The Performance of Bio-Baffle and Immobilized Carbon Catalytic Oxidation Reactors Treating Domestic Sewage

Ms. K. S. Sri Sunmithaa [1], Dr. S. Keerthinarayana[2], Dr. S. Swarnalatha[3]

[1]*PG Student, Department of Civil Engineering, Coimbatore Institute of Technology, Coimbatore, India*
[2]*Professor, Department of Civil Engineering, Coimbatore Institute of Technology, Coimbatore, India*
[3]*Environmental Technology Division, Central Leather Research Institute (CLRI), Adyar, Chennai*, India

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Abstract – *A recent investigation showed that the present wastewater treatment facilities available in our country are capable of treating only less than 30% of the sewage water generated. Moreover, the treatment facilities are not capable of removing the pathogenic organisms in an efficient manner. In the present investigation, an attempt was made to treat the domestic sewage in Bio-baffle and Immobilized Carbon Catalytic Oxidation Reactors sequentially. The Immobilized Cell Reactors involved are Fluidized Immobilized Carbon Catalytic Oxidation (FICCO), Chemo-Autotrophic Activated Carbon Catalytic Oxidation (CAACO) Reactor. The rice husk carbon is used as a catalyst in both FICCO and CAACO Reactors. The main objective of the present study is to assess the reduction efficiency of organic pollutants in domestic sewage using Bio-baffle-FICCO-CAACO Reactor system. The hydraulic retention time of Bio-baffle, FICCO and CAACO Reactors were 3 hours, 6 hours and 1 hour respectively. The COD, BOD removal efficiencies were 93.33% and 85.06% respectively. There is also a 99.9% removal of pathogenic bacteria accompanied with the consistent removal of organics.*

Key Words: Domestic sewage, Catalytic Oxidation, Immobilized Reactors, Organic Pollutants, Pathogens, Carbon catalyst.

1. INTRODUCTION

Due to the rapid growth of population and urbanization, there is an increase in discharge and improper management of domestic sewage water which affects the environment to a greater extent. For a proper understanding of the reactions and interactions with organic and inorganic compounds in wastewater, the chemical composition of wastewater should be analyzed (Roila et al). The presence of countless pathogenic microorganisms in the untreated domestic sewage water threatens the public health. Hence proper treatment should be identified satisfying environmental, economic, political and social concerns (Metcalf and eddy).

In conventional technologies, the removal of pathogenic organisms from the domestic sewage water is not significant (Sekaran *et al.*, 2006). Hence the blending conventional techniques with advanced oxidation techniques increases the performance efficiency compared to the conventional techniques and segregated processes. The major advantage of combining the processes is a higher rate of biodegradation. The main aim of the present study is to evaluate the effectiveness of reducing the organic pollutant in the domestic sewage water through Bio-baffle-FICCO-CAACO Reactor system sequentially.

In this study, the Bio-baffle reactor used is a Sequential Oxic cum Anoxic Reactor in which the plastic medium is used as a carrier for the growth of microorganisms enhancing the degradation of organic matter. In the Immobilized reactors, the catalyst is rice husk activated carbon, which adsorbs the contaminants. A dynamic condition develops as the wastewater passes through a confined bed of rice husk carbon creating a mass transfer zone (Sekaran *et al.*, 2013). The principle goal of the present investigation is to demonstrate the performance of Bio-baffle-FICCO-CAACO reactor system for the effective removal of dissolved organics expressed as Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) in the domestic sewage water.

2. MATERIALS AND METHODS

2.1 Sewage Water Collection

The sewage water was collected from sewage treatment plant at Central Leather Research Institute. The collected samples were analyzed for physicochemical parameters such as pH, BOD, COD, TDS, Sulphides, Sulphates, Chlorides, and Ammonia (NH_3-N) as per standard protocol.

2.2 Preparation of Rice Husk Activated Carbon

The rice husk was washed with water for a number of times in order to remove the impurities and oven dried for 6 hours at 110°C. The rice husk passed through the 600µm sieve is taken for carbon preparation. Porous carbons were prepared in two sequential steps: pre-carbonization and chemical activation. In pre-carbonization process, the rice husk is heated to 400°C for 4 hours at a rate of 10°C/min and cooled to room temperature and the resulting carbon is called as Pre Carbonized Carbon (PCC). In chemical activation, the carbon is activated by mixing the carbon with

85% H_3PO_4 and heating to 900°C in N atmosphere at a rate of 5°C/min and kept for 1hour in 900°C before cooling. The carbon obtained is washed in water for a number of times to maintain neutral pH and to remove excess phosphorous compounds then oven dried to obtain the rice husk activated carbon. (John Kennedy et al., 2007)

2.3 Design of the reactors

The Reactors were made of an acrylic sheet. The Bio-baffle reactor is of height 25 cm and width 16.5 cm divided into 3 compartments with a working volume of 3.8 L. Also each compartment is divided into the oxic and anoxic zone. The FICCO reactor is of height 45.5cm and width 15.5 cm with an upper hopper and a provision for aeration. The volume of the reactor was 10.5L with working volume of 6.8 L the reactor was then filled with 30g/L of rice husk carbon and the air is distributed through the provision to facilitate oxygen transfer for oxidation. The CAACO Reactor is a packed bed reactor with a height of 18.5 cm, the diameter of 11 cm and a working volume of 1 L. The CAACO reactor is packed by rice husk carbon immobilized with Bacillus sp. and aeration is provided from the bottom. The raw water, Bio-baffle, FICCO and CAACO treated waters were analyzed for characteristics which include pH, sulfates, chloride, COD, BOD, TDS, Ammonia (NH_3-N) levels.

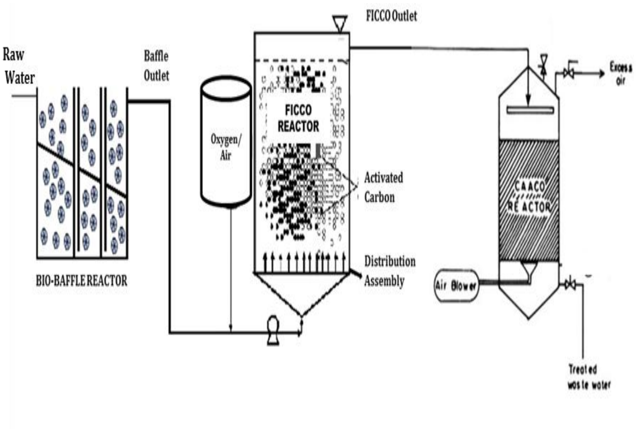

Fig -1: Schematic of Bio-baffle-FICCO-CAACO Reactor system

2.4 Catalytic Oxidation of Organics

The sewage water is primarily treated using Bio-Baffle reactor with a retention time of 3 hrs in which the suspended solids are removed. The effluent from Bio-Baffle Reactor is fed into the FICCO reactor with a retention time of 6hrs in which the removal of organics by oxidation takes place. For increased efficiency in removal of organics the effluent from FICCO reactor is further treated by CAACO reactor with a retention time of 1 hr and the final treated water is obtained.

3. RESULTS AND DISCUSSION

3.1 Characteristics of Domestic Sewage

The physicochemical characteristics of sewage were analyzed freshly soon after collection. The quality of sewage in the initial condition and after treatment in various reactors is summarized in Table 1. In Table 2 the Total Viable Counts of Bacteria (TVCB) and Total Viable Counts of Coliforms (TVCC) were summarized.

3.2 Characteristics of Rice husk Activated carbon

The characteristics of rice husk activated carbon are studied before and after the activation and are presented in Table 3.

Table -1: Physico-chemical characteristics of raw domestic sewage and treated wastewater from various reactors.

Parameters (mg/L)	Initial	Bio baffle	FICCO	CAACO
pH	7.83 ± 0.35	7.19 ±0.23	6.55 ± 0.22	6.84 ± 0.19
ORP (mV)	-162.2 ± 42.03	-84.2 ± 3.30	-64.1 ± 2.8	13.5 ± 9.33
TDS	820 ± 77.65	690 ± 50.33	520 ± 38.87	320 ± 46.9
COD	240 ± 63.07	128 ± 16.87	64 ± 19.96	16 ± 8.26
BOD	71.43 ± 30.47	38.33 ± 6.76	23.34 ± 2.75	10.67 ± 1.65
Ammonia	26.88 ± 4.3	20.16 ± 3	13.44 ± 2.26	1.68 ± 0.44
TKN	30.24 ± 5.58	26.88 ± 1.76	15.12 ± 3.45	10.08 ± 1.76
TOC	142.8 ± 21.20	87.13 ± 7.91	25.27 ± 3.9	15.33 ± 3.72
TN	30.72 ± 2.68	29.26 ± 1.04	25.23 ± 1.64	24.85 ± 1.74
Sulphates	118.81 ± 15.10	95.01 ± 2.91	85.09 ± 4.74	51.88 ± 3.83
Iron	2.13 ± 1.31	2.01 ± 0.11	0.7 ± 0.08	0.34 ± 0.13
Chlorides	238.22 ± 20.60	223.34 ± 9.17	168.74 ± 15.33	94.30 ± 7.82

Table -2: Biophysical characteristics of raw domestic sewage and treated wastewater from various reactors

Parameters(mg/L)	Initial	Bio baffle	FICCO	CAACO
TVCB(CFU/mL)	1 x 10^8	45 x 10^6	18 x 10^3	6 x10^3
TVCC(CFU/mL)	4 x 10^8	2 x 10^3	12 x 10^2	6 x10^2

Table -3: Characteristics of Rice husk activated carbon

PARAMETERS	PCC	RHAC
Specific gravity	2.07	2.04
Bulk Density (g/mL)	0.121	0.405
pH	5.7	6.66
BET Surface Area(m2/g)	289.1	438.9
Pore Volume(cc/g)	0.0053	0.034
Size of Activated carbon(μm)	424.3	424.3
Pore Length (Å)	39.36	35.28
Ash content (%)	16.25	42.61

There is an increase in pore volume from 0.0053 cc/g to 0.034 cc/g after the activation which indicates the efficiency of formation of pores. The increase in BET surface area indicates the increased efficacy of adsorption of contaminants by the catalyst due to asorption. The increase in ash content may be due to the presence of phosphorous compounds used during the activation of rice husk carbon.

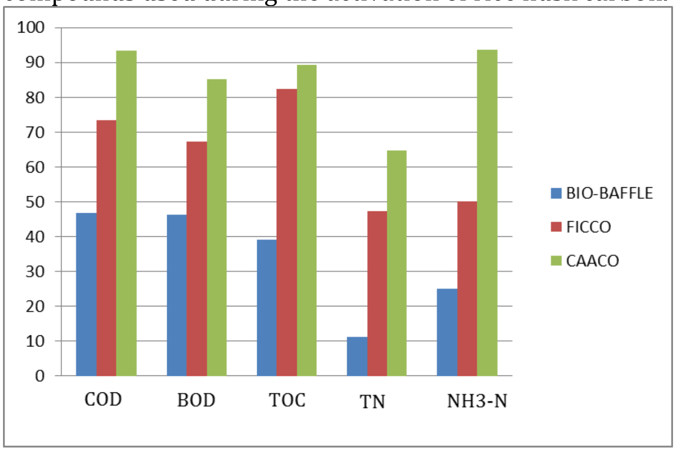

Chart -1: Removal efficiencies of COD, BOD, TOC, TN and Ammonia (NH_3-N) in various reactors

The removal efficiencies of COD and BOD of Bio-baffle-FICCO-CAACO Reactor system is about 93.33% and 85.06% respectively. The BOD/COD ratio of the raw domestic wastewater is 0.30 which indicates the presence of dissolved inorganics is wastewater making the wastewater poorly biodegradable. The removal efficiency of sulphates in the system was 56.33% and the reason for the decrease in sulphate content of wastewater may be due to its participation in oxidation of organics in wastewater. Despite the removal of organics in wastewater the removal of inorganic compounds like iron and chlorides took place to some extent may be due to adsorption of contaminants by the rice husk activated cabon. The complete mineralisation of dissolved organics in wastewater during passage through CAACO reactor is due to the generation of OH^- radicals accompanied by oxidation. The chemo autotrophs (Bacillus sp.) used in this study were immobilized in the meso pores of activated carbon which constitutes about 69% of the total pore systems in activated carbon prepared at activation temperature of 900°C.

4. SUMMARY AND CONCLUSIONS

The rice husk based carbon was used as catalyst for the oxidation of organics in wastewater discharged from domestic origin. The rice husk based was efficient enough to reduce COD, BOD by 93.33% and 85.06 % respectively. The consistent removal of pollution parameters was accompanied with the removal of pathogenic and antibiotic resistant bacteria. The present investigation consists of immobilization of anaerobic and aerobic bacteria in rice bran based activated carbon and air was supplied for the oxidation of organics in wastewater, thus the system was named chemo-autotrophic activated carbon oxidation (CAACO). The immobilized bacterial species and activated carbon were quite successful in removing the organics in wastewater at low detention period of 1 h. The sludge production is only 60% of the conventional sewage treatment plant. The investment cost towards Sewage treatment plant by employing rice husk based carbon would be drastically reduced and thereby the operational cost towards electrical energy consumption will also be very much reduced.

REFERENCES

[1] Amarasinghe, U. A., Shah, T., & Anand, B. K. (2008). India's water supply and demand from 2025-2050: business-as-usual scenario and issues. In IWMI Conference Proceedings (No. 235165). International Water Management Institute.

[2] Belmont, M. A., Cantellano, E., Thompson, S., Williamson, M., Sánchez, A., & Metcalfe, C. D. (2004). Treatment of domestic wastewater in a pilot-scale natural treatment system in central Mexico. Ecological Engineering, 23(4), 299-311.

[3] Bukhari, A. A. (2008). Investigation of the electro-coagulation treatment process for the removal of total suspended solids and turbidity from municipal wastewater. Bioresource technology, 99(5), 914-921.

[4] Chernicharo, C. D. (2006). Post-treatment options for the anaerobic treatment of domestic wastewater. Reviews in Environmental Science and Bio/Technology, 5(1), 73-92.

[5] Chittala, G., Sekaran, G., Mogadati, P. S., & Anjireddy, M. (2012). Chemoautotrophic activated carbon oxidation: an advanced oxidation process for the reduction of sulphate in pharmaceutical effluent. Int. J. Life Sci. Biotechnol. Pharma Res, 1, 328-333.

[6] CPCB (2009), Status of water supply, wastewater generation and treatment in Class I cities and Class II towns of India. Series: CUPS/70/2009-10. Central Pollution Control Board, India.

[7] CPHEEO (2012), Manual on Sewerage and Sewage Treatment, Part A: Engineering Final Draft, Central Public Health and Environmental Engineering Organisation, Ministry of Urban Development, New Delhi.

[8] Fang, H. H. P., & Chung, D. W. C. (1999). Anaerobic treatment of proteinaceous wastewater under mesophilic and thermophilic conditions. Water science and technology, 40(1), 77-84.

[9] Glaze, W. H., Kang, J. W., & Chapin, D. H. (1987). The chemistry of water treatment processes involving ozone, hydrogen peroxide and ultraviolet radiation.

[10] Hulshoff PLW, Lettinga G (1986). New technologies for anaerobic wastewater treatment. Water Sci Technol , 18, 41–53.

[11] Karthikeyan, S., Titus, A., Gnanamani, A., Mandal, A. B., & Sekaran, G. (2011). Treatment of textile wastewater by homogeneous and heterogeneous Fenton oxidation processes. Desalination, 281, 438-445.

[12] Kaur, R., Wani, S. P., Singh, A. K., & Lal, K. (2012, May). Wastewater production, treatment and use in India. In National Report presented at the 2nd regional workshop on Safe Use of Wastewater in Agriculture.

[13] Kennedy, L. J., Vijaya, J. J., & Sekaran, G. (2004). Effect of two-stage process on the preparation and characterization of porous carbon composite from rice husk by phosphoric acid activation. Industrial & engineering chemistry research, 43(8), 1832-1838.

[14] Kiziloglu, F. M., Turan, M., Sahin, U., Kuslu, Y., & Dursun, A. (2008). Effects of untreated and treated wastewater irrigation on some chemical properties of cauliflower (Brassica olerecea L. var. botrytis) and red cabbage (Brassica olerecea L. var. rubra) grown on calcareous soil in Turkey. Agricultural water management, 95(6), 716-724.

[15] Kulkarni, S. J., & Kaware, J. P. International Journal OF Engineering Sciences & Management Research.

[16] Lau, I. W., Wang, P., & Fang, H. H. (2001). Organic removal of anaerobically treated leachate by Fenton coagulation. Journal of environmental engineering, 127(7), 666-669.

[17] Lettinga, G., & Pol, L. H. (1986). Advanced reactor design, operation and economy. Water Science and Technology, 18(12), 99-108.

[18] Lettinga, G., De Man, A., Van der Last, A. R. M., Wiegant, W., Van Knippenberg, K., Frijns, J., & Van Buuren, J. C. L. (1993). Anaerobic treatment of domestic sewage and wastewater. Water Science and Technology, 27(9), 67-73.

[19] Lin, H., Chen, J., Wang, F., Ding, L., & Hong, H. (2011). Feasibility evaluation of submerged anaerobic membrane bioreactor for municipal secondary wastewater treatment. Desalination, 280(1), 120-126.

[20] Luo, Y., Guo, W., Ngo, H. H., Nghiem, L. D., Hai, F. I., Zhang, J., ... & Wang, X. C. (2014). A review on the occurrence of micropollutants in the aquatic environment and their fate and removal during wastewater treatment. Science of the Total Environment, 473, 619-641.

[21] Martín, M. B., López, J. C., Oller, I., Malato, S., & Pérez, J. S. (2010). A comparative study of different tests for biodegradability enhancement determination during AOP treatment of recalcitrant toxic aqueous solutions. Ecotoxicology and Environmental Safety, 73(6), 1189-1195.

[22] Martins, S. C. S., Martins, C. M., Fiúza, L. M. C. G., & Santaella, S. T. (2013). Immobilization of microbial cells: A promising tool for treatment of toxic pollutants in industrial wastewater. African Journal of Biotechnology, 12(28).

[23] McGrath, D., Postma, L., McCormack, R. J., & Dowdall, C. (2000). Analysis of Irish sewage sludges: suitability of sludge for use in agriculture. Irish Journal of Agricultural and Food Research, 73-78.

[24] Meriç, S., Guida, M., Anselmo, A., Mattei, M. L., Melluso, G., & Pagano, G. (2002). Microbial and COD removal in a municipal wastewater treatment plant using coagulation flocculation process. Journal of Environmental Science and Health, Part A, 37(8), 1483-1494.

[25] Metcalf & Eddy, Burton, F. L., Stensel, H. D., & Tchobanoglous, G. (2003). Wastewater engineering: treatment and reuse. McGraw Hill.

[26] Nemati, M., & Webb, C. (2011). Immobilized Cell Bioreactors. Comprehensive Biotechnology (Second Edition), 2, 331-346.

[27] Obradovic, B., Nedović, V. A., Bugarski, B., Willaert, R. G., & Vunjak-Novakovic, G. (2004). Immobilised cell bioreactors. In Fundamentals of cell immobilisation biotechnology (pp. 411-436). Springer Netherlands.

[28] Parmar, A. (2014). Fenton process: a case study for treatment of industrial waste water. Int J Innov and Emerg Res in Eng, 1(2), 23-30.

[29] Pires, A. M. M., & Mattiazzo, M. E. (2003). Biosolids conditioning and the availability of Cu and Zn for rice. Scientia Agricola, 60(1), 161-166.

[30] Polito Braga, C. M., Von Sperling, M., Braga, A. R., & Pena, R. T. (2005). Control Strategies for a Combined Anaerobic (UASB)–Aerobic (Activated Sludge) Wastewater Treatment System. Environmental technology, 26(12), 1393-1402.

[31] Saidi, M. (2010). Experimental studies on effect of Heavy Metals presence in Industrial Wastewater on Biological Treatment. International journal of environmental sciences, 1(4), 666.

[32] Sashidara, P. K., Sharmila, J., Karthikeyan, S., & Sekaran, G. (2013). Treatment of Domestic Sewage through Immobilized Cell Reactor with Minimum

Sludge Production. Research Journal of Engineering and Technology, 4(4), 8.

[33] Schellinkhout, A., & Collazos, C. J. (1992). Full-scale application of the UASB technology for sewage treatment. Water Science and Technology, 25(7), 159-166.

[34] Sekaran, G., Karthikeyan, S., Mandal, A. B., & Gupta, V. K. (2012). Immobilized Micro-Organism in Mesoporous Activated Carbon for Treatment of Tannery Waste Water. Tenside Surfactants Detergents, 49(6), 472-480.

[35] Sekaran, G., Ramani, K., Kumar, A. G., Ravindran, B., Kennedy, L. J., & Gnanamani, A. (2007). Oxidative destabilization of dissolved organics and E. coli in domestic wastewater through immobilized cell reactor system. Journal of environmental management, 84(2), 123-133.

[36] Shuler, M. L., & Kargi, F. (2002). Bioprocess engineering (p. 65). ^ eUpper Saddle River. Upper Saddle River.: Prentice Hall.

[37] Singh, K. P., Mohan, D., Sinha, S., & Dalwani, R. (2004). Impact assessment of treated/untreated wastewater toxicants discharged by sewage treatment plants on health, agricultural, and environmental quality in the wastewater disposal area. Chemosphere, 55(2), 227-255.

[38] Terras, C., Vandevivere, P., & Verstraete, W. (1999). Optimal treatment and rational reuse of water in textile industry. Water science and technology, 39(5), 81-88.

[39] Uemura, S., & Harada, H. (2010). Application of UASB technology for sewage treatment with a novel post treatment process. Environmental Anaerobic Technology, Applications and New Developments. Fang, HHP (Eds), Imperial College Press, London, 91-112.

[40] Von Sperling, M. (2007). Activated sludge and aerobic biofilm reactors. IWA publishing.