Landfill Leachate Treatment using Plasma-Fenton's Process

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Abstract

A new technique, Plasma Assisted Processing, was used to treat synthetic landfill leachate solutions. The process is based on using cold, liquid plasma as a source of light and radicals in the solutions to reduce the COD load. The advanced plasma process which relies on cold liquid plasma as source of light for radical productions was used as a new technique to treat landfill leachate solutions. The study explores the effectiveness of plasma processing alone and its use in combination with the Fenton catalytic process. The optimum treatment processing conditions were determined for a bench-scale batch reactor. The source operates by using kHz electric fields to create vapour bubbles, through Joule heating, in which the plasma is generated.

This is achieved at low voltages of 300 V by increasing the conductivity of the liquid by adding NaCl. The process involved the use of both Fe^{2+} catalyst and hydrogen peroxide while the plasma process required an additional NaCl diluted solution to promote the electrolysis by increasing the conductivity of the operating solutions. This is achieved at low voltages of 300 V by increasing the conductivity of the liquid by adding NaCl. The results of varying the plasma exposure time and the Fenton catalytic process details will be presented.

Keywords: *Batch Reactor, Landfill Leachate, Fenton Reagent, Solid waste, Plasma technology.*

1. Introduction:

Advanced Plasma Process as new technique was used to treat the synthetic landfill leachate solutions. This process is based on the cold liquid plasma as source of light and radicals in the solutions to reduce the amount of the COD load. In the mean time the study covers the factors affecting plasma process and the combinations between Fenton catalytic process and plasma as integrated new process. The technology and procedure of this treatment process and operation conditions were studied in a bench-scale batch reactor for Fenton catalytic process and plasma unit where the plasma generated to feed the liquid samples by the plasma probe through pulses within different periods of times.

Both processes used Fe^{2+} catalyst and hydrogen peroxide oxidation conditions as Fenton catalytic process. In plasma process the addition of NaCl dilute solution is used to increase the electrolytic activity of the plasma samples in order to increase the conductivity of the solutions and optimizes supporting catalysts.

2. What is Plasma?

In physics and chemistry, plasma is a state of matter similar to gas, in which a certain proportion of its particles are ionized. It is electrically conductive because of the presence of a non negligible number of charge carriers so that it responds strongly to electromagnetic fields. It has properties quite different from those of solids, liquids, or gases and is considered to be a distinct state of matter.

3. Plasma Types

According to the relative temperatures of the electrons, ions and neutral species, plasmas can be classified as "thermal" and "non-thermal". Thermal plasmas have electrons and heavy particles at the same temperature i.e. they are in thermal equilibrium with each other. Non-thermal plasmas have the ions and neutral species at a much lower temperature (normally room temperature) whereas electrons are much "hotter". It is possible to generate non thermal plasma in gas, liquid, and solids for different applications.

There is obviously a benefit for O_3 ozone gas oxidizer generating with plasma as the reactions are induced by the energetic electrons which leads to several advantages when used this plasma. But there increased of the total performance for the whole process when using the light, heat and radicals in addition to the ozone gas generated from the plasma unit with the Fenton catalytic reaction, such as higher removal efficiency. This process need more modification of the whole unit to allow the modelled landfill leachate passing through the plasma light through the pipes to get more effect of plasma radicals not just ozone gas flow.

4. Liquid Plasma Process

The device has different power settings but only the maximum was used here. This is done to maintain consistency, and because at lower settings plasma discharges may not form, or may form intermittently or less consistently. Additionally since the goal of most of the experiments performed is to measure a chemical effect, it is assumed that maximum chemical activity will occur at the highest power setting, and so is usually most suited for this type of experiment.

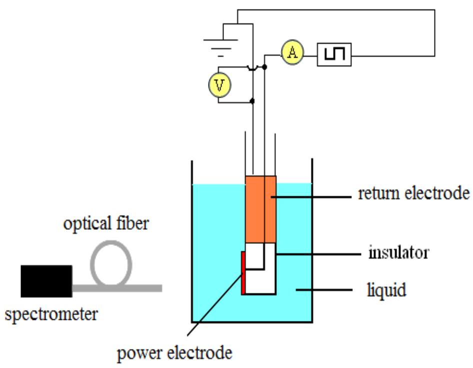


Figure 4.1: Plasma generation unit.

Current and voltage probes enabled the electrical characterisation. The driving circuitry uses transformers to produce 100kHz RF bipolar square wave voltage signals and is capable of drives each electrodes independently. The output voltage is can be varied in 25-30V increments, the current drawn is determined via the various impedance influencing factors dependent on the environment in which the plasma is formed. Such factors include saline conductivity, which in turn depends on temperature and concentration, as well as on the presence of other dissolved or suspended particles, or nearby physical structures, and on the discharge chemistry in each specific instance. From combined electrical and optical measurements in it is noted that luminous plasma discharges are observed at voltages above 175V.

5. Treatment the samples with NaCl

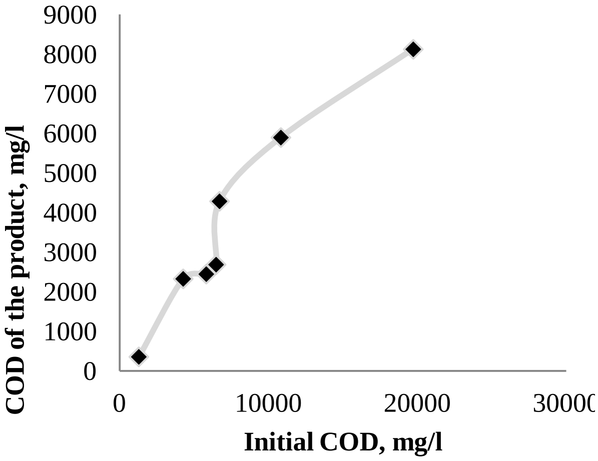
Table (5.1) shows the effect of treatment the samples of NaCl. Before exposing the samples to the plasma process, a solution of sodium chloride (NaCl) with a concentration of 0.9% was added to the fresh samples and the samples after Fenton treatment. The purpose of addition of NaCl solution is to increase the electrolytes ions inside the samples allowing liquid plasma to be operated as full waves through the ions. It is clear from the table that the samples treated with NaCl have higher COD removal at different exposing time to the plasma, in which for initial concentration 1290 mg/l and exposing time 40 sec, the output COD is 250 mg/l and 350 mg/l for NaCl treated samples and the samples without treatment, respectively. This can be attributed to the increase of sample conductivity which allows a suitable media for efficient plasma current generation. A volume of 10 ml of COD samples of 50 % were added to 10 ml of NaCl solution.

Table (5.1): Effect of NaCl treatment on COD removal

COD input feed for all (mg/l)	Expos-ing time (sec)	COD output for samples treated with NaCl (mg/l)	COD output for samples without NaCl treat.(mg/l)
1290	40	250	350
	80	245	344

6. Results and Discussion

However, the COD removal for all processes was nearly the same at the same COD. It is clear from these processes that plasma process work as additional force by generating radicals to enhance the performance of COD reduction.

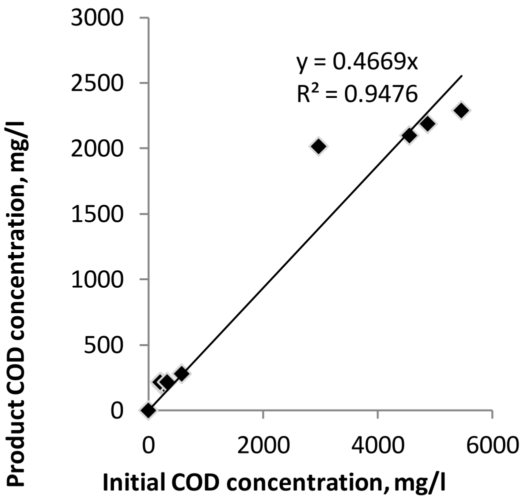


6.1 Effect of the initial concentration on the plasma process:

Fig. (6.2) shows the COD of products from a single plasma process for an exposing time of 40 seconds and initial concentration of the COD in the landfill leachate ranging from 100 to 6000 mg/l. The time of 40 seconds was an average value among the exposing time values of 5 to 80 seconds as described in the following sections. These samples prepared, then directly exposed to the plasma process without any Fenton treatment presages. It is clear from the figure that the relation between the feed and the product concentration is mostly linear with some deviation it could be from the experimental errors or accuracy.

Fig. (6.3) shows the effect of initial COD concentration using constant exposing time of plasma 40 seconds with low COD concentration of modelled leachate in range of 100 mg/l to 600 mg/l. it is clear that a linear relationship between the raw and final concentration as well in low range of COD. Figure (5.8) also shows the effect of initial COD concentration with low COD concentration of modelled leachate in range of 100 mg/l to 600 mg/l using constant exposing time of plasma 40 seconds on the percentage removal. Also it is clear that a linear relationship between the raw and percentage removal in **Fig.**

Fig. 6.1 shows the comparison between the COD of the feed and the product after the Fenton oxidation process as single treatment process. As shown from the figure, it is a linear relation.



(6.2): Effect of initial COD concentration by using constant exposing time of plasma 40 seconds and different concentration of modelled leachate

which as the initial concentration increased the percentage removal increased.

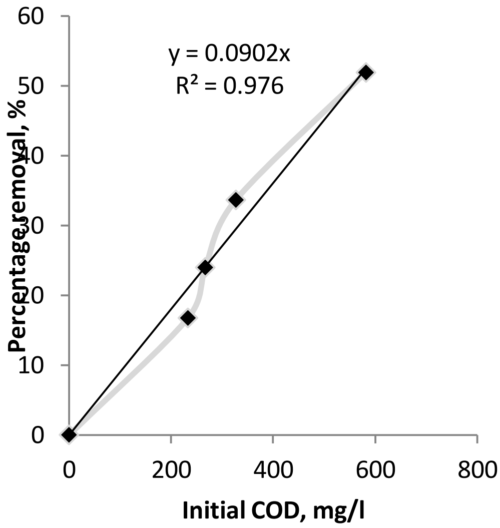


Fig. (6.3): Percentage removal of COD with different concentration and constant plasma time

In the other Figure (6.4) the initial COD concentration of the samples plotted against the raw and final concentrations of the COD samples. This difference in the product to the initial Concentration is increased by the increasing of COD concentrations, where is it as linear relationship between the raw and final concentration.

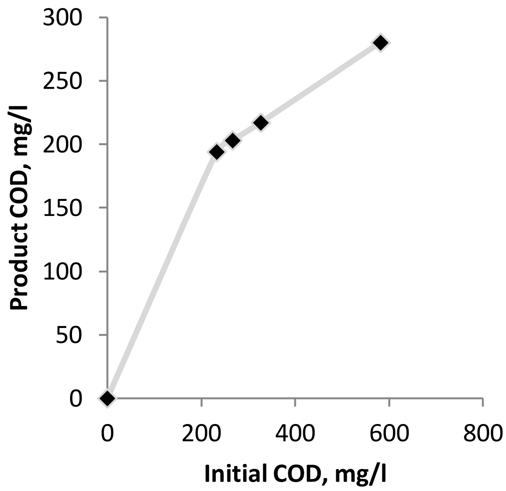


Fig. (6.4): Different concentrations study using (constant plasma rate and exposing time of 40 seconds)

5.2 Effect of exposure time on the plasma process:

In this section, a three sets of initial feed concentration with COD of 1560 mg/l. These sets are about 15 samples, in the average of five samples of each one. The three sample sets composed of five samples each with a raw concentration of COD of 1560 mg/l. The exposure times used for this plasma process are as follows: 5, 10, 20, 40 and 80 seconds. Table (5.3) shows the product COD concentration after exposure at different times of plasma for feed with COD of 1560 mg/l. The purpose of using three sets for each time is to study the reducibility of the data and to take the average for each time. It is clear that the data are reproducible at each time.

The plot of Figure (6.5) also shows that the rate at which this COD is removed by plasma is constant with time which indicates also the feasibility of the plasma process as a single unit of treatment for modelled landfill leachate where the differences between 5-10-20-40-80 seconds of treatment are low and the reduction of COD between 200-550 mg/l within the short period of the effective exposure time. It is clear that there is no effect of the exposure time of plasma to get COD reduction in which case it reduces plasma process cost and increase visibility of the process.

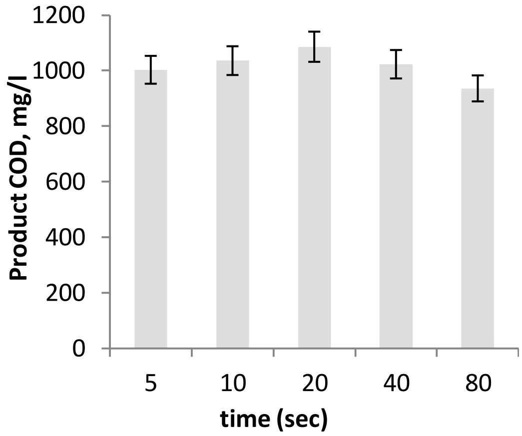


Fig. 6.5: Removal of COD (three sets) by different plasma exposing time (5, 10, 20, 40, and 80 seconds)

The plot of Figure (6.6) also shows that the rate at which this COD is removed by plasma is constant with time which indicates also the feasibility of the plasma process as a single unit of treatment for modelled landfill leachate where the differences between 5-10-20-40-80 seconds of treatment are low and the reduction of COD between 200-550 mg/l within the short period of the effective exposure time. It is clear that there is no effect of the exposure time of plasma to get COD reduction in which case it reduces plasma process cost and increase visibility of the process.

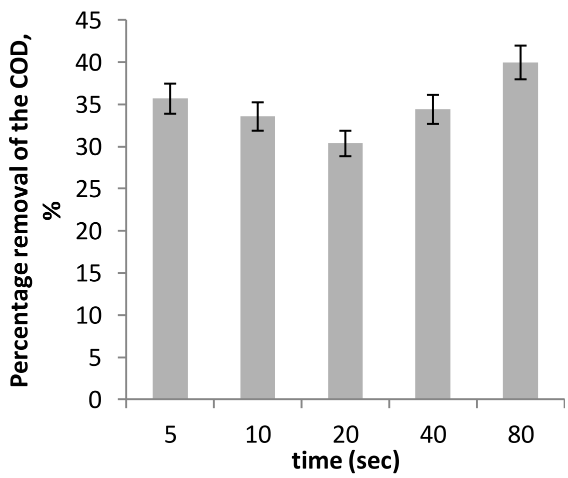


Fig. 6.6: Percentage removal of COD (%) by different plasma exposing time

7. Conclusions:

The main objective of this study was to investigate the combination between the Fenton oxidation and plasma technology to treat the synthetic leachate. Such treatment was examined by a bench-scale batch reactor then exposing the product samples to plasma waves.

Fenton's oxidation was the most effective among all used treatment procedures. The advanced plasma process which relies on cold liquid plasma as source of light for radical productions was used as a new technique to treat landfill leachate solutions. The efficiency of single plasma process and its combination with conventional Fenton catalytic process as an integrated process on COD removal were investigated. The experimental procedure was carried out in a bench-scale batch catalytic reactor where the plasma unit probe was immersed in the liquid phase generating periodic pulses for various periods of time. The process involved the use of both Fe^{2+} catalyst and hydrogen peroxide while the plasma process required an additional NaCl diluted solution to promote the electrolysis by increasing the conductivity of the operating solutions.

Overall, it had been shown in this study that the plasma treatment of leachates was capable generally to reduce the influent concentrations of COD as a new techniques. However, a lot of experimental techniques and more idea’s need to get new advanced liquid plasma unit in the real case at real COD removal from Landfill leachate.

Finally, it would be recommended that different types of oxidation leachate treatment and operation cycles to be used as second stage treatment method and need to examine in order to establish the most efficient configuration of leachate treatment in Batch reactor.

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