A preliminary study on the treatment of restaurant wastewater using electrocoagulation technique

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Abstract: Restaurant Wastewater (RW) is characterized by high volume and strength, with minimal treatment before its release into the environment. Electrocoagulation (EC) could be a better alternative due to its environmental friendliness. The study investigates the use of EC in RW treatment. The samples were collected from the University of Ibadan student Union Building restaurant, between 7-9 am. The EC consisted of an aerator, carbon electrodes, power source, a beaker, and stirrer. Electrodes were connected in mono-polar system at inter-distance of 10 mm, with retention times of 0, 30, 60 and 90 minutes. The RW was aerated before passing direct currents of 0.25, 0.5, 0.75, and 1.0 Amperes. The Colour, Particulate Phosphorus (PP), Soluble Reactive Polyphosphate (PO\textsubscript{4}\textsuperscript{3-}), Phosphorus Pentoxide (P\textsubscript{2}O\textsubscript{5}), Chemical Oxygen Demand (COD) and Dissolved Oxygen (DO) were determined. The study was three replicates. Mean percentage removal efficiencies for PP, PO\textsubscript{4}\textsuperscript{3-}, P\textsubscript{2}O\textsubscript{5}, COD, DO and colour at 30 minutes (16.85, 19.33, 17.15, 12.58, -32.88 and 20.12%), 60 minutes (30.88, 27.1, 30.57, 21.13, -57.18 and 34.30%), and 90 minutes (40.75, 33.00, 32.83, 25.83, -87.88 and 40.7%) respectively. Better treatment efficiencies of treated wastewater using the electrolytic reactor were obtained with an increase in direct current passing through.

Keywords: electrocoagulation, electrodes inter-distance, restaurant wastewater, retention time

Introduction

The population of Nigeria is increasing, and the rate at which wastewater is generated is becoming uncontrollable, with most people discharging untreated wastewater into the nearest watercourse, which could be as a result of the expensive cost of treatment. From research carried out by Boyd (2006), it was observed that the effluent from the wastewater generated has some effects on the environment which are negative in nature because of the usage thereby contain some waste products (Ewemoje and Ihuoma, 2014); this, however, results in degeneration of the ecosystem. In some countries, sewerage systems are often used to convey wastewater from various domestic and industrial areas to the treatment point where the water is properly treated (Bassey and Stoveland, 2000). Channelling the effluent into the nearby water environments is not hygienic to the human body, as the decomposition of the pollutant can cause contamination of the water quality (Sarala, 2012).

Furthermore, contagious diseases can easily be transmitted by some of the pathogenic microorganisms present in the water. Some nutrients like phosphorus, nitrogen; alongside with some organic matter, when channelled to the water bodies. This can result in eutrophication, which is the growth of algae and also the contamination of the subsurface water system (Sarala, 2012). Pollutants in raw waters and wastewaters are
typically colloidal particles, which are not easily removed with typical filtration sedimentation or flotation due to their stability in water. These particles have special properties due to their small size and large total surface area. Wastewater is mostly treated using different methods; out of these methods, biological methods using aeration are vastly used. Also, the Activated Sludge method of treatment in a biological method is prominently used. This is as a result of the high-quality treatment effluent that is derived when considered the removal of pollutants such as Suspended Solids (SS) and Biological Oxygen Demand (BOD) (Metcalf and Eddy, 2003). The aforementioned methods of treatment have some demerits which include compulsory sludge removal, regular supply of oxygen air, high maintenance cost, longer retention time and high operating cost. Some researches carried out on coagulation showed that Chemical Oxygen Demand (COD) treatment between the ratios of 55 and 75%, especially when SS is present in the wastewater, can be achieved using Activated Sludge method (Debik, 1999). Another method of treating wastewater is through the use of the Electrocoagulation (EC) method, which involves the use of electricity. Electricity means of treatment was first adopted in the United Kingdom in 1889 (Mollah et al., 2001). Using electrocoagulation method for the treatment of drinkable water was first applied on a large scale in the United States in 1946 (Sarala, 2012). Due to the high cost of treatment at the initial stage of execution and the high cost of electricity, adopting this treatment technique was not considered viable globally (Mehmet et al., 2003). Also, further research in developed countries in recent times gave the method better recognition and generated more results. In addition, policies guiding the disposal of effluents in environmental regulations are increasing every time giving electrocoagulation an edge over other treatment methods in recent time (Chen et al., 2000). At the moment, this new technology has been compared with other methods of treatment in terms of capital and maintenance cost and has been seen to be a very good and reliable means of treatment. It was also observed to contain refractory pollutants (Chen, 2003).

Electrocoagulation (EC) system is a setup that consists of electrodes that allow the passage of electricity which moves in a horizontal direction and allows the flow of water (Chen, 2004). Different ways were identified for the arrangement of the electrodes. These arrangements are bipolar and mono-polar forms. The arrangement is determined by the positioning of the power source used. Arrangement in the bipolar system shows that the side of the electrode faces the anode which is termed the negative polarity and on the other side of the second electrode is termed the cathode which is positively polarized. Considering the monopolar system, the outermost electrodes are connected to the power source making the current to pass through the outer electrodes and vice versa. The cost of treatment operation in a monopolar system is cheaper when compared with the bipolar system (Chen, 2004).

The objectives of this research work were to study the efficiency of carbon electrodes in kitchen wastewater treatment, and the effects of varying direct current on treatment efficiency.

Materials and Methods

Study area

The Restaurant Wastewater (RW) was collected at the Student Union Building restaurant, University of Ibadan. The study was carried out at the Department of Agricultural and Environmental Engineering Laboratory, at the University of Ibadan. The experimentation site was selected based on its proximity to the laboratory. Ibadan is located in Oyo State, Nigeria with, 7°22’ N Latitude and 3°58’ E of the Greenwich meridian. The metropolitan area lies within between Latitudes 7°15’ and 7°30’ north of the equator, and Longitudes 3°45’ and 4°00’ east of the Greenwich meridian. The study area is within the metropolitan area.

Experiment design and procedure

This study carried out was a lab-scale reactor system, which consisted of an electrolytic cell, a Direct Current power source of model EA-PS7016-400, 0-30V, 0-40A regulator, a magnetic stirrer, four electrodes, aerator and wooden stand (Figure 1). The electrolytic cell composed of a 2-litre plastic transparent beaker. It contains four electrodes of 2 anode electrodes and 2 cathode electrodes of length 150 mm and diameter 15 mm, of which was connected in a mono-polar system, plywood was used as support for the electrodes and rubber which served as insulator between the connecting electrodes. The wastewater was collected in a 20-litre container which was then subjected to an air pump through the use of aerator for a period of 10 minutes to allow floatation to occur on top of the wastewater. The electrolytic cell was mounted on a magnetic stirrer and the magnet was positioned at the bottom centre of the beaker. Four currents namely 0.25, 0.5, 0.75, and 1.0 amp were considered for the experiment. Experimentation was carried out for electrode inter-distance of 10 mm apart. In each reactor, the current was generated through the adjustable DC supply.
The current was left to pass through the solution for a period of 30, 60 and 90 minutes. The sample collected before subjection to electrocoagulation served as the control. During this period of electrocoagulation, the solution was subjected to rapid mixing of 100 rpm with the help of a magnetic stirrer. At the end of each treatment time, some sample was taken and was allowed to settle for 20 minutes and was later analyzed for Chemical Oxygen Demand (COD), Colour, Phosphorus, Soluble Reactive Phosphorus, Phosphorus Pentoxide and Dissolved Oxygen (DO) and Colour. Three replicates were carried out for the experiment.

Results and Discussion

Effect of treatment on colour

Figure 2 revealed that for 0.5 Amp, 30 minutes treatment time had a treatment efficiency of 8.0% which made it the lowest treatment efficiency for the entire treatment when considering colour as a parameter. The highest treatment efficiency of (47.9%) was obtained at 0.5 Amp in 90 minutes of treatment time. The high values in the efficiency could be as a result of closer distance used in the electrodes. The increase in efficiency as a result of the increase in treatment time shows better treatment with longer subjection in the reactor. This corresponds with what was obtained by Ni’am and Othman (2014), which stated that an increase in treatment time results to colour better colour removal. Increasing order of percentage treatment efficiency was seen in all the currents used, at 0.25, 0.5, 0.75 and 1 Amp, which shows that the more time required to treat the wastewater the better the clarity of the water. Similarly, all the treatment time considered does not remove colour pollutant up to 50% efficiency. This does not correspond to what was obtained by Amita (2015) which could be as a result of the aluminium electrodes used by the researcher.

Effect of treatment on particulate phosphorus

In Figure 3, the treatment efficiency was at optimum at 90 minutes of 1.0 Amp (53.3%). The high level of removal as observed in 1.0 Amp throughout the time of treatment and spacing interval could be attributed to the fact that electrocoagulation at high current provides a high dose of coagulant into the reactor.

Effect of treatment on soluble reactive phosphorus

Considering Figure 4, soluble reactive phosphorus, (53.6%) was observed at 1.0 Amp of 90 minutes which was the highest level of treatment. It is also the only treatment time that can be recommended for consideration. A trend of an increase in treatment current and treatment time resulting in an increase in removal efficiency was observed in 60 minutes and 90 minutes. The better treatment could be a result of higher current which enhances the production of ions and more retention time allowed. The removal at 0.75 Amp at 30 minutes treatment time had the least removal efficiency (12%). It was as well noticed that there was an increase at 0.5 Amp at 30 minutes treatment which
could be as a result of an electrical surge. Considering the treatment time, 90 minutes treatment time was observed to have better treatment time in electrode inter distance for soluble reactive phosphorus, which was in line with what Nassef (2012) reported that the highest treatment efficiency was at 90 minutes treatment time.

Effect of treatment on phosphorus pentoxide
Phosphorus Pentoxide had the highest removal at 1.0 Amp of 60 minutes treatment time (39.8 %) as shown in Figure 5. The lowest treatment removal (12.6 %) was noticed at 0.25 Amp of 30 minutes treatment time. This also shows that the system had an effect on the purification of the wastewater to an extent. An increase in current in the reactor created an avenue for deposition of more ions from an element into the solution, which serves as coagulant and as a result provided the means for water purification.

Furthermore, considering 0.25 Amp resulted in poor treatment efficiency which shows that it is not recommended. The chart also revealed that 90 minutes treatment time had the highest pollutant removal which suggests it as the best treatment time. This is similar to what was reported by Nassef (2012) that 90 minutes treatment time was best. This was a result of higher retention time for the subjection of electrodes into the wastewater solution as a result of creating dissolution of the elements into the system.

Effect of treatment on dissolved oxygen
A negative graph was observed in the chart in Figure 6, which shows the opposite direction. An increase in oxygen content resulted in better performance of the system. Minimum treatment efficiency the reason was that oxygen was released during the treatment process which makes the efficiency to increase and as such resulting in a negative value. A trend of reduction in pollutants as a result of an increase in the treatment time was observed in the figure. The minimum level of treatment was observed at current of 0.75 Amp was poor (*5, *10 and *15 %) respectively. (Note that *represent negative value).

Effect of treatment on chemical oxygen demand
Figure 7 shows that chemical oxygen demand removal is not effectively removed by this method of electrocoagulation. This is because the highest level of pollutant removal was 39.1% which corresponds with Neil et al. (2014). The effect of this is the toxicity present in the water which is dangerous for human consumption, and also for agricultural purposes. Varying the treatment time, 90 minutes of treatment time was shown to treat the water better when relating to different currents. Current at 1.0 Amp had higher removal efficiency when compared with other currents, which showed that the current had a little effect on the treatment. This was in-line with what was observed (Katal et al., 2011), which could be as a result of the type of electrode used for the experiment.
Conclusion

At the end of the research, it was observed that the highest treatment efficiency was at 53.6%, which shows that the higher the current, the better the treatment efficiency, and also the carbon electrode treated the wastewater to a reasonable extent.

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