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Waste Water Disinfection Utilizing Ultraviolet Light

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ABSTRACT
This study was carried out to investigate the effectiveness of Ultraviolet light for waste water disinfection. Recent studies have shown that water chlorination causes several environmental problems and therefore the need for safer methods. Ultraviolet light is currently a more preferable method for water disinfection. It has some inherent advantages over all other disinfection methods which are: no chemical consumption, no transportation and handling, no harmful by-products formed, a minimum of, or no, moving parts therefore high reliability and low energy requirements. Three critical points of water quality were focused on incoming and outgoing points of the fish culture tank and outlet of the filter tank. The outlet is important because it indicates the effectiveness of Ultraviolet light, specifically the ability to disinfect the water so that pathogenic bacteria are killed after the water has been treated with Ultraviolet rays. Waste water from the sampling points were analysed for different parameters. Temperature was determined using Mercury in glass thermometer (British standard BS593). pH was determined using a Hanna pH meter model No. 02895, $CaCO_3$, NO_3, NO_2 and NH_3 were determined using water analysis kit by Hague while the microbial analysis was carried out using the MacConkey agar plate. The UV disinfection method was found suitable for treatment of waste water. This is obvious since the treated sample of water had lower coliform count than the other waste water samples. The favourable quality of the UV disinfected water was also observed in its improved chemical properties especially ammonia and dissolved oxygen.

Key words: Disinfection, ultraviolet, chlorination, fish, water, bacteria, ammonia

INTRODUCTION
For many years chlorination has been the standard method of water disinfection. Chlorine is used in most water treatment facilities to kill harmful microorganisms in drinking water that cause serious disease. While this certainly works, the chlorine itself causes many health problems such as asthma, cancer, fertility problems, heart disease, eczema and birth defects. Not to mention the smell and taste of chlorinated water is terrible (Reese, 2010). Also, residuals and byproducts from chlorination can be toxic to aquatic life in receiving waters. Particularly, some by-products of chlorination may be carcinogenic and may require removal in a drinking water treatment plant. It has actually been discovered that chlorination is much less effective in virus destruction than in killing bacteria. Ultraviolet light is currently a more preferable method for water disinfection. Actually, UV disinfection has gained widespread use for municipal wastewater and more recently, interest in using UV for water reuse applications has increased too (Kamani *et al*., 2006). It has the

following inherent advantages over all other disinfection methods: no chemical consumption thereby eliminating large scale storage, no transportation, handling and potential safety hazards, low contact time-no contact basin is necessary and space requirements are reduced, no harmful by-products are formed, a minimum of, or no, moving parts-high reliability and low energy requirements (Anonymous, 2010b). Ultraviolet disinfection, thus solves the environmental and safety problems and is cost-effective as well.

Ultraviolet disinfection of water employs low-pressure mercury lamps. They generate short-wave ultraviolet in the region of 2537 Angstroms which is lethal to microorganisms including bacteria, protozoa, viruses, molds, yeasts, fungi, nematode eggs and algae. The mechanism of microorganism destruction is currently believed to be that ultraviolet causes molecular rearrangements in DNA and RHA, which in turn blocks replication (Eccleston, 1998). The acceptance of UV disinfection at wastewater plants treating in excess of one billion gallons daily is proof that UV is no longer an emerging technology, but rather an accepted technology to be used routinely by engineers to safeguard human health and alleviate environmental pressures. Wastewater reuse has been practiced in various forms for decades, with the United States leading the way in reuse research. It is now a major issue in the US where large areas of the Western and Southern states experience chronic water shortages (Anonymous, 2010a).

Ultraviolet (UV) water purification lamps produce UV-C or germicidal UV, radiation of much greater intensity than sunlight. Almost all of a UV lamp's output is concentrated in the 254 nm region in order to take full advantage of the germicidal properties of this wavelength. Most ultraviolet purification systems are combined with various forms of filtration, as UV light is only capable of killing microorganisms such as bacteria, viruses, molds, algae, yeast and oocysts like cryptosporidium and giardia. UV light generally has no impact on chlorine, VOCs, heavy metals and other chemical contaminants. Nevertheless, it is probably the most cost effective and efficient technology available to homeowners to eliminate a wide range of biological contaminants from their water supply. UV water treatment offers many advantages over other forms of water treatment for microbiological contaminants. Most importantly, it does not introduce any chemicals to the water and it does not alter the taste, pH, or other properties of the water. Accordingly, in addition to producing safe drinking water, it is not harmful to your plumbing and septic system. Furthermore, it is easy and cost-effective to install and maintain without any special training (Eccleston, 1998). Partial Re-use Systems consisting of gravity bed filter was used with UV System in the prevention of out-break of Ichthyophthlrius multifilis and furunculosis (WMT, 2004). This study was therefore carried out to investigate the effectiveness of UV light for waste water disinfection.

MATERIALS AND METHODS

The project was carried out between January, 2009 and December, 2009 at the National Centre for Energy Research and Development, University of Nigeria Nsukka. Nsukka is located at 6.9°N and 7.4°E and 445 m above sea level.

Treatment tank installation: Procurements of biofilters namely bioblocks, biobrush, Maifan stones, coral sand, ceramic ring, activated charcoal and UV light were used for this study. They were arranged inside the treatment tank in the following order.

Biobrush→Bioblock→Maifan stones, Coral sands, Ceramic ring and Activated Charcoal→UV light→(the arrows shows the order of arrangement of the compartments of the treatment tank).

The dimensions of treatment tank which was constructed with concrete are 3.4×1×1.5 m. There were four compartments in the water treatment tank each measuring 1×0.6×1.25 m. The first compartment contains the biobrush, the second has bioblocks, the third contains maifan stones, coral sands, ceramic ring and activated charcoal, finally the last chamber houses the UV fluorescent tube which was placed at close proximity to the water surface but was not immersed in the water. Two pumps, Interdab electropome Jet 100 M 1 horse power pump and Grundfos KPBasic 300A submersible pump were procured at Onitsha and Lagos, respectively. Interdab electropome Jet 100 M uses electricity while Grundfos submerssible pump was powered by solar modules (photovoltaic) to ensure constant power supply and to serve as comparative between electric and solar energy. The quantity of water pumped by both pumps is 50 L min^{-1} at the depth of 1.25 m. Air stone aerator supply oxygen constantly to the ponds. Ceramic rings-surface area 1200 m^2 L^{-1} and weighing 10 kg, bamboo carbon (activated carbon)-surface area 1200 m^2 L^{-1} and weighing 10 kg were purchased at Kingdom Aquarium and fisheries Ltd. Lagos, Nigeria. Two overhead plastic tanks, volume 1000 L each were procured at Onitsha for water storage.

Treatment process: Water from the overhead tank (Inlet water) entered the pond where fishes are kept and then flowed into the treatment tank as waste water. As waste water flowed through biobrush, bioblocks, maifan stone, coral sand, ceramic ring and activated carbon it is filtered. Solar powered pump water and electric powered pump water were then collected. Water lastly flowed into the UV light compartment where it was disinfected (UV treated water). After the waste water had passed through the treatment tank, the treated water was air lifted into the culture tank for use by the fish and recirculated back again into the filter again for purification.

Sample collection: Three critical points of sample collection were focused on; incoming and outgoing points of the fish culture tank and outlet of the filter tank. The outlet is important because it indicates the effectiveness of UV light, specifically the ability to disinfect the water so that pathogenic bacteria is killed by ultra violet rays after the water has been conditioned. One sample each was collected from the incoming and outgoing points of the fish culture tank while 2 samples were collected from the outlet of the filter tank, i.e., from the solar powered pump water then electric powered pump water. They were collected into already properly washed two litres plastic containers. The containers were labeled and stored in the laboratory refrigerator prior to analysis. The water samples for dissolved oxygen were collected in properly washed glass bottles of 120 mL capacity with glass stoppers labeled and stored in the laboratory refrigerator prior to analysis.

Determination of relevant parameters: Temperature was determined using mercury in glass thermometer (British standard BS593). The pH was determined using a hanna pH meter model no 02895, calcium carbonate ($CaCO_3$), nitrate, nitrite and ammonia, dissolved oxygen were determined using water analysis kit by Hague made in Canada (ASTM, 2008). Microbial analysis was carried out using the Monkey agar plate method as described below:

Micro biological analysis: The four water samples were cultured using nutrient agar: Petri dishes were used for the culturing. Water samples were diluted ten times from 10^{-1} to 10^{-10}. Fifty milliliter of diluted samples spread on the plate and incubated. Colony count was done on plates after incubation and total cfu calculated. Isolation was carried out using the Mac Conkey agar plate; 50 μC =>0.05 mL was used. Average micro agar mL^{-1} was counted and colony forming unit (cfu) recorded (Monica, 1984).

RESULTS AND DISCUSSION

As shown in Table 1, the results of the microbial analysis for the water samples were 2.2×10^3, 6.8×10^3 and 1.8×10^3 cfu mL^{-1} for Solar powered pump water, Electric powered pump water and UV Treated (outlet water), respectively. The Borehole inlet water had no aerobic mesophilic Bacteria. There was no *E. coli* in any of the water samples. The total count show the number of organisms recorded while the sensitivity tests conducted show the type of the organism identified is non pathogenic only aerobic mesophilic bacteria was seen as shown above. Inlet water has no fungal and no aerobic mesophilic bacteria were seen in the inlet water. Water from the electric powered pump recirculating system had the highest average aerobic mesophilic bacteria of 6.81×10^3 cfu mL^{-1} followed by solar powered pump water which had 2.2×10^3 cfu mL^{-1} aerobic mesophilic bacteria count total. The lower microbial count for the solar powered pump water could be due to the fact that the solar powered pump is not restricted by power shortage and there for with continuous flow, the water flows freely and is recirculated unlike the electric powered which is restricted by light and might be stagnant during power shortage. Treated water had the lowest aerobic mesophilic bacteria present. This is an indication that the UV is effective in controlling the microorganism that might be in the system which might result in the disease outbreak in the system. Micro-organisms (including disease-causing bacteria) are killed when exposed to the proper amount of ultraviolet (UV) radiation unlike treatment of wastewater with chlorine which has been reported not to be an efficient disinfectant method, besides its potential to promote the production of antibiotic resistant bacteria (Khleifat *et al*., 2006).

Eccleston (1998) reported that although UV sterilization is very good, the effectiveness depends upon the size of the organism, the amount of UV radiation and the level of penetration of the radiation into the water. To be effective micro-organisms must come in close proximity to the UV radiation source (0.5 m, 0.2 inches or less). The main advantage of UV sterilization for treatment tanks is that it is safe to operate and is not harmful to the cultured species. Infection can result with recirculation of water but it can be exposed continuously to UV radiation to prevent it. For the recirculating systems, good water quality must be maintained for maximum fish growth and optimum effectiveness of bacteria in the biofilter.

Water quality factors that must be monitored and/or controlled include temperature, dissolved oxygen, carbon dioxide, pH, ammonia, nitrate and also nitrite (Zhu and Chen, 1999; McGee and Cichra, 2000; Greiner and Timmons, 1998). Table 2 shows the results of the physicochemical properties for the different water samples. pH was in the range of 6.2-8.0, dissolved oxygen was between 5.7 to 9.4 mg L^{-1}, temperature was between 26.2-26.5°C while the $CaCO_3$, NO_3, NO_2 and NH_3 were on an average of 20.0±0.0, 8.8±2.5, 0.2±0.2 and 0.4±0.2 mg L^{-1}, respectively. The inlet water had the highest quantity of dissolved oxygen which is more favourable for aquatic life, followed by the UV treated water, solar powered pump water and then Electric powered pump water. Amirkolaie (2008) also reported lower dissolved oxygen concentration from waste water

Table 1: Results of microbial analysis of the water samples

Water samples	Total aerobic mesophilic bacteria count (cfu mL^{-1})	Identified microbes
Borehole (inlet water)	Nil	No *E. coli* present
Solar powered pump water	2.2×10^3±200	No *E. coli* present, *klebsiella aerogenes* present
Electric powered pump water	6.8×10^3±10	No *E. coli* present, *klebsiella aerogenes* organisms present
UV treated (outlet water)	1.8×10^3±10	No *E. coli* present, *Klebsiella aerogenes* organisms present

Table 2: Mean values of physicochemical properties of the water samples

Water samples	Dissolved oxygen ($mg\ L^{-1}$)	pH	$CaCO_3$	NO_3	NO_2	NH_3	Temperature (°C)
			($mg\ L^{-1}$)				
Borehole (inlet water)	9.4	6.4	20.0	5.0	0.0	0.1	26.5
Solar powered pump water	6.2	6.9	20.0	10.0	0.3	0.6	26.2
Electric powered pump water	5.7	6.2	20.0	10.0	0.3	0.6	26.3
UV treated (outlet water)	7.2	8.0	20.0	10.0	0.3	0.3	26.4
Mean	7.1±1.6	6.9±0.8	20.0±0.0	8.8±2.5	0.2±0.2	0.4±0.2	26.4±0.1

samples. However, depletion of dissolved oxygen to very low levels is not favourable for aquatic life (Dawodu and Ipaiyeda, 2007). All the treated samples affected by the fish activities had the same concentration of calcium carbonate, nitrate and nitrite, which were higher than the concentration for that of inlet water. However the concentration of ammonia in the UV treated water was much lower than that of the solar powered pump water and then electric powered pump water. This shows that UV disinfection as stipulated by other authors is really a good method of disinfection.

CONCLUSION

The UV disinfection method was found suitable for treatment of waste water. This is obvious since the UV treated sample of water had lower coliform count than the other waste water samples. The good quality of the UV disinfected water sample was also observed in its favourable chemical properties especially ammonia and dissolved oxygen.

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