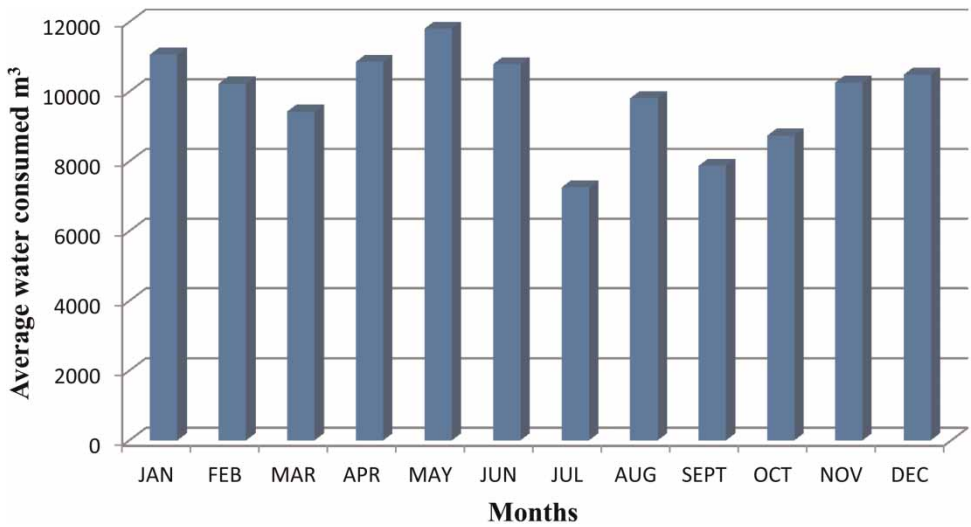

Figure 2 | Average monthly water consumption for the five year period.

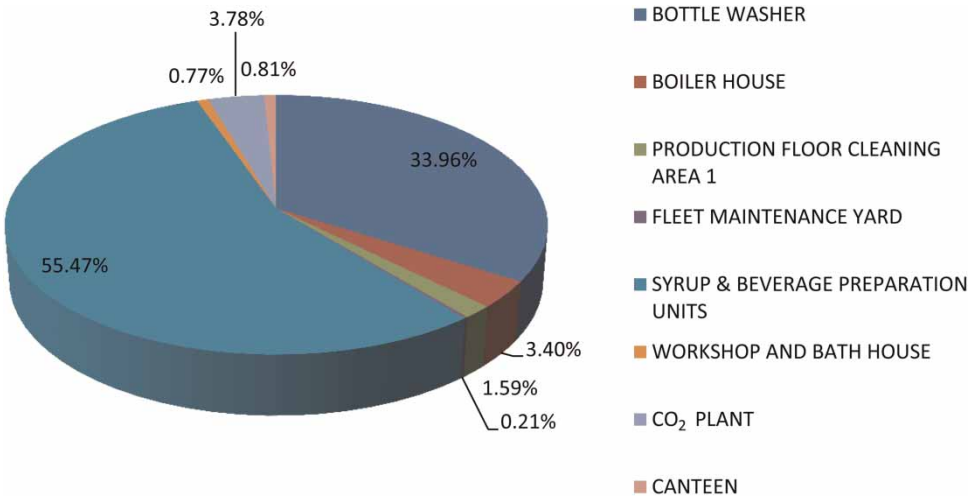

Figure 3 | Average water use at the metered stages of the plant for August, September, October and November.

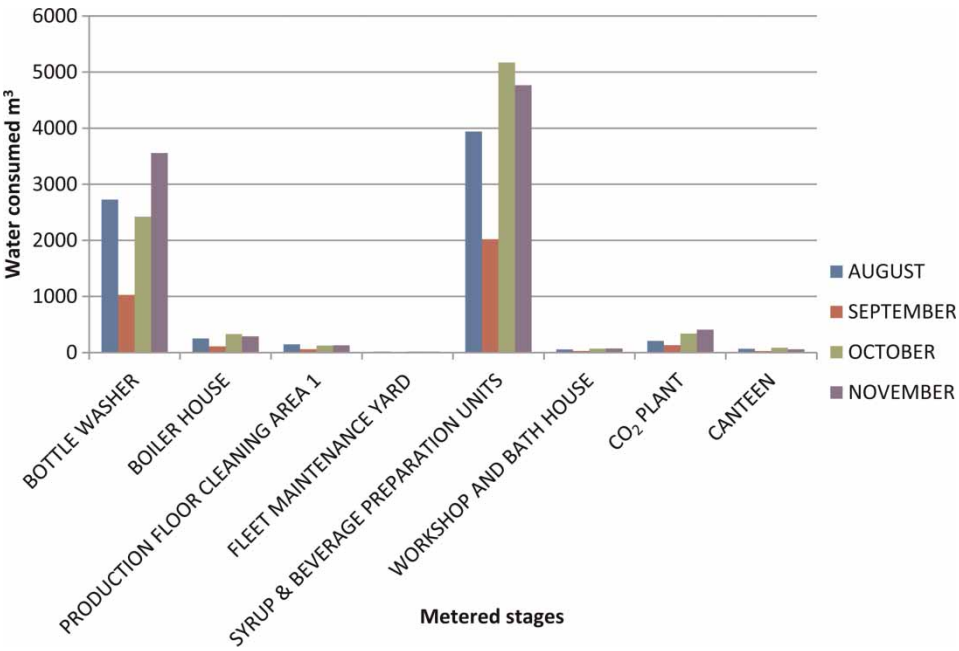

Figure 4 | Water use at the metered stages of the plant.

The variations in water consumption at the metered stages of the plant could be attributed to the differing water requirements for specific activities of the plant. The most water-intensive requirement stages identified were the Syrup and Beverage Preparation Units and the Bottle Washer Equipment. The high consumption of water in these areas may be due to the simple reason that the syrup and beverage preparation stage as well as the bottle washing stage requires more water during the beverage manufacturing process. Again judging from the plot of water consumption against the period under study for the various stages above, it was quite evident that water consumption kept on increasing from the month of August to the month of November. The gradual increase could be attributed to the fact that from the month of August to September the plant gradually enters its peak season due to Christmas and the New Year Celebration,

characterised by family gathering and merrymaking, and therefore experiences high market demand of its products.

Determination of the specific water consumption

The specific water consumption of a beverage plant is a ratio of the total volume of water consumed in the plant to the total volume of beverage produced during that same period. Specific water consumption is a measure of the water use efficiency of a plant compared to a set standard.

The plant under study like other conventional Africa Beverage Plants has a specific water consumption standard of (4 : 1) which is explained as for each 4 litres of water consumed, 1 litre of beverage must be produced. Figure 5 is a plot of specific water consumption against the 12-week period under study.

During the period of the study, the maximum, minimum and mean specific water consumption recorded was 3.8, 3.4 and 3.5 respectively with a standard deviation of (±0.1). The specific water consumption measured in the first week was 3.8 and then it dropped gradually from 3.7 to 3.4 between the second to the fourth week. From the fifth to the seventh week, the specific water consumption rose from 3.4 to 3.6 and then dropped again during the eighth and ninth week remaining fairly constant to the twelfth week.

The variation in the specific water consumption pattern during the period could be attributed to factors such as personnel water use minimisation explained as plant's personnel commitment to saving water and involves using specific requirements of water for specific duties, in order to ensure efficient practices and conditions of process equipments and pipelines. Registering a mean of 3.5 against the 4 as set by the plant, it was quite obvious that the plant is operating within its set standard. Even though the plant is within its water use efficiency standard, opportunities exist to reduce the current specific water consumption figure or maintain it. This, when achieved, could consequently result in a reduction in the total cost of production and thereby increase the profit margin of the plant's business.

If the plant operates above its set specific water consumption standard of 4 : 1, this would result in an increase in the total cost of producing beverage, a reduction in the plant's total profit margin, and consequently lead to increased energy and wastewater treatment costs. In order for the plant to establish a foundation for launching continuous improvement in water use, achieve sustainable water use minimisation practices and to reduce the total volume of wastewater generated, water use efficiency and conservation strategies must be adopted and comprehensively implemented. The following factors could be considered: personnel water use minimisation practices, conditions of process equipments, conditions of pipelines and valves and retrofitting.

Personnel water use minimisation practices

One key factor contributing to the success of a water use minimisation programme includes the creation of awareness among employees about the importance of water

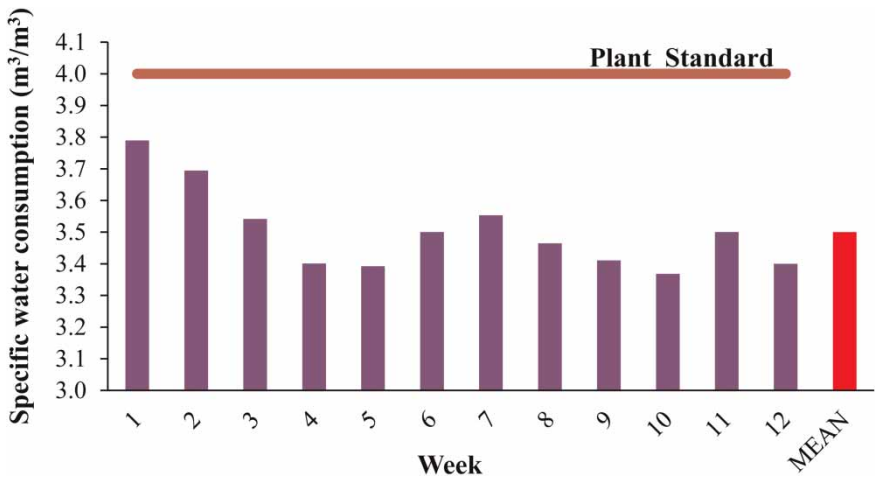

Figure 5 | Weekly specific water consumption computation.

conservation and water use efficiency and the commitment by employees to saving water. A number of published works on waste minimisation in industries emphasise the importance of personnel participation in waste minimisation programmes (Puplampu & Siebel 2005). They reason that unless companies establish a work environment where employees are actively participating by submitting and helping implement ideas that improve business, the company has not fully established a foundation for launching a continuous improvement programme.

Because employees are the most knowledgeable about the various processes, they should be encouraged to take part in proposing new ways of minimising water use in the plant. In this case capacity building can be achieved through training programmes organised periodically by the utility sections of the plant. This can be done through the use of announcements, interviews, group discussion, one-to-one chat, water seminars, and putting up of notices and reminders at vantage points in the plant.

Condition of process equipment

Apart from the fact that personnel water use minimisation practices can cause a significant decrease in the volume of water consumed, the condition of process equipment must also be considered. If process equipment, such as water vessels, bottle washer equipment, etc. are kept in good condition and are not left to develop leakages, this water conservation mechanism can be a cost effective strategy. Minor and major leakages as well as faulty equipment should be reported immediately and repaired. Routine maintenance for process equipment must be carried out at appropriate intervals in accordance with the maintenance schedule. It is only if process equipment is maintained properly that water conservation through leakage prevention can be achieved.

Conditions of pipelines and valves

The importance of the conditions of pipelines and valves cannot be overemphasised. It is important that all pipelines and valves used in the plant are not buried but are made visible so that leaks can be detected and rectified more easily. Routine maintenance of pipelines and valves should be carried out so as to repair leakages and broken pipes. Any leaking valves should be repaired as soon as possible. Wherever possible, dry clean up practices such as wiping or sweeping are to be used either in place of or prior to wet clean up.

Retrofitting

Retrofitting is very necessary in order to conserve water in the plant. It was noticed that the bath house of the plant is fitted with high volume low pressure shower heads. This situation has resulted in a high volume of water gushing out when the showers are opened consequently leading to wasting water. Again in the workshop a tap was found leaking for close to a week until it was changed. It is therefore imperative that faulty equipment, pipelines and valves are attended to as soon as possible in order to conserve water.

CONCLUSION AND RECOMMENDATION

The study revealed that the maximum, minimum and average monthly water consumption for the beverage plant was 11,801, 7,251 and 9,825 m^3 with a standard deviation of ($\pm$1,399). Stages with high water usage were the Syrup and Beverage Preparation stage (55.48%) and the Bottle Washer Equipment stage (33.95%). The specific water consumption of the plant determined was 3.5 : 1 which is better than the plant's standard of 4 : 1 and therefore encouraging. In order for the plant to fully establish a foundation for launching a continuous improvement programme of water use, plant personnel must be committed to saving water. Furthermore process equipments, pipelines and valves should be kept in good condition in order to conserve water.

REFERENCES

Agyemang, E. O. 2010 *Water Auditing of a Ghanaian Beverage Plant*. MSc. Thesis, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana.

Andren, S. 2004 An integrated perspective on sustainable production and consumption. In: *Municipal Water Planning and Management Implications: A case of Thika Municipality in Kenya*. Njagi Felix Mwiathi. Moi University, Department of Environmental Monitoring, Planning and Management, Eldoret, Kenya.

Ghana National Water Policy Document 2007 Government of Ghana and Ministry of Water Resources, Works and Housing. http://docs.watsan.net/Downloaded_Files/PDF/Ghana-2007-National.pdf pp. 1–2 (accessed, August 2009).

Odoyo, J. O. 1998 Sewage Reuse for Irrigation at Athi River Town; Its Implication On Public Health. M.Phil Thesis, Moi University.

Puplampu, E. & Siebel, M. 2005 Minimization of water use in a Ghanaian brewery: Effects of personnel practices. *Journal of Cleaner Production* **13**, 1139–1143.

Rangwala, S. C., Rangwala, K. S. & Rangwala, P. S. 2007 *Water Supply and Sanitary Engineering, Environmental Engineering*. 22nd edition, Charotar Publishing House, Annad, Gujarat, India, pp. 1–3.

First received 27 February 2012; accepted in revised form 22 May 2012