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Life Cycle Assessment and Management of Water Use in Selected Breweries in Nigeria

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Abstract Capacity to promote resource conservation and efficiency must be embraced in all nations of the world**.** Nigerian brewery is one of the fastest growing branches of manufacturing Company and intrinsically water intensive industry in Nigeria. It has five brewing plants. Brewing was one of the first commercial scale food processing industries. The modern brewery can produce a stable product even though raw materials, plant types and the scale of operation are changing. It is time to take our use of water much more seriously.This paper assessed the water use in selected breweries in Oyo and Osun state by using Ibadan brewery and Ilesha brewery as case study. It has been discovered that the water supply in brewery is grossly insufficient for the available demand. The methodology employed for this research work was questionnaires, field study and water audit tool. A combination of purposive and random sampling techniques was used to select those that are relevant to this research work. A holistic approach was developed which would not only move the wastewater from brewery out of sight but would reduce the volume and ensure effective disposal in an environmentally manner. It has been concluded that the efficiency levels of the two breweries can at best be described as medium, with rather wide variations in and between countries and breweries. The two breweries are still far from the accepted international best practice benchmark level of 6.5 hl/hl, let alone the best technology level of 4 hl/hl. Presently, Ibadan brewery is having 10.22 hl of water per beer while Ilesha brewery is having 8.75 hl of water per beer. The two breweries are not meeting up to the standard, but we can say that the efficiency of water use at Ilesha brewery is better than that of Ibadan brewery. The financial implication of water loss can be minimized if the management method is improved for maximum effectiveness and optimal benefit.

Keywords Assessment, Brewery, Effectiveness, Life Cycle, Management

1. Introduction

Water resources engineering is the profession that is responsible for the planning, development and management of water resources. From estimating the amount of water available to designing the physical and non-physical infrastructure needed to meet the water needs of society and the environment. Nigeria is endowed with abundant water resources although its distribution and availability for use varies widely, with quite a number of countries facing water shortage and water stress. Regional and national water figures often conceal the dramatic effects of local water scarcity, limited or polluted supplies and inadequate distribution systems. Access to fresh water has been identified repeatedly as a key condition for development.

The impact of water use on our ecosystems should be an intricate issue of special concern in every area of the world as water is the one resource we cannot live without. Water is our most precious resource. Yet it is currently under attack by our waste, pollution, privatization, and the exacerbation of climate change. We must be aware of this and work to preserve and conserve water for future generations. This will be our legacy to our children (Harlander and Labuza, 2006).

A prospective Life Cycle Assessment (LCA) was carried out to examine the potential environmental impacts of water use in Nigerian brewery. To our knowledge this is the first study to create an LCA model of an integrated water and wastewater system with this degree of complexity and it has started in African countries such as Ethiopia, Ghana, Morocco and Uganda (UNEP, 2006).

It is good to finally see life cycle assessments being done for water use. More water is wasted (and polluted) in industry, yet they are not accountable for the water they use. And even though these assessments are not based on changing factors over time, they at least give a good idea of what is being used, wasted, and how best to conserve water in different regions of the world experiencing different effects regarding that usage due to population, population growth, deforestation, agriculture, and now chiefly, climate change which is precipitating drought and melting glaciers more rapidly which absolutely effects the life cycle of water and all that depend on it (Osho and Dashell, 1997).

Life Cycle Assessment (LCA) is useful as an information tool for the examination of alternative future scenarios for strategic planning. In the design stage of a new brewery, it is useful to study the old unit with respect to the sustainability and effectiveness of different internal part-processes and also to study the history of consumption of auxiliary materials. The Life Cycle Assessment (LCA) method is amenable for such a study. Although additional buildings have been added to the production unit (brewery) of the investigated beer from time-to-time, the physical location has remained constant. The decision for relocating and building a new remote complex has recently been made (Ayatse et al, 2005).

1.1. Aim of the Study

The aim of this paper is to assess the current status and opportunities for reducing water use and wastewater generation in the Nigerian brewery industry through a cleaner production approach and by using the water audit tool. The study also focuses on sector study and framework analysis of water consumption in Nigerian Brewery in Ibadan and international brewery Ilesha.

1.2. Objectives and Scope

This study was undertaken as part of the African Brewery Sector Water Saving Initiative (ABREW). It is a project aiming at assessing the needs and opportunities for reducing water use and wastewater generation from the brewery sector in Africa, by applying the cleaner production approach. A report compiled by a multidisciplinary team drawn from a variety of African and other countries, under the leadership of the United Nations Environment Programme (UNEP). As Nigeria is part of the country in Africa,

The overall objectives of this Life Cycle Assessment study are to:

(a) Minimize the volume of wastewater generated in Nigerian Brewery Industry.
(b) Assess the potential environmental effects of the different stages of the beer life cycle and to also obtain new and updated information for establishing the new facility.
(c) Check the environmental performance at the brewery.
(d) Gain insight into the production of brewery products and assess the source of raw water to selected brewery.
(e) Improve the quality of water use in Nigerian Brewery.
(f) Investigate the methods of storage, collection, transportation and final disposal of water in Nigerian brewery.
(g) Assess the relative effectiveness of the management methods

1.3. Justification of Research

The study will provide data on the sources of water, compositions, generation, rate, handling and storing practices and wastewater generated in within the Nigerian Brewery Industries. This will serve as a valuable tool for uncovering inadequacies and the associated menace and a good basis for setting regulations and policies for water use in brewery industries.Only limited enforcement of legislation and the government lack capacity to monitor trends. There has been a lot of water wastage on daily basis in the production and distribution of brewery products. This problem can be traced to:

- Insufficient water monitoring at plant level
- Environmental control seen as issue of wastewater treatment, not improving production efficiency
- Limited understanding of cleaner production (CP) approach
- Management focuses on expanding output, not reducing production costs
- Management unaware of concomitant costs associated with high water use, e.g. energy costs, higher chemicals use, costs of pumping and treatment
- Study identified key constraint factors associated with Government and brewery industry
- Limited information on national water use comparing industrial with agricultural/ domestic use. Pasteurization uses heated water but mostly this is circulated and thus used repeatedly (UNEP, 2006).

The study will also contribute to the limited number of literature on assessment of water use and management issues in Nigerian Brewery. A typical water losses from pasteurisation processes are shown in plate 1.1.

Plate 1.1. Water losses from the pasteuriser pipe A

Historically, different regions have become famous for their classic beer styles as defined by the waters available for brewing. For example, the famous brewing waters from the deep wells at Burton-on-Trent are known for their excellent qualities in brewing full-flavored pale ales. Burton water is high in permanent hardness because of the high calcium and sulfate content, but it also has a lot of temporary hardness from a high level of bicarbonate. Munich water is poor in sulfates and chloride but contains carbonates, which are not very desirable for pale beers but ideal for producing darker, mellower largers (Olafimihan,2005).

Table 1 gives Water use in breweries of some African countries. African BREwery sector Water savings initiative (ABREW) aimed at assessing the current status and opportunities for reducing water and wastewater generation in African brewery sector through cleaner production approach. Sector study and framework analysis of water consumption in African breweries

Focus on the situation in Ethiopia, Ghana, Morocco and Uganda

Breweries in Ghana, Morocco and Uganda compete for water with other industrial and domestic users. In Ethiopia breweries contend with irrigation for crop farming. Often minimal wastewater treatment affects receiving water bodies and threatening water supplies of other users. Acute shortage of fresh water in urban centres and dependence of nearby rural communities on rivers is already source of conflict and dispute (UNEP, 2013)

2. Water Treatment Plant in Nigeria Brewery Ibadan

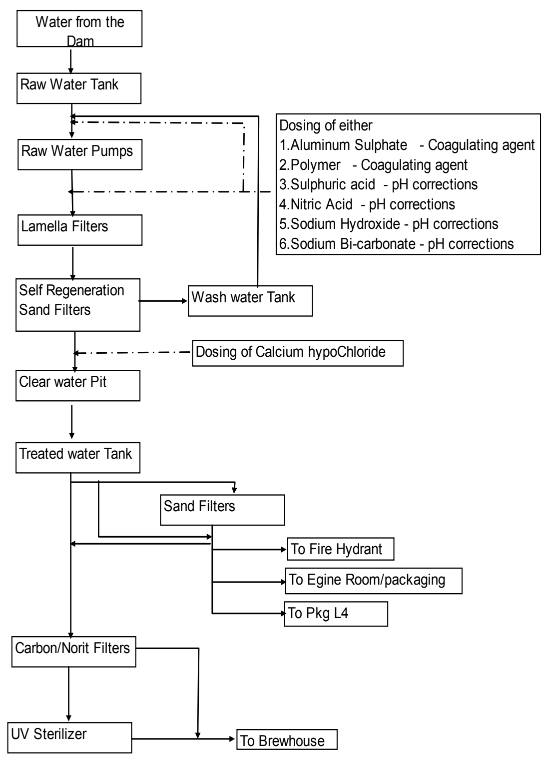
There are three main sources of water to Ibadan Brewery namely:

1. Underground water (Bore hole)
2. Surface Water (River, stream and lake)
3. Public supply

Figure 2.1 indicates the flow process diagram of Ibadan Brewery Water Treatment. Plant The brewery uses surface water more than other sources. The government charges N30.00 on every $1m^3$ of raw water (untreated) pump into the tank.

Table 1. Water use in breweries of some African countries

Country	Total annual production (hl/year)	Total annual water consumption(hl/year)	Specific water use (hl water/hl beer)
Ethiopia (5 companies)	1.5 million	20 million	9.0 – 22.0
Ghana(4 companies)	1.3 million	12 million	7.4 – 9.5
Morocco(1 company)	0.9 million	Not available	Not available
Uganda(2 companies)	1.5 million	12 million	7.2 – 9.0
Total	5.2 million	> 44 million	



Source: Taylor (2006).

Figure 2.1. Flow Process Diagram of Ibadan Brewery Water Treatment Plant

2.1. Raw Water Pump

There are two pumps that pump the water from the raw water tank to the Lamella separator filters. The water from the raw water tank flows by gravity to the pump while the pumps suck and pump into the Lamella separator filters at about 5 bar pressure.

Between the pumps and the Lamella separator filters, again Aluminum sulphate and polymer are dosed to coagulate the flocs and dirt. While Aluminum sulphate coagulates into smaller particles, polymer aid coagulation into bigger particle for easy filtration at the Lamella separator/sand filter. Hydrochloric and Nitric Acid are also dosed for pH correction when it tends towards alkaline, while Sodium Hydroxide and Sodium Bi-carbonate are dosed for pH correction when it tends towards acidic. Plate 2.1 gives the Cross section of the Pumps in the Treatment Plant.

Plate 2.1. Cross section of the Pumps in the Treatment Plant

3. Materials and Methods

3.1. Preliminary Activities

Preliminary activities involved collection and grouping of data and selection of samples.

3.1.1. Collection, grouping and selection of available data

Available data in lbadan and Ilesha breweries were collected. A combination of purposive and random sampling techniques was used to select those that is relevant to this project work.

3.2. Administration of Questionnaire

Questionnaires were administered to each of the selected breweries to collect information on:

(i) Type of brewery and authority responsible
(ii) Name of production plant:
(iii) Typical wastewater generated from each department
(iv) Quantities of wastewater generated per day.
(v) Methods of storage, collection, transportation and final disposal being used in managing the wastes from the brewery
(vi) Authority responsible for wastes management.

3.3. Field Study

A field study was carried out for collection of data in Nigerian breweries Ibadan and Ilesha brewery. This involved using the techniques of oral interview, questionnaires, researchers' observation strategy and physical involvement in each of the production processes especially the water supply, water treatment facilities utilisation and wastewater disposal in Ibadan and Ilesha breweries. The primary facilities and the specialized services were based on the questionnaires and researchers judgement quality.

At Nigerian brewery Ibadan and Ilesha brewery, questionnaires ware supplied to each departments to obtain relevant data.

Results from questionnaires and field study were analysed and quantities of water use and wastewater generated per day in each of these breweries were obtained with reference to production processes. This was used to estimate the quantity of water use and wastewater that will be generated by these industries yearly.

3.4. Assessment of Existing Handling Methods

The existing methods of each elements of handling were assessed and the reports were evaluated. It was during this assessment that photographs were taken and compiled.

From the assessment and evaluation, an option for a safe management of the wastes was developed. The methodology of the assessment is derived from the CP manual from UNEP: Environmental Management in the Brewing Industry (Technical Report No 33). The purpose of CP is to continuously reduce consumption and emissions from production processes, products and services. The preferred CP option is reduction of waste at source. Upgrading a brewery in order to implement CP, requires action in three areas that are interrelated as illustrated below. Action in one area without taking complementary action in the other two areas may greatly reduce its effectiveness.

Critical analysis must be done on engineering, plant, equipment, training, High Consumption Breweries and Low Consumption Breweries.

3.5. Method of Collecting Data

Questionnaire is one vital tool that has been used. Questionnaires were distributed to various staff in Ibadan and Ilesha brewery in order to extract relevant data that will enhance the life cycle assessment of water use in Nigerian breweries. Some of the questions are in the appendix A

High Consumption Breweries can immediately achieve substantial reduction by addressing management issues and small changes in ancillary operations and process systems. Low Consumption Breweries need to begin focusing on all three functional groups in detail.

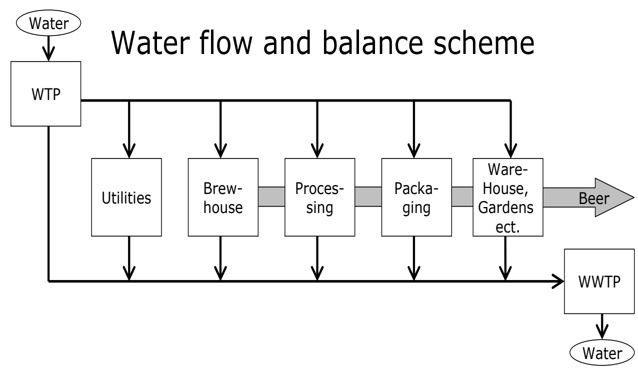
Preliminary activities involved collection and grouping of data and selection of samples will be done after site visitation and the process of a CP-assessment as described in Technical Report No 333 will also be used. Normally the process would be initiated by the brewery, but in this situation the process is initiated by UNEP with a reduced objective compared to normal CP.

The Water Audit Tool for Breweries will also be used. This tool supports the water assessment of a brewery by preparing water balances for the relevant functions and calculating theoretical potentials for savings. It is the software made from Microsoft Excel with column for Input, Model and Output data.

3.6. Guides for Water Audit Tool

The purpose of the Water Audit Tool is to provide a guide line for the water balances in each part of the process. This requires a process overview, measurements for the relevant parameters and benchmarks. With this information potential water saving can be calculated for each part of the process in order to focus the effort to save water. But the tool also intends to support the decision process of implementing water saving initiatives by calculating the value of the water saving.

The brewing process is described generically in the Technical Report. The generic process also includes other inputs than water and it includes the malting process. For the purpose of an Audit with focus on water usage, +B107 the holistic process from Technical Report needs to be simplified. This is illustrated below in the schematic layout of a brewery. A further simplification of the water flow is illustrated in figure 3.1 and is the platform of the Water Audit Tool, which is used in the water CP-assessment of the brewery.



Source: Norton (2005).

Figure 3.1. Water flow and Balances Scheme

For each of the functions in the process a water balance can be made that defines

1. Input of water
2. Output of beer
3. Output of beer loss
4. Output of waste water
5. Quality of waste water (kg. COD/HL) (only total)

The actual readings can be compared to benchmarks and potential saving can be calculated as the difference between the actual and the benchmark. The focus area of the in-plant assessment\should be where the largest potential saving exists.

In order to motivate a water saving effort the water savings are theoretically converted into amounts. This is done I two perspectives; the input / output perspective and the Beer loss perspective.

The input/output perspective is base on the assumption that efforts to reduce water consumption at the brewery will also result in saving of other consumptions and of cause in lees output of waste water. A major input to the brewery is energy that is used to circulate the water around and both to cool and to heat the water. The water audit tool calculates the potential saving on energy by a simple extrapolation between the low and high consuming benchmarks. This approach is use on malt and adjunct, energy, fuel and waste water and the price of all these input and output are therefore part of the data collection. It could be argued that workforce should also be included as well as the cost of the equipment, but the aim is to keep the model as simple as possible and secondly to stay in line with the input/output definitions of the UN Technical Report No 33.

The beer loss perspective is relevant in the sense that beer loss is also loss of water and that the Value of beer is quite high since it's the product of all the inputs to the process.

Both the perspectives are based on the assumption that a reduction in water usages will result in reductions according to benchmarks in other fields of the process. This is a very rough assumption, but experience with Lean manufacturing shows that such rough simplifications work. Lean manufacturing is also based on an assumption of that focusing on waste and continuous improvement will reduce cost.

Secondly the model can be used for ongoing monitoring of water consumption and discharge at a brewery in order to support continuous improvement.

The main menu of the model is the Gateway sheet, from where all the sheets of the model can be accessed quickly and easily. Furthermore, the Gateway sheet provides a simple overview of the model in terms of how the model works, and if all required input data has been entered.

The main input sheet of the model is the Readings sheet, where the volumes of water can be entered month by month. In order to compare actual with the targets for the brewery there is an input sheet for the targets. The value of the savings is calculated from the unit prices that can be inputted in the Unit Price sheet. In order to have the right information on prints, information about the company should be entered in the Input Sheet.

In the model section there are 3 sheets. The calculation and principles of the model are illustrated in the Water Flow sheet. The Time Series Sheet has the same calculations but in a format that is usable for the charts in the output section. The Benchmark sheet is where the Benchmarking numbers are pre-entered.

The output section contains a benchmarking report that compares the actual with the values from low consumption breweries. The report also calculates potential savings in volumes as well as values. The Follow Up report works the same way but with the Target number of the brewery instead of benchmarking numbers. The Graphics sheet contains charts of showing development in water consumption for each function in the brewery in a 2 year timeframe.

The output section is controlled by the two input fields on the Gateway sheet. Here the currency for all Output report can be determined as well as the period that shall be reported. All reports including the water flow can be printed in one operation by using the "Print Outputs and Water Flow" button.

The documentation section contains information about how the model should be used and operated.

Pale blue fields are input fields. Purple fields are calculated fields. Grey fields are summaries or headlines. Description of the sheets

The sheets in the model are structured in four groups: Input, Model, Output and Documentation. The Input sheets provide data for the Model sheets that provide data for the Output sheets. Appendix II indicates guide for water audit tool and figure 3.2 shows the water beer ratio for various uses.

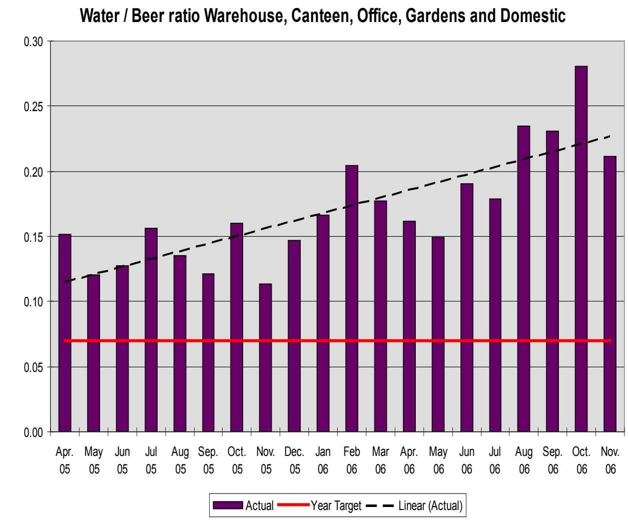


Figure 3.2. Water/ Beer ratio for various uses in Ibadan and Ilesha Brewery

4. Data Analysis and Results

In the two breweries used as case study, the life cycle assessment of water use conducted indicates that there is need for improvement of water supply and wastewater treatment.

4.1. Water Use In Ibadan and Ilesha Brewery

In the two breweries used as case study, the life cycle assessment of water use conducted indicates that there is need for improvement of water supply and wastewater treatment.

To facilitate the data collection procedure, this study brings to greater prominence the situation of the African brewing industry with respect to water use. The cleaner production approach is known to dramatically reduce resource consumption while at the same time increase process efficiency. Improved efficiency also has positive financial implications as it means less money wasted on valuable resources released to the environment. These simple and seemingly obvious facts raise the key question of why this is not occurring automatically in the industry without the stimulus of outside intervention. Cleaner production has the potential to make a major contribution to reducing water consumption in African breweries.

4.2. Evaluation of Effectiveness of Existing Water Use

Plate 4.1. Gauge Meter for the Water Treatment Plant

Plate 4.2. Pasteurizers and Water Treatment Plant

Plate 4.3. Cylindrical Container and Meter for the Treatment Plan

The existing water used for the two breweries were assessed and the reports were evaluated. It was during this assessment that photographs were taken and compiled. Adequate data were obtained to allow for more detailed decision-making at all levels to solve the problem that can influence water use. Hydraulic machinery such as pumps and turbines, hydraulic controls such as valves are necessary for effective distribution of water and to prevent water losses. These are indicated in plate 4.1, 4.2 and 4.3.

Table 4.1. Statistical Data on Efficiency of water use in Ilesha Brewery

Week	Filler efficiency %	Overall efficiency %	total stops %
1	52.3	36.5	30.0
2	53.1	40.0	24.4
3	54.5	41.9	23.2
4	47.6	29.8	37.3
5	41.6	20.8	40.5
6	53.7	34.0	36.7
7	48.7	38.1	21.7
8	47.3	33.9	28.6
9	47.6	32.6	31.6
10	40.9	29.5	27.8
11	42.0	26.7	36.5
12	47.8	32.5	32.0
13	41.1	32.9	19.9
14	35.5	15.1	48.6
15	27.8	16.1	32.0
16	32.0	24.0	24.9
17	28.8	14.8	35.3
18	32.0	17.1	46.7
19	37.2	24.4	34.3
20	39.3	28.4	27.7
21	40.7	29.2	28.2
22	38.3	27.6	27.9
23	43.7	27.9	36.3
24	42.5	26.4	38.0
25	43.4	31.3	27.9
26	47.0	29.8	36.6
27	39.4	34.7	12.1
28	39.2	29.81	24.1
29	40.32	30.3	25.0
30	31.02	23.9	23.0
31	34..40	26.25	23.7
32	43.69	27.0	38.25
33	41.95	27.64	34.1
34	40.7	31.9	21.7
35	45.11	33.1	26.6

Source: Field Study (2010)

Table 4.5. Weekly Production and Stock Report in the Brewery

		Brewery 1	
	Actual	Target	Difference
		2006	
	762,220	762,220	-
Utilities	552,445	266,777	285,668
Brewhouse	2,360,826	1,333,885	1,026,941
Beer Processing	626,861	1,547,306	-920,446
Packaging	2,343,332	2,134,216	209,117
Warehouse ect.	146,425	53,355	93,069
	6,029,888	5,335,539	694,350
Wastewater in HL	4,926,354	2,667,769	2,258,584
COD in Waste water mg/l	1,560	4,286	-2,726
BOD in Waste water mg/l	1,040	2,286	-1,246
Brewhouse	9,909	7,622	2,287
Processing	39,635	19,055	20,580
Packaging	13,720	11,433	2,287
Warehouse	0	381	0
	63,264	38,492	25,153
	Ratio per HL of Beer. 2006		
	Actual	Target	Difference
		2006	
Utilities	0.72	0.35	0.37
Brewhouse	3.10	1.75	1.35
Beer Processing	0.82	2.03	-1.21
Packaging	3.07	2.80	0.27
Warehouse ect.	0.19	0.07	0.12
	7.91	7.00	0.91
Wastewater in HL	6.46	3.50	2.96
COD kg	1.01	1.50	-0.49
BOD kg	0.67	0.80	-0.13
Brewhouse	0.013	0.010	0.003
Processing	0.052	0.025	0.027
Packaging	0.018	0.015	0.003
Warehouse	0.000	0.001	0.000
	0.083	0.051	0.033

Source: Field Study (2010)

At the regional level, there will be business framework for information exchange or technical cooperation. A typical overview of Statistical Data on Efficiency of water use in Ilesha Brewery is presented in Table 4.1 .

Brewery COD emissions are not high due to the effective municipal wastewater treatment plant that treats the brewery's wastewater.

Table 4.6. Annual brewery production in Ibadan Brewery

	star	gulder	Legend big	Legend Small	maltina	amstel	FayrouzAple	Fayrouz Pear
Btls	747182	383332	147595	44391	135747	42038	57203	38829
Can	109749	52555	na	Na	199461	97872	48887	35693

The brewery annual beer production stood at 1,490,863 hl
With off peak period being June to august
oft drink production
The brewery annual soft drink production stood at 655,731 hl
With off peak period being June to august
Line 4 = 30000 btls per hour Big bottles
Line 5 = 28000 btls per hour Big bottles
Line 6 = 36000 cans per hour.
OPI = Line Output X Man time / Nominal speed
Tunnel pasteurizer in use and is use for all brand

Table 4.11. Data on Losses per brand

Quater	Result %	star	gulder	legend	maltina	amstel	FayrouzAple	Fayrouz Pear
1	4.31	2.39	4.48	10.52	3.86	3.99	6.58	4.89
2	5.72	1.85	6.89	11.36	5.65	5.68	7.5	8.81
3	4.10	1.79	9	7.8	1.45	2.44	2.4	4.29
4	3.48	2.23	7.04	5.74	2.41	2.40	2.46	2.30
2009	4.44	2.07	6.75	8.5	4.26	3.54	4.5	5.43

Table 4.12. Annual brewery production

	Star	gulder	Legend big	Legend Small	maltina	amstel	FayrouzAple	Fayrouz Pear
Btls	747182	383332	147595	44391	135747	42038	57203	38829
Can	109749	52555	na	Na	199461	97872	48887	35693

Source: Field Study (2010)

Ilesha Brewery used to obtain their raw water from EsaOdo dam and they have all their drainage and liquid wastes discharged to a big reservior and then off via a DN 200 pvc pipe to the nearest ditch.

5. Conclusions

Based on the field study, investigations and physical assessment conducted during this research, the following conclusions have been drawn. A general observation is that despite much previous activity in Africa, cleaner production initiatives do not seem to have flowed naturally to the brewery sector.

The conclusions of this study are likely to apply to Nigeria and most African countries, as improved water management is an important objective across the entire continent. The efficiency levels of Nigerian breweries can at best be described as medium, with rather wide variations in and between countries and breweries. Most breweries are still far from the accepted international best practice benchmark level of 6.5 hl/hl, let alone the best technology level of 4 hl/hl. Therefore there are many opportunities for improving water use efficiency. The study highlights that improvements do not always need large financial investments, and that simple housekeeping and minor plant changes can often produce significant reductions in water use (and effluent volume). Planned increases in beer production will exacerbate this competition with other (growing) water uses. Nevertheless, awareness is still limited among the main partners – company, government, and public – about the need for water savings in breweries, and of the best way of achieving them. Environmental control is still often seen as an issue of wastewater treatment rather than improving production efficiency, even though many studies have shown the latter to be more cost-effective to the company. The concept of reducing waste flows before building treatment facilities has yet to take a firm hold in the mindset of industry managers.

At this moment, the primary driver for reduced water consumption and pollution reduction are the corporate environmental policies of the multinational companies active in the brewing industry, and even then, these policies are not always implemented to their full extent. This, Combined with low environmental enforcement

5.1. Recommendation

Based on the field study, investigations and physical assessment conducted during this research, the following conclusions have been drawn. A general observation is that despite much previous activity in Africa, cleaner production initiatives do not seem to have flowed naturally to the brewery sector.

The conclusions of this study are likely to apply to Nigeria and most African countries, as improved water management is an important objective across the entire continent. The efficiency levels of Nigerian breweries can at best be described as medium, with rather wide variations in and between countries and breweries. Most breweries are still far from the accepted international best practice benchmark level of 6.5 hl/hl, let alone the best technology level of 4 hl/hl. Therefore there are many opportunities for improving water use efficiency. The study highlights that improvements do not always need large financial investments, and that simple housekeeping and minor plant changes can often produce significant reductions in water use (and effluent volume). Planned increases in beer production will exacerbate this competition with other (growing) water uses. Nevertheless, awareness is still limited among the main partners – company, government, and public – about the need for water savings in breweries, and of the best way of achieving them. Environmental control is still often seen as an issue of wastewater treatment rather than improving production efficiency, even though many studies have shown the latter to be more cost effective to the company. The concept of reducing waste flows before building treatment facilities has yet to take a firm hold in the mindset of industry managers. At this moment, the primary driver for reduced water consumption and pollution reduction are the corporate environmental policies of the multinational companies active in the brewing industry, and even then, these policies are not always implemented to their full extent. This, Combined with low environmental enforcement, has resulted in low implementation of cleaner production. There are likely to be concurrent savings in energy and chemical consumption as well.

In view of the aforementioned, it is necessary to give the following recommendations so as to enhance the optimum ways of managing wastewater disposal and water use in Nigerian brewery industries.

1. Research into the subject matter should be funded at all levels since there are no adequate data to define the problem clearly. Government to make better use of financial instruments, e.g. water abstraction and discharge fees.
2. Develop comprehensive follow-up programme to ensure more focussed and prolonged CP outreach to brewery sector and promote public-private partnership on water utilisation in African breweries
3. Increase awareness raising in all stakeholder groups (companies, government, public) on national importance of improved water management in breweries
4. Improved information on water allocation, water use and discharge to allow for effective application of government policy
5. Promote CP as process enhancement tool
6. Introduction of optimal pricing for water extraction and discharge
7. Further work is required to reduce water use in African breweries.
8. Environmental regulation and enforcement of effective legislation

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