Sachet Drinking Water in Cape Coast Metropolis, Ghana: Production, Quality and Equipment Maintenance

Baffour-Awuah, Emmanuel
Mechanical Engineering Department,
Cape Coast Technical University,
P. O. Box AD 50, Cape Coast, Ghana.
emmanuelbaffourawuah37@yahoo.com

Tenkorang, Emmanuel Yamoah
School of Development Studies,
University of Cape Coast, Cape Coast, Ghana.
eytenkorang@ucc.edu.gh

Abstract
The quality of sachet water has become of great importance to stakeholders in order to ensure good health and hygiene to consumers. The purpose of the paper was to review literature on the emergence, production and quality of sachet water, and examine maintenance and repair issues in the industry with particular reference to Cape Coast Metropolis in the Central Region of Ghana. Five Hazard Analysis Critical Control Points (HACCP) were identified. The paper identified equipment inspection as the most practiced maintenance technique by all the organizations, corrective maintenance being the least. The paper recommends industry players to adopt chip packet foils that reflect solar UV radiation into a glass tube to disinfect water without external power source as an innovation instead of conventional UV lamps powered by electricity. The results of the study is limited to the study area and therefore not recommended for generalization.

Keywords: *Corrective maintenance, HACCP system, preventive maintenance, repair, routine maintenance,*

Introduction

Sachet water, the most common form of packaged water in rural and urban communities of developing nations, when properly recognized and improved, would offer great hope in achieving sustainable development (Dada, 2011). According to Dada (2011), improving upon existing processes in developing countries could help achieve this objective, and ene way by which existing processes could be improved is to adopt the Hazard Analysis Critical Control Point (HACCP) system (Cheabu & Ephraim, 2014). Taking cognizance of the emergence of the sachet drinking water industry and marking the control points within production stages, water quality and maintenance processes could be relevant to increasing access to potable water in developing countries.

Sachet water is considered as the latest, low cost technological evolution of vended water (Cheabu & Ephraim 2014); and as a cheap, potable and omnipresent solution for reducing the gap between safe and unhealthy water access within cities in these countries (Little, 2015). The importance of packaged drinking water gained prominence in India in the late nineties when the Bureau of Indian Standards in collaboration with the Health Ministry of India drafted rules and regulations as part of the prevention of Food Adulteration Act to ensure safety in the industry (Dada, 2011). In Nigeria, the government asserted that the introduction of sachet water into the economy was one of the most successful poverty alleviation endeavors that had been attempted since the country gained independence (Dada, 2007). The emergence of sachet water as a cheaper option to bottled water in Ghana was recorded by Okogia (2007). The Ghana government entrusted into the hands of the Ghana Standards Boards (now Ghana Standards Authority) the authority to ensure safety and sanity of sachet drinking water for three reasons. First, sachet drinking water is affordable to the ordinary Ghanaian; second, large portions of the populace rely on sachet drinking water and third, municipals have been unreliable in providing safe drinking water to the populace.

One of the important stages in the sachet water industry is the production stage where water is processed and bagged. Production requires a water sachet filling machine. The source of raw material is municipal water or water from “upgraded wells” usually referred to as borehole water. Other production processes include UV sterilization, polyethylene bag-forming, filling and sealing, among others. Within the industry, and through the supply chain, water quality is of crucial importance to individuals, researchers and governments as a means to reduce health care cost, among others. Various literature have dealt therefore with sachet water quality in Ghana (Little, 2015; Stoler et al., 2012). Ahimah and Ofosu (2012), evaluating the quality of sachet water in the New Juaben Municipality of Ghana concluded that the physico-chemical and bacteriological indicators of sachet water samples comply with drinking water standards of the Ghana Standards Board. In another vein, Wright et al., (2016) observed that packaged drinking water has higher public health benefits than other sources in terms of E. coli contamination.

Various locations where sachet water quality has been evaluated in Ghana include Bolgatanga, Tarkwa, New Juaben, Obuasi, and Cape Coast among others. Stoler et al. (2012) and Stoler (2012) have also discussed extensively, environmental impacts of the sachet water industry in Ghana. Though scholarship in the production of sachet drinking water in Ghana have also been identified (Stoler et al., 2012; Dada 2011), it appears scholarship related to maintenance in the sachet water industry has been unavailable. A pilot study in the Cape Coast municipality appears to suggest public misgivings on water quality in the municipality. Maintenance of equipment is one of the critical points in Hazard Analysis Critical Control Point (HACCP) systems that may contribute to unhealthy and unsafe product. Healthy production equipment and machinery could ensure safe drinking water. In view of the importance of the product to the populace and misgivings in relation to sachet water quality in the Metropolis, there is the need for continual studies related to the product. The objective of this study was to investigate equipment maintenance issues in relation to the production of sachet water in the Metropolis.

Production of sachet drinking water

Omeh (2013) outlines several reasons for investing in the sachet water production industry. With a large profit potential, other reasons include lack of potable water due to government’s inability to provide for every household; increase in population; water being one of the most essential commodities on earth; absence of close substitutes to sachet water as a result of high cost of bottled water and the strong positive correlation between sachet water availability and accessibility on one hand and increase in consumption on the other. Omeh (2013) also attributes investing in the industry to the popularity of sachet water in both towns and villages (across various countries in sub-Saharan Africa); affordability and inexpensiveness; governments’ support to sachet water production since it is a major source of revenue; patronage that cuts across social class and status, being patronized by both rich and poor, young and old, teacher and student, the sick and the strong; and consumption having no religious, political, social or cultural boundaries.

The advantages of sachet water production could also be financial and economical. According to Omeh (2013), the payback period for sachet water business is less than six months, with full assurance that investment would pay. Start-up capital is also relatively small as compared to related businesses with guaranteed returns. In addition to these, marketing the product does not require much advertising and marketing techniques since water as a product has natural automatic market. Furthermore, the product has more than 50% return-on-investment (RDI) with high expansion potential. Last but not the least, water as a free gift of nature, demands little or no periodic acquisition.

Omeh (2013) intimates that ideally, sachet water production begins with acquisition of a structure where the business will be located. Registration of the business and the provision of license for operation should be of necessity. Brand names of the products also need to be registered to avoid piracy. Producers are, out of necessity, usually required to drill a borehole against the intermittency of municipal water supply in order to ensure regular water supply to feed the plant. Overhead tanks are installed to store raw water, whether from municipal or upgraded wells (connected with pumps). Such wells are encased with miniature concrete blocks or concrete culverts to make sure that the raw water is not contaminated with soil particulate matter. The water purification may include carbon, micro filters or cup filters. A distillation system may be included in the carbon, micro filters or cup filters.

The inclusion of a distillation system may be optional and may therefore be included in the installation design. Ultra violet sterilization systems may also be included. These design systems may be introduced depending on start-up capital and the degree of purification that the system is designed to operate. Ideally, all these need to be part of the design if absolute purification, where the product is completely safe for consumption, is expected. In Ghana, operators acquire licenses from the Food and Drugs Authority (FDA) for approval to carry out the business. Operators need to acquire an automatic sealing machine before getting approval from the Food and Drugs Authority (FDA) because before approval is given, the FDA inspects the premises of operation as well as the quality of water to be sold.

Sachet water business operators (small family businesses) employ not more than six persons at commencement of operation with the potential of increasing the number as the business expands (Omeh, 2013). With a good distribution system using either hired or purchased trucka, a power generator to deal with "dumsor" (power outages) and plastic materials for the sachets. An investor could begin producing sachet water. The situation in Nigeria (Omeh, 2013) is similar to other sub-Saharan countries such as Ghana; Tanzania (Kassenga, 2006); and Kenya (Whittington et al., 1989).

The production process of sachet water begins by pumping water from upgraded wells into overhead storage tanks, or storing water from municipal sources (Stoler et al., 2012). Raw water may also be sourced from boreholes. Raw water first passes through a filtration process and or an ultra violet purification system where solid particles as well as bacterial and viral elements, respectively, are eliminated. Machines used may be either new or used ones. Stoler et al. (2012) reports that used machines may have retrofit ultraviolet purifiers while new ones have the feature internally incorporated by manufacturers. The filtration mechanism is bolted to the wall and has a combination of carbon and sand filters as the filtration media to trap solid particles in raw water. The treated water then enters the sachet machine where it fills 500ml volume plastic rolls (sachets), heat-sealed and sliced into sachets. Sachets would drop into open containers, handpicked and hand packed into larger plastic containers each containing 30 units of 500ml sachet water. The bags are stored on wooden pallets, ready to be loaded onto trucks for retailers and wholesalers. Some wholesalers retail directly to consumers. Producers may also retail directly to consumers, particularly households and students in educational institutions. Koyo sachet water machine, made in China, is the most popular brand used in

Ghana and that they may come as either used or brand new and are the most used across West Africa as well (Stoler et al., 2012).

Sachet drinking water quality in Ghana

Review of recent literature on sachet drinking water quality in Ghana shows that research appears to concentrate on quality standards, transmission of diseases and health impacts. This was observed by Stoler et al. (2012) after reviewing over 200 articles and summarizing thirty with 23 from Nigeria, 6 from Ghana and 1 from India. The present study reviewed 12 articles on sachet drinking water with particular reference to Ghana. It is important to note that some studies have exonerated sachet water from the contamination accusation (Ahimah & Ofosu, 2012; Egwari et al., 2005; Olowe et al., 2005) though most findings attest to positive contamination by pathogens (Stoler et al., 2012).

Literature reviewed in relation to the present study supports the positive contamination assertion (Cheabu & Ephraim, 2014). Stoler et al. (2012) were of the opinion that in spite of the long list of impurities that scholarship has dealt with, there might be many others that have not come to light, particularly in the developing world. Impurities and contamination caused through storage and transportation (Gundry et al., 2006; Wright et al., 2015; Clasen & Cairncross, 2004; Duwiejuah, et al., 2013), health effects of phthalates and other chemicals that could leach from sachet water containers (polyethylene) (Sax, 2010) and the effect of sunlight on sachet drinking water have not been elaborately researched into (Stoler et al., 2012) and according to the present study, the possibility of plastic packaging causing health risk still remains unknown and this area also needs to be researched. Stoler (2012) in a short communication was of the view that access to drinking water has expanded within the West Africa sub region. The paper concluded that sachet water is doing more harm to the environment as a consequence of the plastic waste challenge. The paper therefore suggested that there is the need for proper monitoring of local drinking water sources, especially sachet water, if the millennium development goal target for the provision of drinking water is to be achieved.

Evaluating the quality of sachet drinking water in the New Juaben Municipality in Ghana through interviews and laboratory experiments, Ahimah and Ofosu (2012) concluded that sachet water vended generally met the Ghana Standards Authority (GSA) quality standards. Parameters tested include appearance, taste and odor, color, turbidity, negative log of hydrogen ion concentration, conductivity, total alkalinity ($CaCO_3$), total hardness, manganese, iron, sulphate, ammonium nitrogen (NH_4-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), total and feacal coliforms, E-coli (enterovirus thermo-tolerant coliforms) and total heterotrophic bacteria. All parameters, except in 5% of the samples, failed to meet GSA quality standards in terms of the presence of heterotrophic bacteria. GSA recommends that heterotrophic bacteria in drinking water should not be above 3.00cfu/100ml. The study, therefore, recommended that regular monitoring in the producing factories should be conducted to ensure maintenance of proper standards.

A study on lead concentrations in sachet drinking water in Accra, Odumase-Krobo and Nsawam, all in the Greater Accra Region in Ghana was done by Ackah et al., (2012). Other chemicals analyzed include Na, K, $SO4^{2-}$ Cl, Mg, $PO4^{3}$, HCO_3 Cu and Cr. With varying degrees of ion concentrations, the concentrations of copper and chromium were below detectable limits while 68% of the samples had lead levels above World Health Organization's guidelines. The study further observed that label requirements, such as manufacturing date, expiry date, nutritional information, and batch number were virtually non-existent. Only FDA number (55.6%) and contact information (100%) were found to be somewhat encouraging. A recommendation was therefore made for regulators (FDA and GSA) to implement regulatory requirements with regards to labeling on sachet water containers.

Lead when accumulated in the body over a long term may give rise to health hazards such as wrist drop and painful bones (Baffour-Awuah, 2015; Baffour-Awuah & Tenkorang, 2014). The high concentration of lead in majority of the samples may be as a result of leaching from automotive repair activities in the municipality into underground water aquifers before the water is extracted for the production process and therefore enters the sachet. Thus, raw water for producing sachet water may be polluted at source by lead, particularly when the source river, lagoon, stream or underground water is close to vehicle maintenance and repair garages (Baffour-Awuah, 2015) since sachet water machines cannot eliminate lead during treatment.

Oyelude and Ahenkorah (2016) assessing the quality of sachet water and bottled water in the Bolgatanga Municipality of Ghana dwelt on physico-chemical and bacteriological characteristics. These include total hardness, turbidity, dissolved solids and color. Other characteristics were magnesium ions, calcium ions, nitrate ions, sulphate ions and phosphate ions. The rest were chloride ions, fluoride ions, total iron, fecal coliform and total coliform. The study found that over 50% of water sampled had fluoride ion levels below World Health Organization (WHO) recommended minimum levels of 0.5mg/l. It was however observed that the physico-chemical characteristics were generally acceptable. Nevertheless, about 75% was contaminated by coliform bacteria to the range of 12-168/ 100ml. In addition to this, over 60% of the samples contained coliform bacteria in the range of 2-63cfu/100 ml. The study further observed that all the hand-filled, hand-tied and unbranded sachet water samples were fecal coliform bacteria contaminated against the backdrop that WHO recommends that there should be no trace of faecal coliform bacteria in a 100ml sample of drinking water. The authors, against this background, therefore, concluded that sachet water samples in the municipality were of variable quality but of good physico-chemical characteristics except the low levels of fluoride ions though bacteriological content did not make them undrinkable. Bottled water was however, found to be relatively better for drinking purposes.

Reporting on the storage effect on the quality of vended sachet drinking water in the Tamale metropolis of Ghana (Duwiejuah et al., 2013), three different storage conditions, namely, ambient, refrigeration and sunshine were analyzed. It was found that the physico-chemical variables were within the WHO recommended limits and did not depend on the mode of storage.

Physico-chemical parameters analyzed include PH, turbidity, total hardness, calcium, magnesium, chloride, fluoride, potassium, phosphate and total alkanity. The concentrations of magnesium, calcium total hardness, sodium and potassium were however low. Coliform and salmonella spp were not observed during the study period of three months. There was no statistically significant difference ($\rho<0.05$) in total coliform counts for stored water under sunlight and refrigeration conditions. Nevertheless, different levels of regrowth of total heterotrophic bacteria and coliform of stored ambient sachet water were observed. The authors attributed the findings to low nutrient concentration, exposure to ultraviolet radiations from the sun, temperature effects and permeability of polyethylene sachet to carbon dioxide, oxygen and water vapour. Recommendations of the study include enrichment of mineral concentrations of sachet drinking water for general dietary requirement demands.

In trying to ascertain sachet water quality, with reference to microbial and physico-chemical quality, in the Obuasi Municipality in the Ashanti Region of Ghana, Cheabu and Ephraim (2014) analyzed 30 samples from 10 brands of vended and hawked sachet drinking water. Parameters analyzed include bromide, phosphate, fluoride, chloride, nitrite, sulphate, nitrate, total dissolved solids and conductivity. Total coliform and faecal coliform (microbes) were also analyzed. The researchers observed that there were no bromide and phosphate traces in all samples tested. It was also observed that traces of fluoride, chloride, nitrite and sulphate were within WHO and Ghana Standards Authority permissible limits except nitrate in one brand. Total dissolved solids and conductivity values were also within WHO permissible ranges. However pH values of 4 brands were below the WHO permissible limits, which mean they were acidic. All samples also had elevated levels of total coliform bacteria with only one brand recording faecal coliform microbes. Furthermore, there was elevation in heterotrophic bacterial level. The authors therefore recommended the adoption of Hazard Analysis Critical Control Point (HACCP) system to assist monitor and eliminate the varying contamination levels in sachet water production.

An assessment by Yidana et al. (2014) on the compliance of sachet drinking water producers with regard to Ghana regulatory standards in the Tamale Metropolis revealed that sachet water quality could be ensured through regulatory tools such as fines, seizure, certification, court sanctions, destruction of unwholesome products and regular monitoring and testing. The authors observed that quality standards in Ghana are under the purview of Ghana Standards Authority (GSA) and Food and Drugs Authority (FDA). Legislative instruments that seek to protect consumers' interest include Ghana Standards Decree, the Food and Drugs Law, Narcotic Drugs (Control Enforcement and Sanctions) Law and the Pharmacy Act. In spite of the availability and access of these tools by regulators, the study concluded that a significant number of sachet water producers did not have certification. Majority of the producers thought that though they did not require authorization from the Ghana Standards Authority (GSA), they needed permission from the Food and Drugs Authority (FDA) for their operations. A tacit but interesting observation was the ignorance of the producers that the absence of a logo or trademarks of regulatory authorities was an indication of uncertified product. The regulations classify sachet water products without a logo or trade mark of the regulatory bodies as uncertified and therefore not marketable. The study recommended the need for regulatory bodies to improve monitoring activities. Other stakeholders were also advised to get involved in public education. A recent study by Wright et al (2015) suggests greater regulatory responsibility in order to ensure safe drinking water in households. A study by Baffour-Awuah and Tenkorang (2014) revealed that such education when communicated using local languages could go a long way to achieve the necessary impact.

Researching on the topic "Effects of sachet water consumption on exposure to microbe-contaminated drinking water: Household survey evidence from Ghana," Wright et al (2015) observed that, household water source types used in international monitoring of accessibility to potable water applies equally to the Ghanaian environment . The study revealed that at the point of consumption, water (sachet and bottled) are safer than piped water in terms of E.coli contamination as fecal-indication bacteria. About 30% of sachet water was however, exposed to microbial contamination. Regardless of the mixed findings on the quality of sachet water in Ghana, Little (2015) describes sachet water in Ghana as "cheap, potable, and an omnipresent solution" for closing the gap between government failure to provide adequate water infrastructure and access to safe drinking water. Little (2015) investigated the state of sachet water as a Ghanaian alternative for the private sector to solve a public infrastructure challenge. The author concluded that, sachet water is more potable than ever while recycling of used plastic sachets have been enhanced. The author drew this conclusion for three reasons. First, Ghanaians appreciate the role of sachet water in enhancing the coverage of potable water; two, water quality generally continues to increase by registered sachet water producers; and three, the role of the private sector in managing sachet water plastic waste continues to manifest with intense interest, seriousness and vigour to deal with the environmental menace associated with it.

It can be asserted that sachet water has come to solve numerous challenges that Ghanaians face with regards to access to safe drinking water. This is because governments have failed to come to terms with this part of social contract with the inhabitants of the country. It appears there is progressive improvement of sachet water quality over the years from the production and handling point of view. In order to encourage total quality management with the aim of attaining complete safe sachet drinking water, there is also the need to attend to maintenance issues in the industry. For when maintenance of production equipment and machines are taken seriously, product quality is more likely to be attained. Indeed there is a positive correlation between maintenance and product quality (Maletic et al., 2012; Brah & Chong, 2004). Though storage and transportation can be sources of contamination (Wright et al., 2014; Duwiejuah et al., 2013; Gundry et al, 2006; Clasen & Cairncross, 2004), contamination can also arise from production sources (Omalu et al., 2010) due to maintenance deficiencies. According to Omalu et al. (2010), for example, water treatment, dispensing into packaging materials, and closure could affect water quality. Thus proper maintenance of sachet water equipment leading to quality production processes could contribute in one way to quality sachet drinking water.

Method

As part of the present survey a fundamentally qualitative study was made with 15 sachet water companies and 35 workers in August 2016 to solicit views with respect to equipment maintenance and repair in the sachet water industry. Respondents were interviewed and/or administered with questionnaires. Observations were also made with reference to the production processes in the companies. All companies were located in the Cape Coast Metropolis in the Central Region of Ghana. The purposive sampling method was employed to sample the firms. Only staff met on the factory premises at the time of data collection were given the opportunity to participate in the study. A structured questionnaire was employed. Both open and closed ended questions were utilized. Some of the participants were interviewed with regard to those willing to do so. The results of the survey are discussed in this paper. Managers/owners/senior staff (12) formed the majority of the respondents. This could be attributed to the fact that firms were solely-owned, located within the residential premises of owners and the owners were therefore present most of the time. Other staff were operators (8), laborers (9) and drivers (6). In some cases, drivers and operators also performed the duties of laborers. The main work of laborers were packing or loading of bagged sachet water into and from loading trucks. They sometimes also transferred bagged sachet water from production floors to storage rooms.

Proprietors might also act as managers and conduct the general supervisory work of the company. Operators, laborers and drivers constituted the junior staff. Senior staff were those who had worked in the company for a relatively long period and might have secondary education. Factories that participated in the study had operated since 1998, with majority (8) commencing operations between 2002 and 2010. All participants were over 21 years old. As observed by Stoler et al (2012), all the firms had one or more family members as part of the company, including the proprietor, who acted as the manager. Most employees were casual workers who got paid according to the days they worked. Permanent workers were paid monthly, though they did not have appointment letters. Based on the National Board for Small Scale Industries (NBSSI) Ghana criteria, the industry is purely informal and micro scale in nature since workers are not more than six in each factory. The National Board for Small Scale Industries in Ghana (NBSSI) defines a small-scale enterprise as an organization with less than 10 employees with plant and machinery assets (excluding land, buildings and vehicles) not more than 10 million Ghana cedis; micro enterprises have less than six employees (Agyapong, 2010).

Results and discussion

The United Nations Organization has projected an urban-majority population in the next decade for sub- Saharan Africa due to industrialization, and relatively high fertility

(United Nations, 2010). The inability of various governments to provide the corresponding infrastructure for water has created water scarcity, encouraging the conditions and subsequent generation of other sources of water including sachet water (Stoler et al., 2012). The gradual evolution of packaged water to the present sachet water prevalence has been feasible as a result of the development of sachet water machinery, the purpose of which is basically to form, fill and seal (FFS). Stoler et al. (2012) report that these machines started Ghana in the 1990's from China with the purpose to only fill, form and seal. Filtration and chemical treatment processes were later incorporated. Machines that came into Ghana later had additional mechanisms, including ultraviolet facilities.

Production systems

Sachet water producers (family-owned and small-scale) in Ghana use the vertical type of the form-fill-seal machines which are extremely flexible by design. The vertical fill form and seal (VFFS) machines can accommodate relatively high packaging speeds. When set optimally and properly maintained, they could have a desirably high longevity. These machines provide airtight packaging and can accommodate printers and labelers; and be reliable and efficient even at relatively higher speeds. After forming the empty sachet, the machine fills the sachet and heat-seals it to prevent any leakage. No adhesives, glue or resin, which can contaminate water when it gets into contact, is applied in the sealing process. This thermal transverse vertical sealing of the sachet is designed for polyethylene film or composite film bags. Preprinted sachets usually bear the company name and Ghana Standards Authority logos. Studies have shown that sachets of water do not usually bear the manufacturing date, expiry date, batch number, and nutritional information (Yidana et al., 2014; Ackah et al., 2012). Indeed, one hundred percent of sachet water examined in the present study had neither manufacturing date; expiry date; batch number nor nutritional information. This is a proof that sachet water machines used by small scale producers in the sample either did not have or had out of order printing facility. Findings from the present study also showed that only a couple of those surveyed had the facility, though they were not functional. Additional cost to production from ink and electricity was the main reason in this regard.

After filling, and sealing, the sachet is cut and dropped to the finished product area which is usually a basket or container. For older machines, and some new ones, machine operators collect filled sachets manually with the hand and drop them in containers. Modern machines can perform functions such as forming, filling and sealing, UV sterilization, thermal vertical sealing, date lamination, quantitative filling bag cutting and automatic counting and thermal transverse sealing. When purchased new, free parts are provided for maintenance purposes. Free parts include oil gun, open-end wrench, Allen wrench set and vertical sealing strip. Other spare parts include transverse sealing strips, V-belt, screw driver set, West Buddha bar, Membrane Ottomans, heater and high temperature cloth. The following are some of the parts obtained from suppliers in the industry: filters; filter covers; and cleaning cartridges. Others are Machine heads, integrated circuits, heating elements and heat seals. The rest are motors, faucets, and hoses; simple tools such as cover keys, Allen and tape spanners.

The purpose of the heating system (heating element and heat seal) is to seal the unit of sachet drinking water. Improper sealing may cause contamination after production.

Integrated circuits (IC) are added to the production system to amplify, time, count, oscillate, memorize or act as a microprocessor. Depending on the type of machine used the IC of the sachet water machine may perform one or more of these functions. The IC consists of resistors, capacitors and transistors with continuously variable electrical output that in turn depends on the input signal level. Thus the entire electrical system of the machine depends on the IC. A malfunctioning IC may affect the pumping system, heating system, disinfection process and or purification system.

Ultraviolet Germicidal Irradiation (UVGI) is used by some of the producers to disinfect sachet water. The purpose is to ensure quality water free from harmful microorganism. UVGI uses short-wavelength ultraviolet (UV-C) light to kill or inactivate microorganisms by destroying the nucleic acids in the DNA of organisms. In its presence vital cellular functions are therefore disrupted making them impotent to cause harm. Ultraviolet radiations can demobilize, disable and deactivate bacteria, viruses, molds and other pathogens (NIOSH, 2008; Muelemans, 1987). Thus in a circulating water system in conjunction with a filtration system, it can be used to sanitize water dose or fluence (the UV dose is the quantum of UV energy absorbed by a population of microbes over a period of time). The effectiveness of a UV system, the dose or fluence depends on flow rate (contact time); transmittance (light reaching the target); turbidity (cloudiness), lamp age, fouling and outages (reduction in UV intensity) (USEPA, 2006). The line-of-sight exposure of the pathogens to the UV light depends on the flow rate.

A faulty treatment system may leave water infected. If a bulb is coated with a film or is irradiating relatively dense water, UV output may be lowered. This may also reduce the degree of disinfection. Turbid water may block the UV radiation from reaching the target pathogens. In a situation where the radiation may reach the target pathogens, intensity might be too low to actually disable them. Where the filtration system is weak the inability of the UV to properly disinfect the water may be further worsened. Maintaining the UV system, whether through prevention or correction is a major point in the HACCP system that must never be lost sight of. It is worth noting that the UV system is more effective in disinfecting high clarity water. As already indicated, shielded microbes by suspended matter renders the system ineffective. A good filtration system, however, is able to clarify the water and purify it as well. Purification removes suspended matter while the lamp may be damaged as a result of high temperatures. If turbidity is too high, this will lead to insufficient UV exposure making the microbes pass without enough quantity to disable them.

Equipment maintenance

Majority of machines are the Koyo brand from China. Few were found to be Freditech brand which according to the managers were produced in Ghana by the Freditech Company located in Accra. Companies had daily and weekly maintenance schedules in accordance with production periods. Companies which produced daily, inspected and maintained machines daily, while those who produced on weekly bases did so weekly. It is worth mentioning that, monthly, quarterly, biennial and annual maintenance were not practiced. Proprietors were of the view that daily and weekly maintenance were enough to keep machines in healthy conditions. Daily and weekly maintenance involves inspection of components, such as heating element and filters. Other activities include adjustments, cleaning and lubrication/greasing. Replacements are done as part of corrective maintenance when situation demands. Companies obtain parts from suppliers outside the metropolis.

Routine, shut down and breakdown maintenance were practiced with daily routine maintenance (inspections) being the most practiced. Shutdown maintenance was done on periods when production was not done; breakdown maintenance being the style least practiced. Breakdown maintenance usually involves heating elements, heat seals, integrated circuits, pumping system and ultra violet (UV) light. Unfortunately these are the systems that control the actual water purification. This means that failure to replace such components on time might lead to loss of water quality. These are therefore some of the Hazard Analysis Critical Control Points in the HACCP system which the industry must critically consider if sachet water quality is to be improved. Raw water storage system, that is storing water for a long period, may lead to contamination. It requires that storage tanks are regularly cleaned (routine maintenance) to minimize, if not prevent, stored-water contamination.

Operators were of the view that this is as a result of the seriousness attached to daily and weekly maintenance schedules. Thus preventive maintenance was mostly practiced by all the companies with corrective maintenance being the least.

Daily and weekly maintenance (inspections) was done before production commenced. With a total of 17,136 bags per day of production, and an average of 952 bags per company per day, most of the machines were in good health since they were producing below production capacity. An average machine could actually produce 50 sachets of water per minute. This means that a production crew on one shift of eight hours could produce (50×8=24000) sachets per day (800 bags per day). Many of the companies were actually running more than one shift a day. A study by Abochie (2011) showed that the average production rate was 1060 bags per day in Ghana. The reduction in production may be due to low demand of sachet water resulting from the recent increase in unit retail price from 10p to 20p (GH¢1.00 = 100p; Gh¢1.00 ≈ $0.17). Increase in the number of producers may also be another reason. Companies may work continuously in more than one shift in one or more weeks and break for one or more weeks. Such companies had adequate storage facilities. It must be emphasized that some companies sold outside the metropolis. Such companies, though few, had more than one production line. Marketing techniques of such companies are relatively advanced than many industry players.

Three categories of mechanics were identified; individual external repairers, repairing firms and company-worker repairer. The external repairer was an individual who has the skill and expertise to repair machines when there is a breakdown. This individual usually did not work with the water producing firm. A repairing firm was a mechanic shop that dealt in repairing such machines. The company worker-repairer was usually an operator of a sachet water machine who had learnt the repair operations on the job or had some experience in repair activities before becoming an operator. Majority of the companies often made use of company workers to repair faulty machines. Such mechanics usually did not have the experience and equipment to practice diagnostic maintenance. They deemed it a responsibility to repair faulty machines since they were the one who operated them. The use of company worker mechanics presented two advantages to the company owners : access and availability of mechanics as well as low repair cost.

The next group was those who often made use of external repairers (individuals). According to players in the industry, they fell on individual repairers when the company repairer was not available or when the company had no worker mechanic. Repairing firms were usually not consulted. The main reason was cost. Charges were usually higher relative to individual repairer and company worker-repairer, in that order.

Spare parts were obtained from suppliers in Tema, Accra (Cantonments and Kaneshie), Kumasi, Takoradi and on a few occasions, Cape Coast. Access to and cost of spare parts one of the major maintenance challenges in the sachet water industry in Cape Coast Metropolis. Though this adds to production cost, producers were not able to add the cost onto the final consumer due to competition of producers from outside the metropolis, particularly Accra. Some sachet water producers in Accra supplied the product into the Cape Coast market. Since these were medium/large scale enterprises with economies of scale, prices of the commodity competed against the prices of those produced in the metropolis.

The major maintenance challenges in the industry, within the metropolis, were water leakages, wearing of machine components, and availability of parts which results from proximity to suppliers, punctuality of repairers and financial constraints. The rest are electrical shocks, inadequate parts and tools and breakdown of machines due to power cuts and power fluctuations. This corroborates the findings of Abochie (2011) and that these challenges delay the production of sachet water within the metropolis.

Conclusion

The dependence of the population on sachet drinking water has become indispensable in various households and public places in Ghana. In educational institutions, a substantial number of students prefer sachet drinking water to tap water and other sources of water. In spite of its simple beginnings with pure water as the trade name among the populace, sachet water has found itself in every corner of the country, rural or urban. The industry has managed to overcome production challenges with machines and equipment available in most settlements in Ghana. The major raw materials being raw water and polyethylene films are also readily available, the latter particularly in the regional capitals. Raw water from wells or boreholes is gradually replacing tap water from Ghana Water Company Limited. In the case of polyethylene films, investors have tried to locate companies in regional capitals such as Cape Coast. Though studies have shown mixed findings of water quality, there is a general observation that sachet water quality in Ghana has been improving over the years. Various points in HACCP systems have been identified as the cause of relatively poor water quality. These points include storage points, handling points and production points. One major HACCP system point of great importance is maintenance. Both preventive and corrective maintenance systems are very salient in this context (those within). Other HACCP system maintenance points identified include raw water storage system, pumping system, integrated circuit system, UV disinfection system, filtration system and heating system.

The study recommends that all water-processing machines should by law be made to incorporate UV disinfection systems in addition to pre-filtration systems. Adopting a new system developed in Australia by the University of Adelaide (2014, September 11) whereby a chip packet foil is used to reflect solar UV radiation into a glass tube to disinfect water without external power source may be an innovative attempt of not relying on UV lamps powered by electricity. UV system is the final point of purification. Its deficiency, therefore, cannot be tolerated if sachet drinking water quality is to be enhanced at the point of production. It requires proper preventive and corrective maintenance. Ensuring its proper maintenance removes many critical points in the HACCP system thus enhancing the quality of sachet drinking water. Adding chlorine, as a disinfectant, will prevent situations when UV disinfected water becomes re-infected during storage periods as a result of microbes and pathogens becoming impregnated and shielded in suspended solid matter in the sachet water.

References

Abochie, B. A. (2011). *Investigation into the maintenance of commercial water purification machines in the Cape Coast Metropolis*. HND project report submitted to the Mechanical Engineering Department, Cape Coast Polytechnic, Cape Coast, Ghana.

Ackah, M., Anim, A. K., Gyamfi, E. T., Acquah, J., Nyarko, E. S. R., Kpattah, L. et al. (2012). Assessment of the quality of sachet water consumed in urban townships of Ghana using physico-chemical indicators: A preliminary study. *Advances in Applied Science Research*, 3(4), 2120-2127.

Agyapong, D. (2010). Micro, Small and Medium Enterprises' Activities, Income Level and Poverty Reduction in Ghana – A Synthesis of Related Literature. *International Journal of Business and Management*, 5(12), 196-205.

Ahimah, J. K. &Ofosu, S. A. (2012). Evaluation of the quality of sachet water vended in the New Juaben municipality of Ghana. *International Journal of Water Resources and Environmental Engineering*, 4(5), 134-138.

Baffour-Awuah, E. & Tenkorang, E. Y, (2014). Concentration of lead and cadmium in the Fosu lagoon and its health implications on lagoon fishermen. *Journal of Environment and Earth Science*, 4(16), 6-18.

Baffour-Awuah, E. (2015). *Heavy Metals in the Fosu Lagoon and its Health Implications.* Saarbruken, Deutchland, Germany. Lambert Academic Publishing. ISBN: 978-3-659-61182-7

Brah, S. A. & Chong, W. (2004). Relationship between total productive maintenance and performance.*International Journal of Production Research*. DOI: 10.1080/00207540410001661418.

Cheabu, B. S. N. & Ephraim, J. H. (2014). Sachet water quality in Obuasi, Ashanti Region, Ghana. *Journal of Biology, Agriculture and Health Care,* 4(5), 37-42.

Clasen, T.F. &Cairncross, S. (2004). Household water management: Refining the dominant paradigm. *Tropical Medicine and International Health*. (9),187-191.

Dada, A. C. (2007). *Pure water phenomenon in Nigeria: Assessment of public health impacts*. Oxford University Centre for the Environment, p.112.

Dada, A.C. (2011). Packaged water: Optimizing local processes for sustainable water delivery in developing nations. *Global Health*. Doi; 10.116/1744-8603-7-24.

Duwiejuah, A. B., Cobbina, S. J. &Akrong, M. O. (2013). Effect of storage on the quality of sachet-vended water in the Tamale Metropolis, Ghana. *Journal of Environmental Protection,* 4(6), 629-637. doi:10.4236/jep.2013.46072.

Egwari, I. O., Iwuanyanwu, S., Ojelabi, C. I., Uzochuku, O. &Effiok, W. W. (2005). Bacteriology of sachet water sold in Lagos, Nigeria. *East African Medical Journal* (82), 235-240.

Gundry, S., Wright, J. & Conroy, R, (2004). A systematic review of the health outcomes related to household water quality in developing countries. *Journal of Water and Health*. (2) 1-13.

Kassenga, G.R. (2006). The health – related microbiological quality of bottled drinking water sold in Dar es Salaam, Tanzania. *Journal of Water and Health*. 5 (1), 179-185.

Little, R. J. (2015). *The state of sachets: Ghana private sector solution to a public infrastructural problem*. Pitzer Senior Thesis, Paper 62. Retrieved from http;//scholarship.claremont.edu/pitzer- theses/62.

Maletic, D., Maletic, M. & Gomiscek, B. (2012), The relationship between continuous improvement and maintenance performance. *Journal of Quality in Maintenance Engineering*, 18(1), 30-41.

Muelemans, C. C. E. (1987). The Basic principles of UV disinfection of water. *Ozone: Science & Engineering,* 9(4): 299-313. Doi: 10.1080/01919518708552146.

NIOSH (2008). *Word of the mouth: Ultraviolet Germicidal Irradiation (UVGI)*. National Institute for Occupational Safety and Health, April 2008.

Okogia, T. (2000). Water *quality and business aspects of sachet vended water in Tamale, Ghana*. MSc thesis, Civil and Environmental Engineering, Massachusetts Institute of Technology, p. 168.

Olayeni, A. B. (1999). Microbial potability of bottled and packaged drinking waters hawked in Ilorin Metropolis. *International Journal of Environmental Health Research* (9), 245-248.

Olowe, O. A., Ojurongbe, O., Opaleye, O. O., Adedosu, O. T., Olowe, R. A. &Eniola, K. I. T. (2005). Bacteriological quality of water samples in Osogbo metropolis. *African Journal of Clinical and Experimental Microbiology* (6), 219-222.

Omalu, I. C. J., Eze, G. C., Olayemi, I. K., Gbesi, S., Adeniran, L. A., Ayanwale, A. V. et al. (2010). Contamination of sachet water in Nigeria: Assessment and health impact. *The Online Journal of Health and Allied Sciences*, 9(4), 15.

Omeh, D. (2013). How to start sachet pure. waterhttps//www.wealthresult.com/entrepreneurship/how-to-start-sachet-pure-water.

Oyelude, E. O. & Ahinkorah, S. (2012). Quality of sachet water and bottled water in Bolgatanga municipality of Ghana. *Research Journal of Applied Sciences, Engineering and Technology*, 4(9), 1094-1098.

Sax, L. (2010). Polyethylene terephthalate may yield endocrine disruptors. Environmental *Health Perspectives*, (118), 445-448.

Stoler, J., Weeks, J. R. & Finks, G. (2012). Sachet drinking water in Ghana's Accra-Tema metropolitan area: Past, present, and future. *J Water Sanit. Hyg. Dev*. 2(4). Doi: 10.2166/wash dev.2012.104.

United Nations (2010). *World urbanization prospects: The 2009 revision*. United Nations Population Division, Department of Economic and Social Affairs; New York, NY.

USEPA (2006). *Ultraviolet disinfection guidance manual for the final long term 2 enhanced surface water treatment rule*. (PDF). Washington, DC: United States Environmental Protection Agency. November 2006.

Whittington, D., Lauria D. T. & Mu, X. M. (1991). A study of water vending and willingness to pay for water in Onitsha, Nigeria. *World Development*, (19), 179-198.

Wright J., Dzodzomenyo, M., Wardrop, N. A., Johnston, R, et al. (2015). Effects of sachet water consumption on exposure to microbe contaminated drinking water: Household survey evidence from Ghana. *International Journal of Environmental Research and Public Health*. 13,303; doi: 10.3390/jerph.13030303

Yidana, N., Osman, I., Yidana, Z., Nyeadi, J. D. & Atogenzoya, C. A. (2014). Assessing the compliance of sachet water producers to regulatory standards in Ghana: a study of the tamale metropolis. *International Journal of Innovative Research and Development*, 3(6,) 426–436.