RESEARCH ARTICLE

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Fenton Process - A Pretreatment option for Hospital Waste Water

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Abstract: The treatment of wastewater with non-biodegradable organic compounds can be done by advanced oxidation processes such as Fenton, Photo Fenton and Photo Oxidation. These processes use iron and hydrogen peroxide as reagents to produce reactive hydroxyl radicals that break down organic pollutants into harmless substances. The Fenton reaction is fast, cheap, non-toxic and easy to operate compared to other advanced oxidation processes. This study explores the use of Fenton reaction as a pre-treatment method for hospital wastewater. The main goal of this study is to assess the increase in biodegradability of pollutants in hospital wastewater by using the photo-Fenton process. The wastewater samples were taken from Korambayil Memorial Hospital, Malappuram, Kerala. The physical and chemical properties of the wastewater were examined. The process variables were optimized by conducting experiments with different doses. The efficiency of the process was evaluated under different operating conditions. The optimal conditions for applying the photo-Fenton process to hospital wastewater are presented for the design of the treatment process.

Keywords: Fenton Process, Waste water management, Pollution control, Biodegradability

1. Introduction

Hospital waste management is a global concern because hospitals produce a lot of medical waste every year. The use of disinfectants in hospitals has increased the amount of waste. Disinfectants are often complex products or mixtures of active substances, formulation adjutants, pigments and dyes that generate waste. Hospitals also use other substances besides pharmaceuticals for medical purposes, such as diagnostics and substances. Many drugs are not metabolized by the patients and end up in the wastewater. Diagnostics agents and disinfectants also end up in the wastewater as leftovers. Pharmaceuticals were first found in the water environment in the 1970s. Some studies showed the presence of drugs in the effluents of public owned treatment works. Hospital wastewater is similar to municipal wastewater, but it may also have various dangerous components, such as microbiological pathogens, hazardous chemical compounds, disinfectants, pharmaceuticals and radioactive isotopes. Hospital wastewater can harm the environment and human health, so it needs to be managed properly. This study aimed to assess the effectiveness of advanced oxidation processes (Fenton and Photo-Fenton-like) in eliminating harmful pollutants from hospital wastewater [1].

2. Review of Literature

2.1 General

Hospital wastewater is a major environmental concern because it consumes a lot of water and contains various dangerous substances. These include pathogens, harmful bacteria, viruses, pharmaceuticals and their metabolites, radioactive elements, toxic chemicals and heavy metals and disinfectants that are used for medical purposes. These substances have different concentrations depending on the laboratory and research activities or the medicine excretion. They can cause diseases and harm the bio diversity. They can also affect the aquatic ecosystems and disturb the natural balance of life. Even small amounts of hospital pollutants can have negative impacts. Usually, the hospital wastewater is sent to wastewater treatment plants that use biological treatment processes. However, these processes are not very effective in removing all the chemical and microbial pollutants. Therefore, many countries have strict regulations and laws to control the pollution and look for new and better water treatment technologies [2]

Hospital wastewater contains various chemicals and microbes that can harm the environment and human health. These include antibiotics, X-ray contrast agents, disinfectants and pharmaceuticals that belong to different groups. Many of these substances are not removed by conventional wastewater treatment. They reach the surface waters and affect the aquatic life and the food chain. Humans can also be exposed to these pollutants through drinking water that comes from surface water. Some of these pollutants persist in the environment, accumulate and magnify in living organisms, and cause adverse effects on humans [3].

2.2 Water use in Hospitals

Hospitals use water for different purposes, such as Sanitary/Amenities (41% Taps, toilets, Showers), Medical Purposes (14%), cafeterias, kitchens, dining (9%), Laundry (5%), HVAC system (22%), miscellaneous (9%).

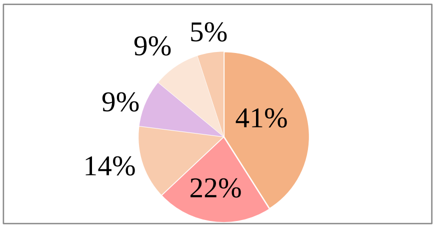

Figure1. Water use in Hospitals

A Pie diagram can illustrate the water use in hospitals as follows [4].

2.3 Pollution Sources in Hospital

Hospital wastewater pollution comes from different departments in the hospital, such as laboratories, surgery rooms, embalming rooms, labour rooms, various clinics, laundries, kitchens and cafeterias, toilets etc [5].

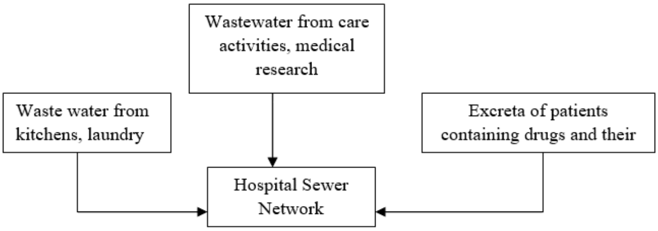

Figure 2. Pollution Sources in Hospital

2.4 Conventional Treatment Technologies

Hospital wastewater is a serious environmental issue in both developed and developing countries. It is a complex mixture of various pollutants that need to be treated before being released into the environment. There are four possible scenarios for treating hospital wastewater: (1) discharging it directly into the environment, (2) treating it together with municipal wastewater in a WWTP, (3) treating it on-site and then discharging the effluent into the environment, and (4) treating it on-site and then sending it to a municipal WWTP. The pros and cons of each scenario are shown in table 1 and illustrated in figure 3 [6].

2.5 Advanced Oxidation Technologies

Biological processes cannot effectively degrade the toxic and non-biodegradable organic substances in hospital wastewaters. These substances are either resistant or harmful to the enzymes that break them down. Therefore, biological processes that are cheap and eco-friendly cannot be used to remove these substances. Instead, non-biological processes that can be either oxidative or reductive are available. However, if the wastewater has non-biodegradable organic pollutants, biological processes alone are not enough, because microorganisms cannot decompose most of the organics. That is why advanced oxidation processes (AOPs) have become more popular in recent years as an alternative or additional treatment. The main purpose of AOPs is to oxidize and destroy organic pollutants in water. These processes are effective and non-discriminatory, so they do not produce any sludge.

Heterogeneous photo catalysis is a type of AOP that can oxidize many organic pollutants in water systems. All AOPs have the same chemical property: they produce radicals (OH•) in a multi step process, but they use different reaction systems. These radicals can oxidize various organic pollutants because they have a high oxidative ability (reduction potential of OH• E0 ¼ 2.8 V) and they are not very selective in their attack [7].

2.6 Fenton Process

The Fenton process uses iron and hydrogen peroxide as the main chemicals that affect the operation costs and the efficiency. The Fenton reaction is faster than other advanced oxidation processes and has some other benefits. Iron and H2O2 are inexpensive and harmless, there is no mass transfer restriction because of its homogenous catalytic nature, there is no energy needed as catalyst and the process is simple to run and control [8].

2.7 Biodegradability Index (BOD: COD)

Biodegradability index (BOD: COD) is a common way to measure how biodegradable wastewater is. Physico-chemical treatment cannot remove a lot of soluble COD. Therefore, biological treatment is needed to achieve the best treatment. The quality of treated wastewater depends on the biodegradability index (BOD: COD). Wastewater is biodegradable if the ratio is between 0.4 and 0.8 [9].

The biodegradability of organic substances is how fast and completely they can be broken down by microorganisms. The BOD5/COD ratio is often used to measure how hard it is to degrade organic substances. The raw wastewater had a low biodegradability, with a BOD5/COD ratio of 0.30. According to Fresenius *et al.* the biodegradation is quick and immediate when the BOD5/COD ratio is 0.5 or higher. But when the BOD5/COD ratio is lower than 0.5, some chemical substances with low biodegradability can slow down or stop the biological process. The hospital wastewater in this study had a low biodegradability, which agrees with previous studies. Also, the raw hospital wastewater was very toxic to microorganisms, with a 100% inhibition [10].

3. Methodology

The wastewater samples were taken from each source before they joined the hospital sewer network, which sent the effluents to the biological wastewater treatment plant without any pre-treatment. The effluent wastewater samples were also taken. The effect of ferrous dosage, H2O2 and contact time was studied. Experiments were done by changing Fe concentrations from 0 to 5 g/l and H2O2 concentrations from 5g/l to 20 g/l to find the best dosage for ferrous and hydrogen peroxide. The effect of irradiation time was also analyzed by using the optimal ferrous and hydrogen peroxide concentration and changing the contact time from 30 minutes, 60 minutes, etc up to 160 minutes to get the highest %efficiency. The best conditions for using the photo-Fenton process to treat hospital wastewater are given for the design of the treatment process [11].

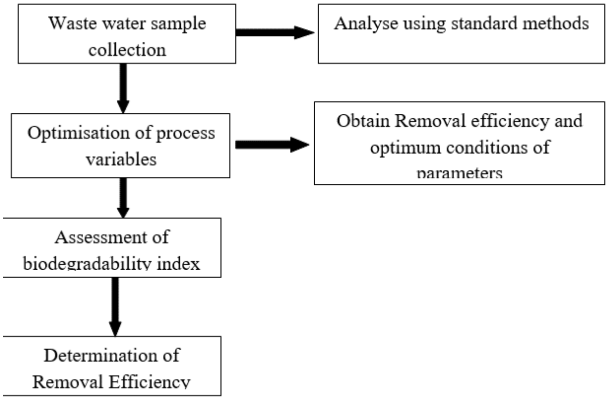

Figure 3. Flow diagram of Methodology

3.1 Collection and preservation of sample

The wastewater samples were taken from various places where the hospital disposes of them. The samples were put in either glass or plastic (usually polythene) bottles. The bottles were sealed tightly during the sampling. The samples were brought to the lab for analysis. All the water samples were stored at 4º C until they were analyzed or used in experiments [12].

3.2 Physico-chemical characterization of hospital wastewater

The parameters such as pH, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS) were analysed in the laboratory [13].

3.3 Fenton Oxidation Set Up

The aim of the studies was to find the best pH, H2O2 and Fe2+ ions dosage for the pre-treatment of hospital wastewater. The studies used 300 ml flasks with stoppers [14].

3.4 Analytical methods

The COD samples were refluxed using the distillation set up shown in figure 4. The standard methods were followed for the COD analysis. The BOD analysis was done by incubating the samples at 270C using an incubator as per standard procedures. An Orion 420

A+ pH meter was used to measure the pH.The Environmental lab of Civil Engineering Department, Ernad Knowledge City Technical Campus Engineering College, Kerala, did the analysis of wastewater. The purpose was to measure the BOD, COD, and pH value of the influent and effluent grey water from various places where the hospital disposes of them. The lab test followed the IS 3025 (PART44):1993 standard [15].

3.5 Test Procedures

The biochemical oxygen demand test is a method that measures how much dissolved oxygen the microorganisms use to break down and oxidize the organic matter in aerobic conditions. The test involves putting the sample in a sealed bottle in the dark at a certain temperature for a specific time.Measure the initial DO for one bottle and put two bottles in the incubator at 27 ºC for 5 days. After 5 days of incubation at 27ºC, measure the final DO of the incubated bottles.

$$BOD5(mg/l)=P(D1-D2)\times 1000$$

Where,

D1 = Initial DO of the Sample in mg/lit.

D2 = Final DO of the Sample in mg/lit.

P = decimal volumetric fraction of sample

Test for chemical oxygen demand (COD)

The following steps will help you measure the COD of a sample using a refluxing condenser and a titration method. First, add 1 g of mercuric sulphate and some glass beads to 50 ml of the sample in a 500 ml flask. Then, dissolve the mercuric sulphate with sulphuric acid and let it cool. Next, mix 25 ml of 0.025N potassium dichromate solution with the sample. After that, attach the flask to the condenser, turn on the cooling water, and add the remaining acid reagent through the condenser. Heat and reflux the mixture for 5 hours. Then, cool it and rinse the condenser with distilled water. Dilute the mixture to about twice its volume and cool it to room temperature. Finally, titrate the excess dichromate with standard ferrous ammonium sulphate using ferroin indicator. The colour change from blue green to reddish indicates the end point. Repeat the same steps with a blank of distilled water with the same volume as the sample.

$$COD\ (mg/l)=V(V1-V2)\times N\times 8000$$

Where,

V1 = ml of ferrous ammonium sulphate used for blank.

V2 = ml of ferrous ammonium sulphate used for sample.

N = Normality of ferrous ammonium sulphate.

V = Volume of sample used [16].

4. Results and Discussion

The wastewater samples were taken from various places where the hospital disposes of them. The samples were put in either glass or plastic (usually polythene) bottles. The bottles were sealed tightly during the sampling. The standard methods were used to analyze the samples in the lab. The results are shown in the table below.

Table 1. Characteristics Of Waste Water Sample 1

Sl No	Parameter	Influent mg/l	Effluent mg/l
1	pH	8.35	8
2	BOD	175	55
3	COD	850	95
4	TSS	183	145

Table 2. Characteristics of Waste Water Sample

Sl No	Parameter	Influent mg/l	Effluent mg/l
1	pH	7.97	7.06
2	BOD	108	45
3	COD	725	96
4	TSS	142.7	128.8

Table 3. Characteristics of Waste Water Sample 3

Sl No	Parameter	Influent mg/l	Effluent mg/l
1	pH	8.07	6.98
2	BOD	186.96	62.15
3	COD	822.58	76
4	TSS	157.27	138.9

Table 4. Characteristics Of Waste Water Sample 4

Sl No	Parameter	Influent mg/l	Effluent mg/l
1	pH	7.77	7.10
2	BOD	150.1	53
3	COD	753.45	102
4	TSS	176	148

Table 5. Characteristics of Waste Water Sample 5

Sl No	Parameter	Influent mg/l	Effluent mg/l
1	pH	8.01	6.97
2	BOD	154.5	35
3	COD	696.65	95
4	TSS	176.3	145

Table 6. Characteristics of Waste Water Sample 6

Sl No	Parameter	Influent mg/l	Effluent mg/l
1	pH	6.58	5.01
2	BOD	142.3	62.3
3	COD	732.3	101.2
4	TSS	166.3	133.98

Table 7. Characteristics of Waste Water Sample 7

Sl No	Parameter	Influent mg/l	Effluent mg/l
1	pH	11.08	8
2	BOD	165.74	55
3	COD	823.25	86.78
4	TSS	193.5	152.5

Table 8. Characteristics of Waste Water Sample 7

Sl No	Parameter	Influent mg/l	Effluent mg/l
1	pH	9.87	7.06
2	BOD	168	46
3	COD	724	65
4	TSS	199.85	165.52

Table 9. Characteristics of Waste Water Sample 8

Sl No	Parameter	Influent mg/l	Effluent mg/l
1	pH	8.07	6.98
2	BOD	186.96	62.15
3	COD	922.58	76
4	TSS	157.27	138.9

Table 10. Characteristics of Waste Water Sample 9

Sl No	Parmeter	Influent mg/l	Effluent mg/l
1	pH	7.77	7.1
2	BOD	150.1	53
3	COD	653.45	102
4	TSS	176	148

5. Conclusion

In conclusion, the utilization of advanced oxidation processes, specifically Fenton, Photo-Fenton, and Photo-Oxidation, holds great promise in addressing the treatment of wastewater containing non-biodegradable organic compounds. The Fenton process, relying on the reaction between iron and hydrogen peroxide, offers several advantages, including its rapid reaction kinetics, cost-effectiveness, non-toxic reagents, minimal energy requirements, and ease of operation and control. This study has focused on investigating the feasibility of employing the Fenton reaction as a pre-treatment technique for hospital wastewater. By conducting experiments and optimizing process variables, we have made significant strides in understanding how this approach can enhance the biodegradability of pollutants in hospital wastewater, specifically in the context of Korambayil Memorial Hospital in Malappuram, Kerala. The findings of this research underscore the potential of the photo-Fenton process as a viable option for the treatment of hospital wastewater. Through a systematic exploration of operating conditions and dosages, we have identified the optimal parameters for the photo-Fenton process, which can serve as valuable insights for the design of wastewater treatment systems in healthcare facilities. This work contributes to the ongoing efforts to develop sustainable and efficient solutions for managing non-biodegradable organic contaminants in hospital wastewater, ultimately benefiting both the environment and public health.

Reference

[1] A. Machulek Jr, F.H. Quina, F. Gozzi, V.O. Silva, L.C. Friedrich, J.E. Moraes, Fundamental mechanistic studies of the photo-Fenton reaction for the degradation of organic pollutants. In Organic pollutants ten years after the Stockholm convention-environmental and analytical update, (2012) 271-292. https://doi.org/10.5772/30995

[2] C.C. Su, L.V. Panopio, G.L. Peralta, M.C. Lu, Application of Fered-Fenton process for m-phenylenediamine degradation. *Journal of Environmental Science and Health, Part A*, 48(9), (2013) 1012-1018. https://doi.org/10.1080/10934529.2013.773207

[3] M.I. Badawy, M.E.M. Ali, Fenton's peroxidation and coagulation processes for the treatment of combined industrial and domestic wastewater, Journal of hazardous materials, 136(3), (2006) 961-966. https://doi.org/10.1016/j.jhazmat.2006.01.042

[4] A.M. Deegan, B. Shaik, K. Nolan, K. Urell, M. Oelgemöller, J. Tobin, A. Morrissey, (2011). Treatment options for wastewater effluents from pharmaceutical companies, International Journal of Environment Science Technology, 8(3), 649-666. http://dx.doi.org/10.1007/BF03326250

[5] F.G. Kootenaei, H.A. Rad, (2013) Treatment of hospital wastewater by novel nano-filtration membrane bioreactor (NF-MBR), Iranica Journal of Energy and Environment, Special Issue on Nanotechnology, *4*(1), 60-67.

[6] A.H. Khan, N.A. Khan, S. Ahmed, A. Dhingra, C.P. Singh, S.U. Khan, A.A. Mohammadi, F. Changani, M. Yousefi, S. Alam, S. Vambol, V. Vambol, A. Khursheed, I. Ali, Application of Advanced Oxidation Process for the pre treatment of Hospital Waste water, Journal of Cleaner Production, 269, (2020) 981-987. https://doi.org/10.1016/j.jclepro.2020.122411

[7] N. Ahsan, Study of widely used treatment technologies for hospital wastewater and their comparative analysis, International Journal of Advances in Engineering & Technology, *5*(1), (2012) 227.

[8] V. Kavitha, K. Palanivelu, Degradation of 2-Chlorophenol by Fenton and Photo-Fenton Processes A Comparative Study, Journal of Environmental Science and Health, 38(7), (2003) 1215-1234. https://doi.org/10.1081/ESE-120021121

[9] S.H. Lin, C.F. Peng, Treatment of textile wastewater by Fenton's reagent, Journal of Environmental Science & Health Part A, 30(1), (1995) 89-98. https://doi.org/10.1080/10934529509376187

[10] M.G. Alalm, A. Tawfik, (2013). Fenton and solar photo-Fenton oxidation of industrial wastewater containing pesticides, In 17th International Water Technology Conference, 2, 5-7.

[11] P. Kowalik, Chemical pretreatment of formaldehyde wastewater by selected Advanced Oxidation Processes (AOPs), Challenges of Modern Technology, 2(4), (2011) 42-48.

[12] B. Pauwels, W. Verstraete, The treatment of hospital wastewater: an appraisal. Journal of water and health, 4(4), (2006) 405-416. https://doi.org/10.2166/wh.2006.0024

[13] P. Kajitvichyanukul, M.C. Lu, C.H. Liao, W. Wirojanagud, T. Koottatep, Degradation and detoxification of formaline wastewater by advanced oxidation processes, Journal of Hazardous Materials, 135(1-3), (2006) 337-343. https://doi.org/10.1016/j.jhazmat.2005.11.071

[14] P. Kajitvichyanukul, N. Suntronvipart, Evaluation of biodegradability and oxidation degree of hospital wastewater using photo-Fenton process as the pretreatment method. Journal of Hazardous Materials, 138(2), (2006) 384-391. https://doi.org/10.1016/j.jhazmat.2006.05.064

[15] S. Mondal, A. Sinha, Treatment of Pharmaceutical waste with special emphasis to treatment processes, International Journal of Environmental Research and Development, 4(2), (2014) 171-174.

[16] S. Dehghani, A. Jonidi Jafari, M. Farzadkia, M. Gholami, Sulfonamide antibiotic reduction in aquatic environment by application of fenton oxidation process, Iranian Journal of Environmental Science and Management, 10(1), (2013) 1-5. https://doi.org/10.1186%2F1735-2746-10-29

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