SIMULTANEOUS DISINFECTION AND REDUCTION OF TRACE HEAVY METALS AND COD FROM HOSPITAL WASTEWATER BY ADVANCED OXIDATION TECHNIQUES

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Abstract - *In this study, photo Fenton process was adopted for the treatment of hospital wastewater with an objective of reducing the chemical oxygen demand (COD), heavy metals and coliform in wastewater. The optimal conditions for the reduction of COD were observed at pH 3, Fe^{2+} dosage of 400 mg/l, and H_2O_2 dosage of 500 mg/l. Under such conditions, the maximum COD removal was 94% at a hydraulic retention time of 90 min. Application of UV irradiation for the optimum fenton condition showed potential capacity for disinfection and removal of heavy metals. The photo fenton method yielded the best results, removing the heavy metals completely and also reducing MPN/100ml of 1.1×10^4 to values less than 2. The proposed Photo fenton method can be considered operationally advantageous which met the requirements of the discharge standard.*

Key Words: hospital wastewater, photo Fenton process, COD removal, heavy metals, disinfection

1. INTRODUCTION

Waste in general is any substance such as solid, liquid or gas which has no direct use and is discarded permanently. According to Department of Environment (DOE) in 2009, hospitals, clinics, pharmacies and nursing homes are referred as health care establishment and care has to take to avoid hazardous wastes let into the environment. Hospitals consume an important volume of water a day. Both liquid and solid wastes are generated in hospitals and it is difficult to manage these kinds of wastes in the premises. These effluents are loaded with number of toxic chemicals, radioactive elements, pathogenic organisms and pharmaceutical partially metabolised elements. Hence it is necessary to take precautionary measures to avoid hazardous wastes let into the environment by applying proper treatment technology and disposal methods (Mohankumar and Kottaiveeran, 2011).

Hospitals consume water for domestic applications on an average of 400-1200 litre per day per bed. In hospitals, the water consumed in different units such as clinics, operation rooms, laundry units, laboratories, kitchen, health services and administrative units which later converted as wastewater generation. Hospitals generate on average 750 litres of wastewater per bed per day. By leaving the wastewater treatment plants, these chemical substances will imbalance the natural environment by letting nature into toxic area (Amouei et al., 2012). Before discharging healthcare wastewater to municipal treatment, it is necessary to pre-treat the wastewater and discharge to the plant.

The effluents generated from health care units will account load on natural environmental system. Hence there is a great burden in maintaining wastewater management in hospital sectors which will lead to point source pollution problems in the society. In order to comply with wastewater legislations and guidelines, wastewater must be treated before discharge. This can be achieved through appropriate treatment methods and technologies which will minimize risks on public health and environment.

Hence there is the need for careful planning with suitable treatment technologies and regular monitoring of plant units (Eze and Onwurah, 2015). Despite the growing concern over hospital waste management, scant attention is paid on discharge of hospital wastewater from various sectors of health care units and hence advance wastewater management is necessary to improve the pollutant discharge into the sewers. In case of health care wastewater, the concerns are to avoid spread of bacteria, viruses and parasite eggs. The Table 1 represents the wastewater discharge standards as prescribed by KSPCB.

Table 1: Liquid Waste Standards

Parameters	Permissible limits
pH	6.3-9
COD, mg/L	250
BOD, mg/L	30
Suspended Solids, mg/L	100
Oil and grease	10
Bio assay test	90 % survival of fish after 96 hours

1.1 General Characteristics of Hospital Effluents

Hospital wastewaters contain antibiotics, toxic chemicals, radioactive elements, pathogenic organisms and pharmaceutical partially metabolized elements and enteric pathogens. Hospital wastewater contains organic chemicals which have relatively low BOD/COD ratio which will indicates that wastewater is non-biodegradable in nature (Beyene and Redaie, 2011). Health care units discharges wide amount of toxic chemicals, substances and microbial agents in their wastewater. They end up in surface waters where they can influence aquatic ecosystem which imbalances the food chain. Besides recalcitrant and potent chemicals, hospitals discharge plenty of undesired potentially pathogenic (Pauwels and Verstraete, 2006).

1.2 Environmental and Health risk associated by Hospital wastewater

It is essential to establish a waste management system in hospitals to evaluate waste generated in quantities. Hospitals represent an incontestable release source of many chemicals compounds in their wastewater which will impact on public health and environment. Hospital wastewater samples are very often different in nature. Hospital wastewater contains microorganisms which can cause outbreaks of diarrhoea and diseases like cholera (Rezaee et al., 2005). The presence of hospital pollutants in aquatic ecosystem will lead to high risk and imbalances the ecosystem system (Azmal, 2014).

The main environmental issues concerning in India is discharging of hospital wastewater into municipal sewer network without any preliminary treatment. Unused medications and expired medicines sometimes are also disposed into the drains. The hospital wastewaters are more toxic and polluted when compare to municipal wastewater and hence proper treatment is essential for its treatment process to avoid effect on humans and environment (PEQ) (Mahesh et al., 2014).

The authorities responsible for hospital management and environmental health should address these aspects urgently and proper legislative actions are warranted. There is a need to develop a matrix of treatment scenarios for hospital wastewater, both with respect to attainable efficiency and costs per m^3 of water treated. Hospital waste management is an essential factor in both developed and developing countries. Waste reduction is an important term for hospital development and sustainability. Therefore it is essential to improve and maintain standard waste management in health care units which reduces pollutant load on society and environment (Suwasono, 2013)

1.3 Present Treatment Technology for Hospital Wastewater Treatment

Many numbers of new technologies are developing for treating hospital wastewater in all over the world to have a greater removal efficiency of pollutants. There are large number of techniques and technologies available for treatment of wastewater.

The hospital wastewater may contain various potential hazardous material require special attention, hence proper treatment and disposal is essential. The various number of treatment technologies includes Extended Aeration, Activated sludge process, Membrane bioreactor, advanced oxidation etc.

- Health care units should adapt integrated waste management system for wastewater treatment which helps in reducing the pollutant load and proper monitoring of treatment units should be proposed under policies and guidelines set by the government.
- Although each of these techniques/ technologies have their own advantages and disadvantages. An attempt has been made for selection of suitable treatment technology among the widely used technologies in domestic wastewater including hospital. It is essential to evaluate removal efficiency, operating costs and maintenance costs while designing treatment units.

A variety of wastewater treatment techniques including physical or physicochemical, chemical and conventional biological process are available for the treatment of effluent. The most commonly used physico-chemical treatment process is chemical coagulation in which a coagulant is added to the wastewater and allows the formation of flocs for the removal of pollutants (Jafrudeen and Ahsan, 2012).

1.4 Advanced Oxidation Process (AOP)

Treatment of hospital wastewater can be carried out by various physical, chemical and biological methods. Removal of various organic and inorganic substances can be removed by advanced treatment methods such as by addition of Fenton reagents to wastewater for their higher removal efficiency. If the wastewater is characterized by high concentration of COD and relatively low concentration of BOD/COD ratio can easily be treated by Advanced Oxidation Process. The use of AOPs can be widely used for high strength wastewater. This method can be coupled with other physico-chemical treatment for higher removal of pollutants (Kulkarni and Kherde, 2015). Advanced oxidation methods are very effective alternative for treatment of wastewater. For effective treatment of hospital wastewater, various oxidising reagents such as Fenton reagents, Hydrogen peroxide and TiO_2 catalyst can be used for effective removal of pollutants.

Electro Fenton and Photo Electro Fenton methods were used successfully for wastewater treatment. Advanced oxidation UV-H_2O_2 process for micro pollutant removal was also effective.

Due to the increasing species and amount of toxic and bio refractory organic pollutants in wastewater, great attention has been paid to one of the advanced oxidation processes such as Fenton and Electro Fenton methods. AOPs are emerging and promising technology as an alternative treatment to conventional wastewater treatment methods. The simplest Fenton process requires an acidic medium and Hydrogen peroxide is one of the most popular non-selective oxidizing agents which favor high pollutants removal efficiency.

2. MATERIALS AND METHODS

2.1 Wastewater Source and Sampling

Hospital wastewater was obtained from one of the major private hospital in mysuru city, Karnataka, India. The treatment system consisting of a grit chamber, carrousel bio reactor, secondary clarifier, aerobic digester and chlorination tank, treatment plant has a capacity of $1000m^3/d$. The wastewater used for the experiment was collected at the outlet of the grit chamber in pre cleaned, sterilized glass bottles that were transported to laboratory and stored at 4°C until testing. Samples were taken during maximal activity periods, usually 8:00 am-6:00pm in hospitals in the month of January, march and may .The sample was collected continuously for 5d at regular times due to large variations in concentration.

2.2 Wastewater analysis

Following wastewater parameters were measured during the study:

- pH
- COD
- Total coliform
- Fecal streptococcus
- Fecal coliform
- Heavy metals (Al, Cr, Fe, Ni and Zn)

2.3 Chemicals

All reagents used in this experiment were of analytical grade and used as received without further purification. The chemicals used in this study are hydrogen peroxide (H2O2 30% w/v), ferrous sulphate heptahydrate (FeSO4·7H2O), sodium thiosulphate (Na2O3S2), sulphuric acid (H2SO4), potassium dichromate (Cr2K2O7), mercuric sulphate (HgSO4), ferrous ammonium sulphate (Fe(NH4)2(SO4)2·6H2O) and sodium hydroxide (NaOH) were purchased from NICE chemicals (India).

2.4 Fenton Process

Experiments were carried out in 1 L glass jars using jar test apparatus with a wastewater volume of 1 L. For Fenton reagent (Iron and Hydrogen peroxide), ferrous sulphate heptahydrate was used as a source of Iron (in the crystalline form) and 30 % w/v hydrogen peroxide was used. To conduct the experiment, wastewater was brought to room temperature and iron source was added to the wastewater and it was mixed in jar apparatus for 10 min and then hydrogen peroxide was added and the reaction mixture was agitated for known intervals of time. In all the experiments the time of addition of hydrogen peroxide is considered as the start of Fenton's reaction. All Fenton experiments were carried out with a mixing speed of 100 RPM.

In Fenton oxidation, the pH value has to be in the acidic range to generate the maximum amount of hydroxyl radicals to oxidize organic compounds. However, pH value should not be too low since at very low pH values (<2.0) the reaction is slowed down due to the formation of complex iron species and formation of H_3O_2 ion. On the other hand, at high pH (pH > 4), the generation of hydroxyl radicals gets slower because of the formation of the ferric-hydroxo complexes. Therefore, the initial pH value has to be between 2 and 4 to generate the maximum amount of hydroxyl radicals to oxidize organic compounds. (umadevi,2015)

Hence the pH was controlled at 3 with H_2SO_4 throughout the experiment. At the end of each reaction time i.e for every 30 min time interval, samples were analyzed for COD

Fig – 1: Fenton process using jar test apparatus

2.5 Photo-Fenton Process

The photo-fenton process was carried out in 2.5L batch reactor using a wastewater volume of 1L. 11 W Ultraviolet lamp was used as UV light source which was surrounded by Quartz glass tube as jacket for lamp were immersed in a wastewater sample at the center of a cylindrical glass reactor in axial position. The reaction solution was stirred with a magnetic stirrer using a constant speed at 150 rpm to maintain a well-mixed solution during the experiments. Before turning on the UV lamp, the wastewater was placed in the dark, covered with black cardboard, and the solution was adjusted to the desired pH. The addition of optimum dosage of photo catalysts (Fe^{2+}/H_2O_2) was added to the hospital wastewater only at the beginning of irradiation process in the batch mode. The study was conducted for intervals of 120 min, where for every 30 min interval samples were drawn and analyzed for microbial and heavy metals parameters respectively.

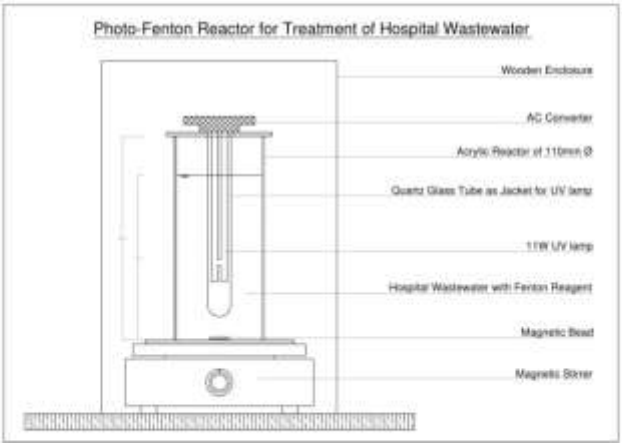

Fig – 2: Photo-Fenton Reactor

3. RESULTS AND DISCUSSION

Table – 2: Characteristics of Raw Wastewater

Parameters	Values
pH	6.56
COD	4040
Total coliform	≥110000
Fecal coliform	≥1100
Fecal streptococcus	≥1100
Al	1.65
Cr	0.01
Cu	0.01
Fe	4.3
Ni	NIL
Zn	4.2

3.1 Effect of Fe2+ Dosage

To determine the effect of Fe^{2+} dosage, the degradation of hospital wastewater was investigated by varying Fe^{2+} dosage from 100 to 600 mg. Maximum COD removal of 78% was observed for Fe^{2+} dosage of 400 mg (Chart-1). When the Fe^{2+} dosage was increased from 100 to 400 mg, the COD removal efficiency increases from 10% to 78% it may be due to increased production of hydroxyl radical. This indicates Fe^{2+} as catalyst can significantly accelerate the decomposition of H^2O^2 to form $HO^\cdot$ radicals. Further increase in Fe^{2+} dosage above 400 mg, COD removal efficiency remains constant and plateau. This may be due to the scavenging effect of Fe^{2+} and consequently, the $HO^\cdot$ radicals concentration decreased dramatically. The low COD removal at low Fe^{2+} concentration might be due to the side reaction between H_2O_2 and $HO^\cdot$ that not much Fe^{2+} react with the H_2O_2. Thus, the amount of $HO^\cdot$ reacting with the other organic pollutants in the wastewater was reduced

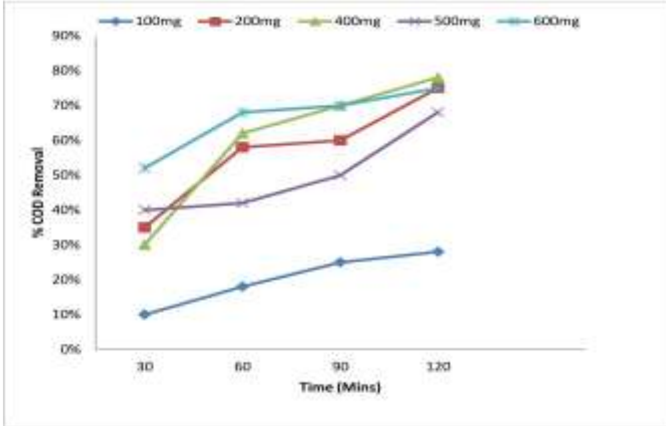

Chart -1: effect of Fe^{2+} on COD Removal (pH=3, H_2o_2=400mg/l)

3.2 Effect of H_2O_2 Concentration

To maintain efficiency, it is necessary to choose the optimum concentration of H_2O_2. The effect of addition of 100–600 mg H_2O_2 on the COD removal is shown in Chart-2. From the chart, it can be seen clearly that efficiency was increased from 78 to 94% when H_2O_2 concentration is increased from 100 to 600 mg. Above this critical concentration, the COD removal decreases or remains constant as a result of the scavenging effect. Also more H_2O_2 molecules are available for Fe^{2+} ions to react, which increase the number of HO radicals. The excess H_2O_2 reacts with the hydroxyl radicals earlier formed and hence acts as an inhibiting agent of degradation by consuming the hydroxyl radical. It was also observed that the process was very fast in the beginning of the reaction and it was due to the exhaustion of H_2O_2. There was no significant difference in the COD removal efficiency of 500 and 600 mg H_2O_2 dosage. Therefore, it was not worth taking of large amounts of H_2O_2 dosage for increasing degradation. Hence, lower dose of 500 mg of H_2O_2 was taken as the optimum dosage in which 94% COD removal were achieved.

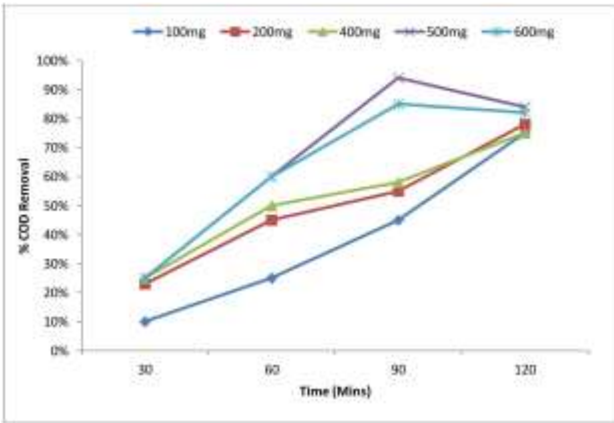

Chart -2: Effect of H_2O_2 on COD Removal (pH=3, Fe^{2+}=400mg)

3.3 Effect of UV Treatment

As shown in Table 3 and 4 indicate the Disinfection by using 11w UV lamp with irradiation time, Optimum condition have been studied for maximum disinfection and heavy metals removal for wastewater using 11W UV lamp, maintaining the speed 50 RPM and pH 3 and reaction time of 0 minutes to 120 minutes. The faecal coliform, faecal streptococci, and total coliform, and heavy metals were analyzed at every 30mins of time interval. Here the best optimum disinfection found at 60 minutes. The percentage removal of TC, FS and FC are 99.72% at 60 mins.

The rate of initiation of photo catalysis and electron-hole formation in the photochemical reaction is strongly dependent on the irradiation time. While increasing the time of exposure of incident light, the probabilities of excitation of electrons as well as the re-excitation of recombined electrons increase. Hence, increase in the degradation is observed with increase in the irradiation time.

Table 3: Disinfection of Hospital Wastewater by Using 11w UV Lamp (H_2O_2=500mg, Fe^{2+}=400mg and pH=3)

Parameter (MPN/100ml)	0^{th} min	30^{th} min	60^{th} min	90^{th} min	120^{th} min
Total coliform	≥110000	300	300	300	300
Fecal streptoco ccus	≥1100	23	3	3	3
Fecal coliform	≥1100	3.6	3	3	3

Table 4: Heavy Metals Removed by Using Photo Fenton Process (H_2O_2=500mg, Fe^{2+}=400mg and pH=3)

Heavy Metals	0^{th} min	30^{th} min	60^{th} min	90^{th} min
Al	1.8	0.02	NIL	-
Cr	0.01	NIL	NIL	-
Cu	NIL	NIL	NIL	-
Fe	4.2	0.2	NIL	-
Ni	NIL	NIL	NIL	-
Zn	4.5	0.45	NIL	-

4. CONCLUSIONS

Photo Fenton process can be utilized in wastewater treatment for overall organic content such as COD reduction, heavy metal removal and disinfection. Reaction generally occurs in chemical and biological systems as well as in the natural environment. It is successfully used in environment protection. OH radical is a major species in the Fenton reaction causing oxidation. Fenton represents a useful solution in many cases where the presence of recalcitrant and toxic pollutants discards the use of conventional biological treatments.

In this study, the performance of photo-Fenton processes on the degradation of pollutant was analyzed. It can be concluded that the degradation is strongly dependant on Fe^{2+} concentration, H_2O_2 concentration, UV irradiation time, initial COD and pH. COD removal efficiency for Fenton process at the optimum conditions of pH 3, Fe^{2+} =400 mg, H_2O_2=500 mg was 94% after 90 min of treatment. Under the optimum condition of fenton process, 99% removal of Tc, FC and FS and complete degradation of heavy meats was achieved by introduction of UV light source for time period of 60 min.

From the overall results of this study, it may conclude that the Photo Fenton process is effective method to treat hospital wastewater, allowing a satisfactory decrease of COD, heavy metal and coliform and helps to maintain the standards to some extent.

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BIOGRAPHIES

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