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Water Audit of Breweries: A Case Study of a Modern Brewery in Ghana

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Abstract:

A modern brewery code named brewery X has been in operation for over four decades in Ghana, producing beer and other drinks in bottles. During this period freshwater consumption, wastewater flows and pollution loads have increased significantly with increasing production, resulting in permissible discharge limit concerns. Considerable volumes of wastewater high in biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved solids (DS) as well as suspended solids (SS) are produced as a result of washing the vessels and equipment used for brewery X' batch operations. A three phase approach involving a pre-audit, an audit and a post audit stage was employed in the study. Samples collected from brewery X' effluent discharge point was subjected to laboratory analysis using standard methods to ascertain the exact concentrations of effluent parameters after which graphPad Prism 5 was used to analyze the data. Means for the main pollution indicators showed significant differences (P<0.005) in comparison with the EPA's permissible discharge limits for food and beverage processing companies. Total fresh water consumed and wastewater generated amounted to 532,693m^3 and 449,835m^3 respectively with water to beer ratio of 7hl/1hl. There is great variability in the nature of the effluent from brewery X and would need equalization to abate the pollution of water bodies.

Keywords: audit team, classification, water audit, water consumption, wastewater

1.0 Introduction:

Previously corporate entities focused their auditing only on their economic operations (Rajapakse and Abeygunasekera, 2006). There is however a shift from this position as the business community has embraced the concept of environmental auditing (Basamalah and Jermias, 2005). Environmental audit investigates material usage and also gives feedback to management for corrective steps to be taken (Chaudhury, 2002). Studies in environmental reporting have grown significantly in the last two decades due to the premium organizations now place on environmental issues (Fekrat *et al.*, 1996; Halme and Huse, 1997; Wilmhurst and Frost, 2000; Welford and Strachan, 2005). Presently, numerous organizations produce environmental reports as part of their conventional financial statements and reports in conformance with regulatory standards which management is obliged to met (Basamalah and Jermias, 2005); to attract investment funds and to comply with borrowing requirements as well as meeting community expectations (Deegan and Blomquist, 2006).

A study by Flejszaman (2009) on the benefits of environmental management systems in Polish companies reported that banks and insurance companies and most potential investors are more willing to cooperate with organizations that have implemented environmental management systems. The same cannot be said of developing countries (Azzone, *et al*., 1996). A study on comparative perspective on certification of environmental management systems by (Peglau, 2005) revealed that, within the last ten years, more than 88,000 organizations worldwide have been certifying their environmental management systems (EMS) to ISO 14001 which requires an independent external auditor as a condition of certification. Generally, disclosure of environmental issues by business entities is mainly non-mandatory (Spence and Gray, 2007). Organizations that report on social and environmental performance do so clearly for

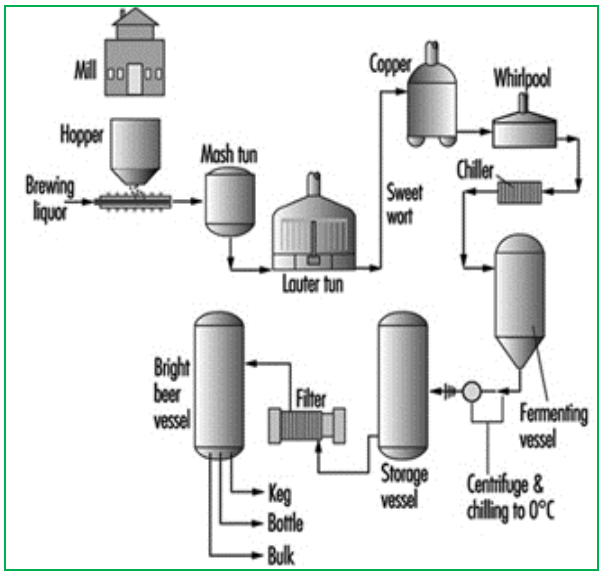
Ethical/Business Performance, Compliance, Investor Confidence, Risk Management and Mitigation and Reputational Enhancement Purposes (Spence and Gray, 2007; Miles *et al*., 2002).

Molson Coors Brewing Company is among the first few breweries that have conducted a comprehensive and voluntary investigation of its pollution and environmental emissions. Coors was encouraged by the Environmental Audit Privilege and Voluntary Disclosure Act which immunizes and credits organizations for conducting environmental self-audits (Carlisle, 2008). After the audit, Coors previously taught to be a minor violator of emissions such as volatile organic compounds was actually emitting 17 times over the estimated value of emissions (Volokh, 2008). Regulating agencies consider environmental auditing as an important management tool due to the fact that it ensures compliance with environmental requirements and related corporate policies (Meikandadaan and Thanksekaran, 2006). This study assessed brewery X' compliance with effluent discharge levels for food and beverage processing companies, ascertained brewery X' programmes that ensures compliance with national environmental laws with reference to water conservation and pollution prevention and also determined the water consumption/wastewater generation.

1.1 Process Description:

The brewing process which involves malting of grain, milling, mashing, wart cooling, fermentation, packaging, and pasteurization consume resources such as water, energy, grist materials, adjuncts and auxiliary materials such as Kieselguhr, bottles, cans, crown corks, glue, enzymes, antioxidants, foam stabilizers, colloidal stabilizers caustic soda and detergents for cleaning bottles and equipment (UNEP, 1995). During the malting process, enzymes are generated, the grain cell walls are broken down and some proteins are hydrolyzed in the germination boxes for a period of between 120-190 hours and air blown through the germinating grain to control temperature and moisture content (BPCE, 1986). The malted barley is ground for enzymes to quickly degrade the starch to sugar on contact with water to be converted into wort (BPCE, 1986; World Bank 1997). The wort is separated from the spent grains by straining through a porous filter in the lauter tun at about 75-78°C and the sweet wort is boiled for about $1^1/_2$ hours to render the enzymes inactive; sterilize and concentrate the wort; and precipitate proteinaceous material. The wort is then hopped and clarified to remove hot trub and other insoluble material (World Bank 1997).

The hopped wort is cooled to about 10°C and yeast added in a fermentation vessel to induce fermentation of sugar wort which is then converted to CO_2, alcohol, heat and new yeast cells. Following the primary fermentation, the produced beer (green beer) is transferred to storage or maturation vessels for a certain period of time and filtration done through a filtration unit coated with filter slurry of Kieselguhr and or lucilite. The resultant product which is a clear or "bright" beer and spent filter slurry is highly polluting (BPCE, 1986). The beer is then filtered in a Kieselguhr (diatomaceous earth) filter followed by a filter cloth. CO_2 concentration in the beer is then adjusted and the beer is transferred to the bright beer tank for packaging into bottles (World Bank 1997).



Source: Eustace *et al.,* 2011

Fig.1: Flow Chart of the Brewing Process

2.0 Materials and Methods

2.1 Study Area:

The study area with a black outline is located between latitude 6°39'3.75"N and longitude 1°36'28.85"W. It occupies a land area of 80,000m^2 of which approximately 65,000m^2 is covered by buildings. The study area falls within the wet semi-equatorial climatic region of Ghana with two rainfall maxima.

Fig.2: Google Earth Image of Brewery X

2.2 Methodology:

The methodology for the study is derived from the cleaner production (CP) manual from the United Nations Environmental Programme (UNEP), titled: Environmental Management in the Brewing Industry.

2.2.1 The Audit Procedure

A three phase approach involving a Pre-Audit, an Audit and Post Audit stages was used. The pre-audit stage of the audit was done to minimize the time spent on the premises of brewery X and also to maximize the productivity of the audit team. During the audit stage**,** environmental records, certificates of compliance and discharge consents were inspected to verify the brewery's compliance with local and national standards/laws. The company's policies, plans and programmes concerning water conservation, wastewater reuse and recycling were also examined to assess the soundness of the brewery's internal control of water usage. Waste water samples were collected into sterilized bottles and transported under dark conditions to a water quality laboratory, for the determination of effluent parameters. The post audit stage involved evaluation and documentation of the audit findings on compliance, water consumption, wastewater generation and programmes for water conservation and surface water pollution abatement.

An audit team involving the environmental manager of brewery X, two of the brewery's production staff, two workers from the brewery's packaging unit, a technician and the researcher was constituted. This was based on two considerations, knowledge and experience in brewery operations and expertise in environmental matters. With the support of senior management a pre-survey questionnaire seeking answers to information on the facility was submitted to the environmental manager after which an in-house meeting was organized to brief the selected staff.

Flow diagrams of brewery X' environmental system and the brewing processes were compiled to educate the audit team on raw materials used in the various units within the brewery and the type of waste generated. Questionnaires were administered to selected staff outside the audit team to be filled in confidence to ascertain the authenticity of the information given by the members of the audit team. Environmental records, certificates of compliance and discharge consents were inspected to verify the brewery's compliance with local and national standards and laws. The company's policies, plans and programmes concerning water conservation, wastewater reuse and recycling were examined to assess the soundness of the brewery's internal control of water usage.

Confidential interviews of selected staff at all levels of operation particularly in the areas of water consumption and wastewater generation were done. A physical inspection of the plant was undertaken to gather relevant information from departmental records, verify the company's own sampling and monitoring procedures and to observe issues of environmental concern. Samples of wastewater were taken and analyzed using standard methods as described in (Eaton *et a*l., 1995) to ascertain the exact concentrations of effluent parameters.

2.3 Analytical quality assurance

For the laboratory analysis of the effluent using spectrophotometer, a control was done together with the experimental. Calibrations using standard solutions were done before any measurement taken. Sample containers were thoroughly cleaned using a detergent, 1:1HCl and rinsed thrice with distilled water and samples respectively (Fatokios and Mathabatha 2001).

3.0 Results and Discussion:

Concentrations of all effluent parameters measured with the exception of nitrate as shown in (Table 1) were significantly higher than the EPA permissible discharge levels for food and beverage processing companies. The mean BOD and COD, concentrations exceeded the EPA permissible value by 36 fold and 11 fold respectively. Mean Nitrate concentration

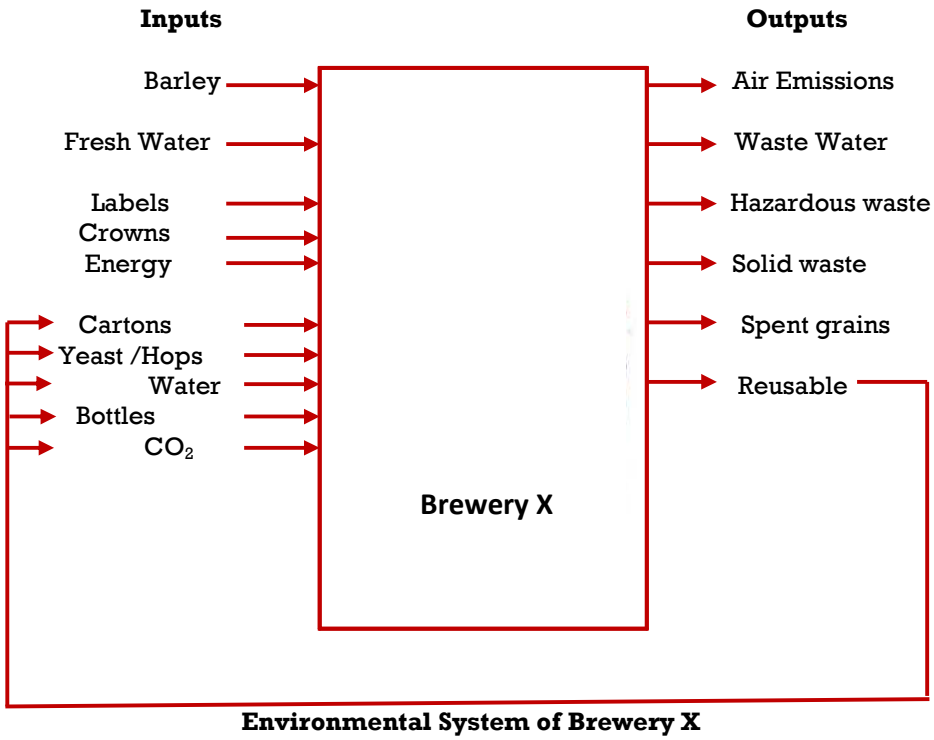
(0.63 mg per liter) was far lower than the EPA figure of 50 mg per liter (Table 1). Total water consumption from water meter readings for the corporate year of the study was 532,693m^3 with a daily average of 1,459.43m^3. Annual and daily wastewater generated amounted to 449,835m^3 and 1,188.40m^3 respectively (Table 2). Seven hectoliters of water was used in the production of one hectoliter of beer at brewery X.

Table 1: Descriptive statistics of effluent parameters with reference to EPA permissible discharge levels

EFFLUENT PARAMETER	EPA STANDARD	OUTCOME	95% CI	P value Summary
TSS	50	129.26 ± 17.68	119.47 - 139.04	***
TDS	1000	1328.38 ± 205.09	1214.81 - 1441.95	***
NITRATE	50	0.63 ± 0.15	0.52 - 0.69	***
OIL & GREASE	5	38.94 ± 14.7	30.70 - 47.17	***
CONDUCTIVITY	1500	2171.84 ± 365.76	1969.29 - 2374.39	***
AMMONIA	1	1.63 ± 0.37	1.42 - 1.84	***
PHOSPHATE	2	3.54 ± 0.79	3.11 - 3.98	***
COD	250	2844.33 ± 606.68	2508.36 - 3180.30	***
BOD	50	1800.72 ± 452.73	1550.00 - 2051.43	***
pH	7.5	9.74 ± 9.40	9.40 - 10.08	***

Table 2: Descriptive statistics of brewery X' water consumption/wastewater generation

COLUMN STATISTICS	WATER CONSUMED	WASTEWATER GENERATED
Minimum	25,493m^3	21,775m^3
Maximum	52,990m^3	48,008m^3
Mean	44,391m^3	37,486m^3
95% CI	39,499-49,283	33,026-41,947
Sum (Annual)	532,693m^3	449,835m^3



Environmental System of Brewery X

Until 2001 brewery X obtained water from three underground wells on site for production and sanitary purposes. Presently brewery X is supplied with water from the Ghana Water Company Limited. The water supplied to the brewery by Ghana Water Company Limited does not undergo any chemical analysis. The supplied water however undergoes further treatment of chlorination and MnO_4 filtration at the premises of brewery X after which it is used for production. Brewery X produces wastewater with high biochemical oxygen demand and suspended solid content. The wastewater generated from brewery X for the corporate year of the study amounted to 76.3% of the total water intake. The effluent contained sugar, wort, trub, spent grains, yeast, green beer and bright beer. Rinse water and residual beer were the main sources of wastewater generated by brewery X. Beer wastes during packaging and washing of aging facilities as well as spent grains, malt and spent yeast were responsible for the high organic load in the waste water from brewery X (Parawira *et al*., 2005; Driessen *et al*., 2003; EEC, 1997).

*The daily and yearly average water consumptions from meter readings were 1,459.43m^3 and 532,693 m^3 respectively. The months of July and March recorded the least and most volumes of 25,493m^3 and 52,990m^3 respectively in terms of water consumption. Water was used as a raw material for the preparation of products and as a washing and cleaning material for equipment and the production area. A complete water balance could not be obtained due to the fact that the brewery lacked meters assigned to various departments to measure specific departmental water consumption. 7hl of water goes into the production of 1hl of beer during beer production at brewery X. This represents water to beer ratio of 7hl/1hl which is in agreement with what was reported by (UNEP, 2007). This ratio is however substantially different from the water/beer ratios of 1hl/2.9hl and 1hl/2.3hl reported for the Abbotsford and Yatala breweries respectively (*www.surepure.net/WEER_Newsletter_201202.pdf*, www.exlporeaustralia.net.au>QLD.Gold Coast & Hinterland).*

Brewery X generated a total of 449,835m^3 of wastewater in the study year with a daily average of 1,188.40m^3. The month of July recorded the least volume of 21,775m^3 and June the highest volume of 48,008 m^3 in terms of wastewater generation (Table 2). The plant recovered 43,376m^3 of the wastewater. Cleaning wastewater from wort separation as well as cleaning water from container washing was re-used. An aqua scan records daily readings of effluent parameters. It was observed that caustic rinses that were discharged to drain formed an integral part of the automatic cleaning-in-place (CIP) system employed for equipment washing by brewery X. The mean daily effluent flow recorded during the study period was 1035.85m^3 /day with the flow patterns for the effluent being extremely variable with a peak flow rate occurring when hot water tank overflow was discharged. Effluent parameters in Brewery X' wastewater showed wide variations and this can be attributed to batch operations by the brewery as reported in articles by (Driessen *et al.*, 2003; SEPA, 1991; UNEP, 1995).

The adjusted arithmetic weighted index for the effluent which was calculated using the table for water quality classification of surface water resulted in a Weighted Solway Water Quality Index (WQI) value of 12.7. This WQI figure of (12.7) categorizes the effluent from brewery X as class IV which corresponds to grossly polluted water (WRC, 2003). The Brewery has initiated a number of programmes to ensure compliance with national environmental laws namely, the Environmental Protection Agency, Act 490 (EPA, 1994) and the Environmental Assessment Regulation LI 1652 (EAR, 1999). The EPA approved an Environmental Management Plan (EMP) in December 2002 and issued an environmental permit for a triennium for implementation by Brewery X towards a greener corporate future.

Brewery X' Effluent Action Plan entails the use of a correct at source (CAS) approach to remove yeast, spent grains kieselgur, excess trub and spent caustic. This has reduced waste generated during brewing and packaging of two products by 5.2% and 1.4% respectively. The separation of Storm water from final effluent through segregation drains has ensured that as storm water flows over the ground, motor oil, industrial chemicals, waste grease, and anything else that might be picked up in its path does not end up in the final effluent to add to the pollution load.
A buffer zone with an oil receptacle has been constructed for the storage of fuel and oil in reservoirs on the premises of brewery X to further ensure oil does not enter the wastewater. Brewery X has had its effluent characterized to serve as the basis for the design of a waste water treatment plant (WWTP) which will have discharge parameters for

full effluent treatment of 250mg/l for COD, 50mg/l for BOD, 50mg/l for Nitrate, 6-9 for pH and 50mg/l for TSS. The effluent from brewery X will thus be fully compliant with discharge levels for food and beverage processing companies as permitted by the EPA after the construction of the WWTP.

A multidisciplinary environmental management committee headed by the environmental manager has been put in place to see to the implementation of brewery X' Environmental Management Plan. Brewery X has a water conservation programme for indoor water usage on the production floor. This includes; recycling of boiler washer and final rinse as well as recycling CIP final rinse. The brewery has conducted a water minimization exercise which has necessitated the installation of additional waters metres. Brewery X has an oil pollution minimisation programme in place which includes regular review of delivery and handling procedures, reviewing recovery and disposal procedures and has installed an oil interceptor.

4.0 Conclusions:

The Physical Plant Structure of brewery X has a good infrastructure to approach efficient water usage and conservation. However with only the production floor having a formal programme for water conservation, 76.3% of fresh water consumed as per meter readings ended up as wastewater.The high standard errors of means obtained for the COD, BOD, TDS, Electrical conductivity, TSS and oil/grease (Table 1) is an indication that there is great variability in the nature of the effluent and would need equalization.

Though all effluent parameters but nitrate exceeded the permissible discharge levels for the release of effluent into surface water, brewery X is mitigating its impact on surface water through the characterization of its wastewater, construction of segregation drains, installation of an oil separator and appointing an environmental manager to deal with all environmental issues.

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