Study On Treatment Of Municipal Solid Waste Landfill Leachate By Fenton Process

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Abstract - *Experimental study has been carried out for the treatment of municipal solid waste landfill leachate waste water by fenton process. Hydrogen peroxide and swarf is used as fenton reagent for the oxidation of pollutants. Fenton process is most effective in degradation of biodegradable and non-biodegradable organic matter in landfill leachate. By varying the depth of swarf i.e. 5cm, 10cm and 15cm study has been carried out. Physico-chemical analysis was carried on raw and treated leachate wastewater to know the efficiency of swarf in removing contaminants. The experimental studies reveal that the swarf of 10cm depth is more efficient in removing pollutants when compared to 5cm and 10cm depth of swarf. Finally obtained effluent characteristics are within limit according to Indian standards which can be discharged for land to irrigation.*

Key Words: *Depth of swarf, Fenton process, leachate wastewater, Removal of pollutants.*

1. INTRODUCTION

Due to rapid urbanization and industrial growth led to the formation of municipal, plastic, hazardous and biomedical waste in huge quantities. With the production of waste causes pollution to air, water and soil. In developing countries the rise of municipal solid waste is increasing day by day [1]. The landfill is the most common technology used to dispose municipal solid residues in developing countries [2]. These MSW is dumped on land in more or less uncontrolled manner. An important problem associated with landfill is the production of leachate. Due to natural humidity, rainfall and water present in residue of organic matter generates the production of leachate. Generally leachate contains high concentrations of inorganic ions and soluble organic matter. If leachate is not treated properly and if it is discharged directly in to environment, there will be severe ill effects on soil, water and as well as to mankind. Landfill effluents (leachate) need to be treated on site to meet the standards for its discharge into the server or its direct disposal into surface water [3].

Leachate is a liquid which is drained or leached from landfill. A leachate is generally characterized by a strong odor and a dark color as well as retaining a large number of contaminants [4].It is a mixture of inorganic and organic substances. The concentration and composition of contaminants of leachate is influenced by what kind of landfill waste and its age. Leachate consists of mixture of organic and inorganic compounds associated with pathogenic microorganisms. The treatability of the leachate depends on its composition and characteristics, which are influenced by the type of waste and the age of the landfill [5] [6]. Release of untreated leachate in to environmental cause's harmful effects on human life which lasts for decays. In land filling operation, management and treatment of leachate is an important standard operation. Leachate is classified based on age of landfill as young and old leachate. For young leachate the concentration of COD will be >10,000 mg/l while COD will be less than 30,000 mg/l for landfills older than 10 years [1].

Leachate characteristics mainly depend on the type of waste, age of landfill and moisture content. Based on type of waste leachate may have higher concentration of calcium as well as alkalinity. Landfill leachate which has ash mono fill is dominated by calcium components with varying amounts. Ash mono fill leachate has higher ionic strength which increases the solubility of minerals and decreases the formation of solid particles. MSW and combustion leachate is dominated by higher level of alkalinity [1]. Due to higher level of alkalinity there is a formation of mineral precipitate. The main characteristics of leachate which effects the environment are BOD, COD, ammonia, chloride, pH, manganese and zinc [2].

Leachate acts a medium for transfer of pollutants from landfill in to surface and ground water. Due to infiltration and passage of water through solid waste with combination of chemical, physical and microbial process led to the transfer of pollutants from waste materials in to water and then forming leachate. Leachate has higher organic strength i.e. 100 times more than raw sewage. Due to varieties of waste huge mixture of chemicals are present in leachate. Because of its high range of contaminants, it can destroy huge aquifers through its migration to ground water. Leachate migration can only possible by unlined and no leachate collection systems in landfills. Pollution of leachate can be only avoided by lining of landfills and treatment.

1.1 Suitability of Chemical Oxidation and Advanced Oxidation Process (AOP) for Leachate Treatment.

When leachate has toxic substances and soluble organic non-biodegradable substances then chemical oxidation is used. Chemical treatment methods based on production of hydroxyl radical ($OH^{\cdot}$) are known as advanced oxidation processes [7]. In past few decades, advanced oxidation process (AOP) is used for the wastewater treatment. It helps to remove the color and organic load from leachate [8]. Fenton's reagent is defined as the catalytic generation of hydroxyl radicals (•OH) resulting from the chain reaction between ferrous ion and hydrogen peroxide, and the oxidation of organic compounds (RH) by Fenton's reagent [9]. The oxidants used are calcium hydrochloride, potassium permanganate, ozone and chlorine is used. By this process COD is removed up to 21% -51%. The limitations of conventional treatment can be overcome by application of Advanced Oxidization Process. The main aim of the AOPs design is to generate and use hydroxyl free radical ($OH^{\cdot}$) as strong oxidant to destroy compounds that cannot be done by conventional treatment methods. The generated oxidants contribute for the removal of contaminants. So the generated oxidant has to be accelerated by combining ultrasound, electron beam irradiation UV radiation, TiO_2, H_2O_2 and O_3. For the effective oxidation of organic pollutants a method known as Fenton's reagent is used. Fenton's reagent is a mixture of ferrous iron and hydrogen peroxide. In order to produce very reactive hydroxyl radicals hydrogen peroxide is catalyzed by iron (II)

$$Fe^{+2} + H_2O_2 \rightarrow Fe^{+3} + OH^{-} + OH^{\cdot} \quad \text{----------------------} (1.1)$$

Fluorine and hydroxyl radicals are among common oxidants that could react rapidly and non- selectively with nearly all organic pollutants. The concentration of hydroxyl free radical ($OH^{\cdot}$) determines the removal of pollutants in the environment and they are called as "Mother nature's vacuum cleaner". Based on pH, time, H_2O_2 and Fe^{+2} concentrations determine the efficiency of Fenton's oxidation. Fenton's oxidation found effective for the removal of other industrial waste water components.

Therefore landfill leachate has to be treated on site to meet the standards for its discharge. Due to leachate complexity, its treatment is a world's problem existed for some time, but a universal solution has not been found. Under emerging cleaner production technologies application of Advanced Oxidation methods are considered to enhance the treatment of landfill leachate. The main objective of the present study is to explore fenton process which removes contaminants from landfill leachate wastewater and to determine the removal efficiency with varying swarf in Fenton process.

2. Materials and Methodology

2.1 Materials required

For experimental study following materials were obtained.

1. Reactor body: PVC pipe reactor is purchased from supplier.
2. Chemicals: Laboratory grade Hydrogen peroxide and swarf are used from laboratory.
3. Gravels are purchased from construction material suppliers.
4. Leachate is collected from Municipal solid waste disposal site at Turmurai, Belagavi.

2.2 Catalyst (swarf)

Hydrogen sulphate and sodium hydroxide used for the pH adjustment is of analytical grade. Swarf acts as a catalyst. Source of swarf is the metal sawing and particle size is 05-2.5mm. In order to activate hydrogen peroxide, swarf acts as a heterogeneous catalyst with wastewater. Iron ions are leached from solid materials when swarf is used as solid catalyst. To activate hydrogen peroxide to produce hydroxyl radicals by iron ions act as homogeneous catalyst in Fenton reaction. Chemical constituent used as catalyst is shown in table 3.1.

Table 2.1: Chemical constitution of the steel used as a catalyst (swarf)

Sl. no.	Chemical Constitution (%)			
1.	Copper	Manganese	Silicon	Specific gravity
2.	0.40-0.50	0.60-0.90	0.04-0.45	0.070

For the production of hydroxyl radicals there are three important mechanisms which as follows

- Swarf is dissolute and Fe^{2+} ions are released,
- Activation of hydrogen peroxide and release of $OH^{\cdot}$ radicals and
- Oxidation process.

Release of Fe^{2+} ions take place in acidic conditions. For the initial step to take place iron ions has to dissolute from swarf where oxidation of pollutants occurs. During the process of oxidation the initial Fe^{2+} ions are consumed to treat the contaminants and oxidation process will depend on dissolution of iron ions.

2.3 Reactor

A bench scale reactor was setup in the laboratory as shown in figure 2.1.column with diameter of 140mm and height 304.8mm. Swarf was filled up to above the sand layer up to 5cm, 10cm and 15cm depth in the column. The column has an inlet to feed and outlet to withdraw the effluent. A suitable capacity of glass beaker was used to collect the waste water from the column.

2.4 Column Study

The column study was done using 5, 10 and 15cm bed with swarf as catalyst. The sample is prepared for 150 mg H_2O_2 was added for one liter of leachate. The prepared solution is fed in to the reactor at constant flow rates of 4ml/min by using peristaltic pump. And the prepared solution is kept constant for a pH 3 with the help of adding H_2SO_4.After the preparation of sample the gravels are placed at the bottom of rector and then sand above gravel layer. The swarf of 5, 10 and 15cm depth is placed above sand layer. For every 30 minutes the samples were withdrawn and added 0.1 NaOH to maintain pH 9 in order to prevent further generation of hydroxyl radicals through the Fenton process

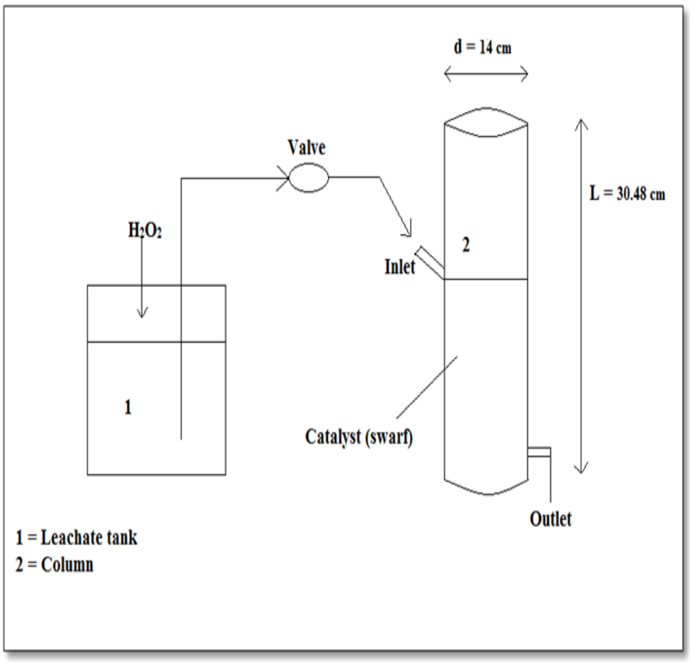

Fig 2.1: Schematic flow diagram of experimental set-up of the Fenton reactor

2.5 Characterization of Leachate

About 20 liter of leachate sample was collected from landfill site. The parameters analyzed were pH, colour, TSS, TDS, Total solids (TS), BOD and COD, sulphates, turbidity.

Table 2.2: Physico-chemical characteristics of raw leachate.

Sl.No.	Parameters Tested	Units	Values
1.	pH	---	8.5
2.	Colour	---	blackish brown
3.	Total Dissolved Solids (TDS)	mg/l	11470
4.	Total Solids (TS)	mg/l	17820
5.	BOD_5 @ 20^0C	mg/l	3540
6.	COD	mg/l	9620
7.	Total Suspended Solids (TSS)	mg/l	6350
8.	Sulphates	mg/l	175
9.	Turbidity	NTU	140

3. Results and Discussions

Analysis of the obtained treated leachate has been done to know the treatment feasibilities on landfill leachate by Fenton process. The results obtained after the treatment of leachate from reactor are analyzed for its physico-chemical characteristics such as Total Solids (TS), BOD_5@20^0C, and COD for 5cm, 10 cm and 15cm depth of swarf as per Standard methods. The loading rate of leachate sample is maintained at 4ml/minute for the entire experiment and samples are connected for every 30 minutes. The obtained results of the above said parameters have been presented in graphical and tabular form.

BOD is the measure of oxygen required by microorganisms to oxidize the organic matter present in wastewater under aerobic condition. BOD test is carried out in laboratory using BOD incubator maintained at 20^0C for 5 days. It is observed that raw leachate waste water is having a BOD of 3540 mg/l has been reduced considerably in 10cm swarf when compared to 5cm and 15 cm bed of swarf. The details of results are shown in figure3.6. BOD is reduced to 470mg/l.

COD is the oxygen required for chemical oxidation of organic and inorganic impurities. COD test is carried out in laboratory using COD digester. It is observed that the raw leachate waste water having a COD of 9620 mg/l has been reduced to 470mg/l in 5cm swarf, 240mg/l in 10cm swarf and 750mg/l in 15cm swarf. The details of results are shown in figure 3.7.

A total solid is the matter or substance that remains as residue upon evaporation to 103^0C to 105^0C for 15 minutes. It is observed that raw leachate waste water having TS of 17820mg/l have been reduced to 470mg/l in 10cm, 750mg/l in 5cm and 550mg/l in 15cm swarf depth. The details of results obtained as shown in figure 3.1.

Total Suspended Solids is that which cannot be filtered out on an asbestos mat or filter paper i.e. suspended solids is a non-filterable solids. It is observed that raw leachate wastewater having a TSS of 6350mg/l have been reduced to 310mg/l in 5cm, 16mg/l in 10cm and 220mg/l in 15cm swarf depth. The detail of results obtained is as shown in figure 3.2.

Total Dissolved Solids contains both organic and inorganic molecules and ions. These are those which can be filtered out on an asbestos mat or filter paper. It is observed that raw leachate wastewater having a TDS of 11470mg/l have been reduced to 440mg/l in 5cm, 310mg/l in 10cm and in 330mg/l in 15cm swarf depth. The detail of results obtained is shown in figure 3.3.

Sulphates are usually present in leachate wastewater because of solid waste. Sulphates are formed due to decomposition of sulphur containing substance in wastewater. The sulphates ions occur naturally in most water supplies and hence they are also present in wastewater. Sulphate test is done in laboratory using Nephelo-Turbidity meter. It is observed that raw leachate wastewater having a sulphate of 175mg/l and it is reduced to 70mg/l in 5cm, 50mg/l in 10cm and 61mg/l in 10cm swarf depth. The details of results are shown in figure 3.5.

Turbidity is the expression of optical property by which light is scattered by the colloidal particles present in wastewater. Turbidity test is conducted in laboratory using turbidity meter. It is observed that the raw leachate sample has a turbidity of 140 NTU and it has been reduced to 16 NTU in 5cm, 12NTU in 10cm and 13NTU in 15cm swarf depth. The details of results are shown in figure 3.4.

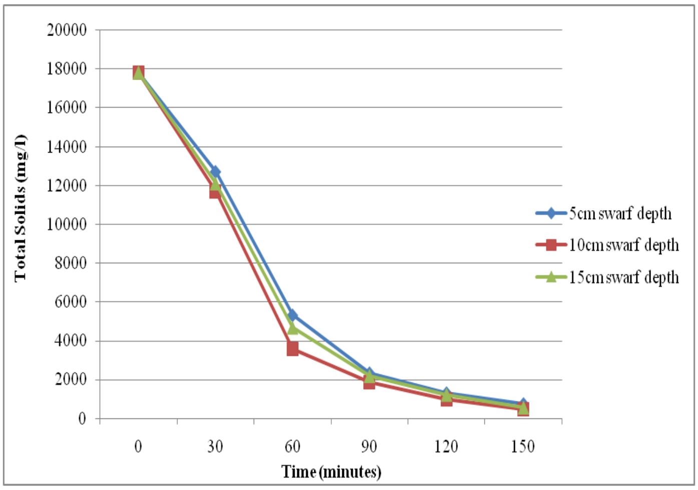

Fig 3.1: Variations of Total solids in 5cm, 10cm and 15cm swarf depth.

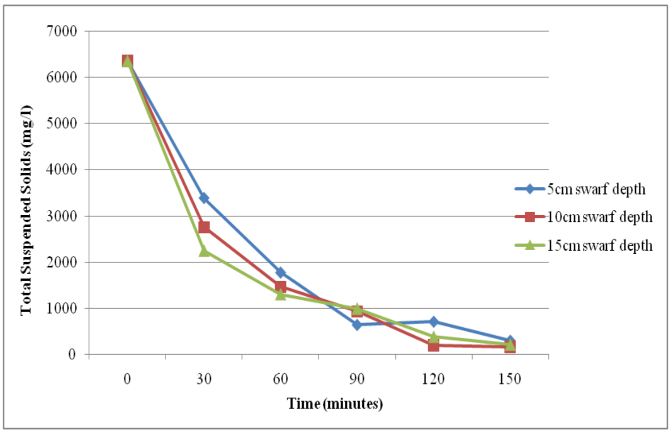

Fig 3.2: Variations of Total Suspended Solids in 5cm, 10cm and 15cm swarf depth.

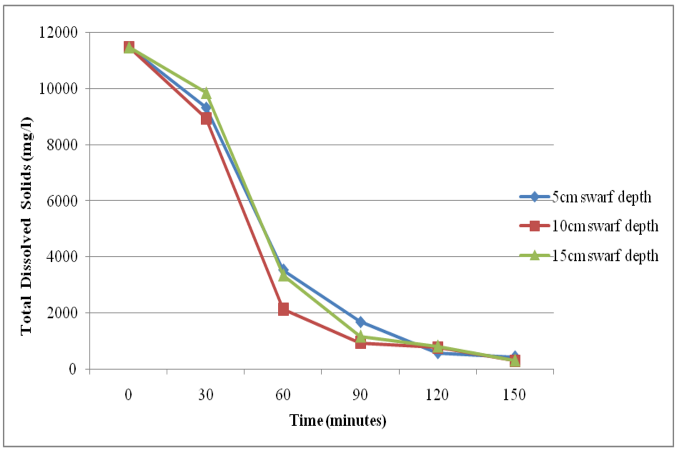

Fig 3.3: Variations of Total Dissolved Solids in 5cm, 10cm, 15cm swarf depth.

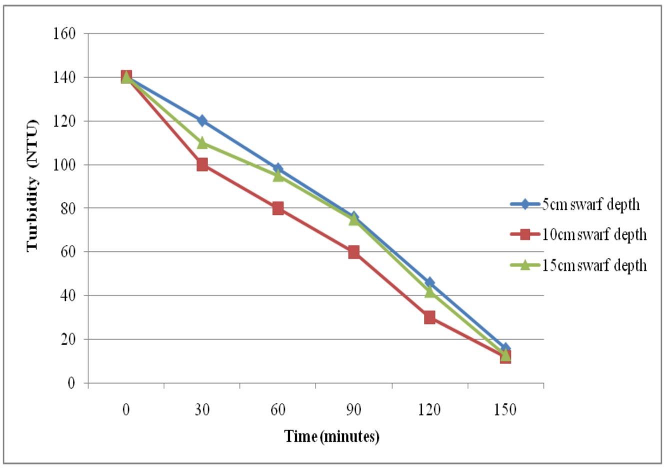

Fig 3.4: Variations of Turbidity values in 5cm, 10cm and 15cm swarf depth.

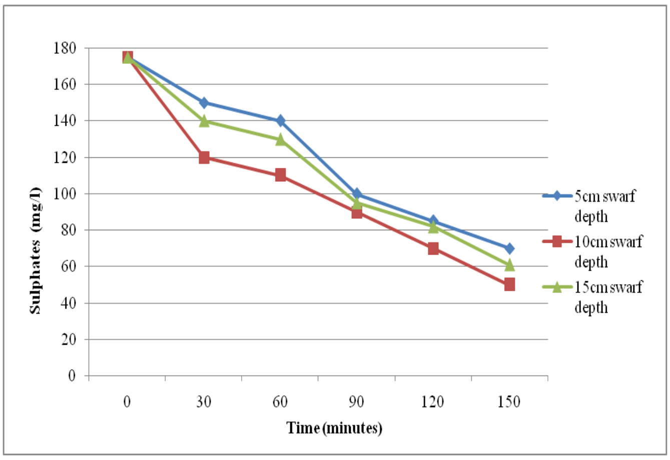

Fig 3.5: Variations of Sulphates in 5cm, 10cm and 15cm swarf depth.

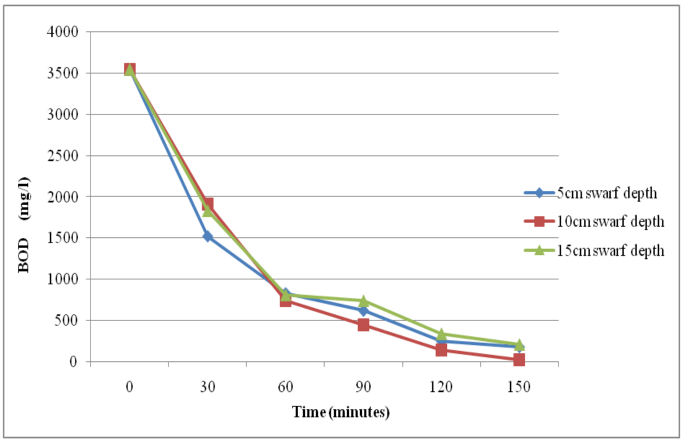

Fig 3.6: Variations of BOD values in 5cm, 10cm and 15cm swarf depth.

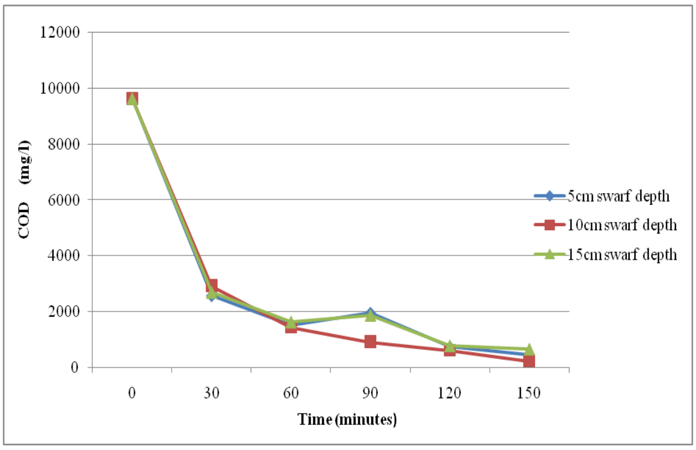

Fig 3.7: Variations of COD values in 5cm, 10cm and 15cm swarf depth.

4. Conclusions and Future Scope

The sample of leachate were collected and analyzed for its characteristics such as BOD_5@ 20^0C, COD, sulphates, Turbidity, Total solids, Total dissolved solids, Total suspended solids, to estimate its pollution potential. It is estimated that the sample of leachate contains high amount of organic and inorganic substance beyond the permissible limits. Therefore the leachate has to undergo treatment to reduce the pollutants before discharging in to receiving system. Fenton process is most effective in degradation of biodegradable and non-biodegradable organic matter in landfill leachate.

The sample of leachate is collected from MSW disposal site at Turmurai and was treated by fenton process using 5cm, 10cm and 15cm swarf depth. Fenton treatment at optimized conditions (pH3, Flow rate at 4ml/min, reaction time 30min) removed 180mg/l of BOD, 470mg/l of COD, 750mg/l of TS, 440mg/l of TDS, 310mg/l of TSS, 70mg/l of sulphates, 16NTU of Turbidity, 28mg/l of BOD, 240 mg/l of COD, 470mg/l of TS,310mg/l of TDS, 160mg/l of TSS, 50mg/l of sulphates, 12NTU of turbidity and 210mg/l of BOD, 660mg/l of COD, 550mg/l of TS, 220mg/l of TSS, 330mg/l of TDS, 13NTU of turbidity, 61mg/l of sulphates for 5cm,10cm and 15cm swarf depth respectively. Removal of pollutants is high for 10cm swarf when compared to 5cm and 15cm swarf depth. The obtained final effluents characteristics from table 4.1 show that the treated leachate can be utilized to land for irrigation purposes.

4.1 Scope of future work

- Removal efficiency of colour, Nitrates and heavy metals such as lead, chromium, mercury etc can be analyzed.
- By varying flow rates removal efficiency of pollutants can be analyzed.
- Analysis can be done by using up-flow reactors.
- By multiple feeding of fentons reagent at regular intervals analysis can be carried out.
- Removal efficiency by 2cm, 4cm, and 6cm bed of swarf can be taken and analyzed.

Table 4.1 Evaluation of performance of results obtained from Fenton process based on relevant Indian Standards.

Sl.no.	Parameters	Final Effluent Characteristics (mg/l)	General standards for discharge of Environmental pollutants Part A: effluents (schedule 6) as per the Environment protective rules, 1986, Govt. of India	
			In to Surface water	To land for irrigation
1.	BOD	28	<30	<100
2.	COD	240	<250	-----
3.	TSS	160	<100	<200
4.	Sulphates	50	<1000	<1000

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