

TREATMENT OF ACID MINE DRAINAGE USING A SANDSTONE COLUMN

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ABSTRACT

Acid mine drainage (AMD) or Acid rock drainage (ARD) from mining industry poses worldwide severe environmental problems including India also. In this study, heavy metal removal was tested in AMD samples collected from the Gorbi abandoned coal mine (India), having iron concentrations of 75 mg/L. Sandstone was collected from mine sites and converted into powders form and used as low-cost adsorbent in a column to treat acid mine drainage (AMD) obtained from the inactive Gorbi opencast coal mines (Singrauli coalfields, NCL). The pH value of the pit water sample improved from 2.48 to 3.90, along with the removal of, 100 % total iron, Lead (Pb), Cadmium (Cd), 71% of the electrical conductivity, 73% total dissolved solids and 50% of the salinity.

Keywords: Heavy metals, Sandstone Column treatment, and acid mine drainage.

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INTRODUCTION

Many active and abandoned mines all over the world are incessantly releasing acid mine drainage into surface and ground water resources.¹⁻³ Acid mine drainage is also known as acid rock drainage had the severe effect on the mining based nation all over the world. Its generation will start with initial stages of mining operations and sometimes continues for a very long time even after mine closures⁴, until famous anyone member (i.e. water, air, and pyrite) absent from the generation site. Acid mine drainage has been generated in open pits workings spoil heaps, mine tunnels, waste rock piles⁵, tailings ponds or mineral stockpiles.⁶ The generation of AMD and its impacts depended on many environmental factors and presently it is increased by the defective management of different mining⁷ and industrial activities. The primary sources of AMD generation are mainly pyrite and pyrrhotite⁸, presence in coal. Coal deposits contain 1-20% amounts of pyritic-sulfur and these strata normally establish with the coal, which exposed to water and oxygen⁹. The oxidation process may be also influenced by some bacteria present in the system from small to large scale by accelerating oxidation of sulfides.¹⁰ The geological and hydrological condition of the sites of the strata is also critical for acid mine drainage generation.

Mining effluents are characterized by low pH¹¹⁻¹⁴ high acidity, turbidity, total dissolved solids and high metal contents¹⁵⁻¹⁷ with high concentrations of iron. These metals leads to decline in concentration of dissolved oxygen (DO) in the water resources¹⁸ a combination which occur that in several cases, mining effluents cause severe environmental nuisance such as poisoning of aquatic organisms and acidification¹ with the harmful impact on human health, animals life, plants, vegetation, and natural ecosystem¹⁹⁻²⁰, soil quality²¹⁻²² and corrosion of many mining tools and structures²³ surrounding mining areas. Some technologies are available for treatment of acid mine drainage²⁴⁻²⁵ and industrial wastewater. Amongst them, few traditional worldwide processes are precipitation²⁶⁻²⁸ ion exchange,^{12,29-30} ultrafiltration,³⁻³², reverse osmosis,^{5,33-34} nanofiltration,³⁵ electro dialysis,³⁶⁻³⁷ coagulation,³⁸⁻⁴¹ flocculation,⁴²⁻⁴⁴ flotation,⁴⁵ electrochemical process,⁴⁶⁻⁴⁷ and Adsorption.⁴⁸⁻⁵¹ However, out of above technology, some have disadvantage like, production of secondary waste (sludge), toxicity, high operation and maintenance costs, skilled personal requirement, reduced efficiency, required excess land and expenses for treatment and management of acid mine drainage, which bound the use of the majority of developed technologies.⁵²⁻⁵⁴ However the adsorption process relatively appears to be a suitable method for treatment of acid mine

drainage mainly due to its advantages, likes ease in design and feasibility in operation, economically cheaply, easily available adsorbent materials.⁵⁴

EXPERIMENTAL

Material and Methods

A sample of acid mine drainage was collected from ditches of Gorbi abandoned mine NCL India. These abandoned mine sites contain the massive quantity of mine water. The pH of collected AMD was 2.48. The sandstone used in this study was obtained from the mine site and crushed in a ball mill and sieve 150 μm sizes, in the departmental laboratory. The XRF analysis shows that the chemical composition of the sandstone as follows, Silica (SiO_2) 67.87 %, Alumina (Al_2O_3) 25.43%, Ferric oxide (Fe_2O_3) 2.27%, Calcium oxide (CaO) 1.70%, Titanium dioxide (TiO_2) 0.086%, Potassium oxide (K_2O) 0.560%, and Nickel (II) oxide (NiO) 0.212%.

Methodology

The water sample was collected from the largest inactive opencast coal mine pit, (Gorbi, Singrauli, India). The raw water sample was collected in twenty, 20 L clean plastic gallons, which were carefully washed with raw water sample before starting water sampling (acid mine drainage) from mine sites. The values of pH, TDS, EC, and temperature were measured in situ using a Hanna multi-parameter (HI 9828), pH meter. The continuous flow experiments were conducted in a prefix circular column with an external diameter of 25 cm and 60 cm in height. At the bottom and top of the column, fine meshes of plastic were attached, followed by glass wool.

Inside in the column 1 cm, deep layer of small size glass beads was placed both the top and bottom portion to provide regular inlet flow of the water sample into the column. The column was then packed with 6.0 kg sandstone in layers and operated in downward flow at room temperature. Every day, 4500 mL water sample was passed through the sandstone column in flow rates of 1500 mL/hr., so that in a month, 135L of water sample had been passed through it. This experimental study was continued for more than two months, during which time, a total of 400 L of water sample (acid mine drainage) was passed through the sandstone column. Periodically samples were collected from the column outlet at regular time intervals and analyzed for physical parameters like pH value, temperature, electrical conductivity (EC), total dissolved solids (TDS), salinity and heavy metals.

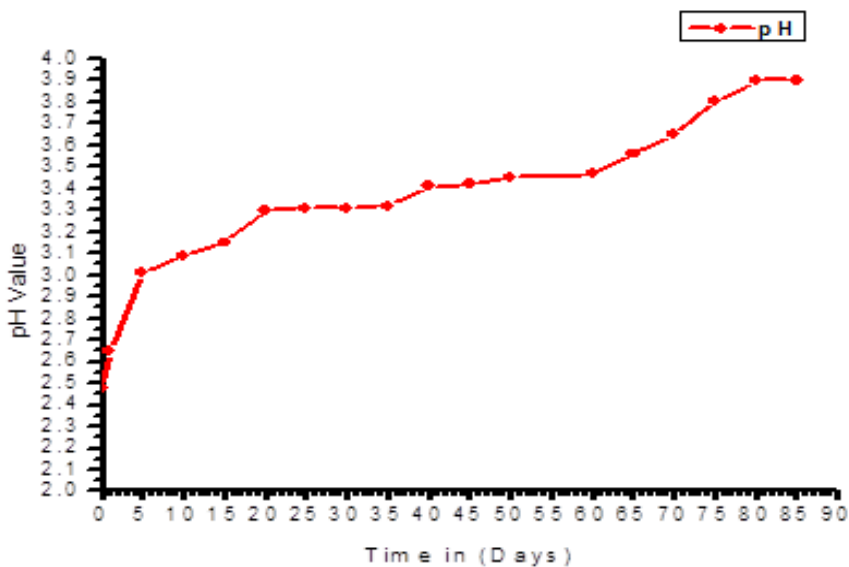


Fig.-1: The pH value of mine water after treatment through sandstone column

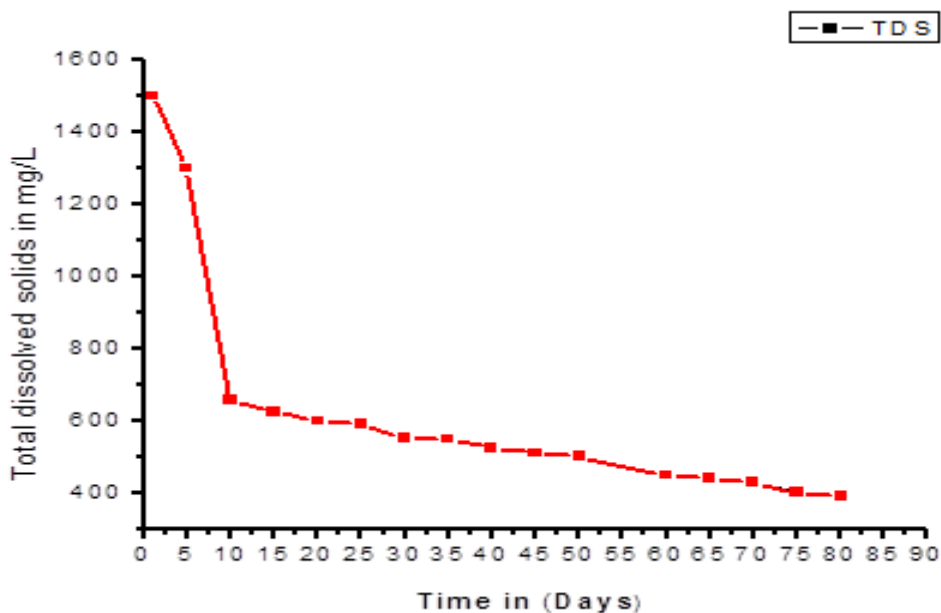


Fig.-2: Removal of TDS from mine water after treatment

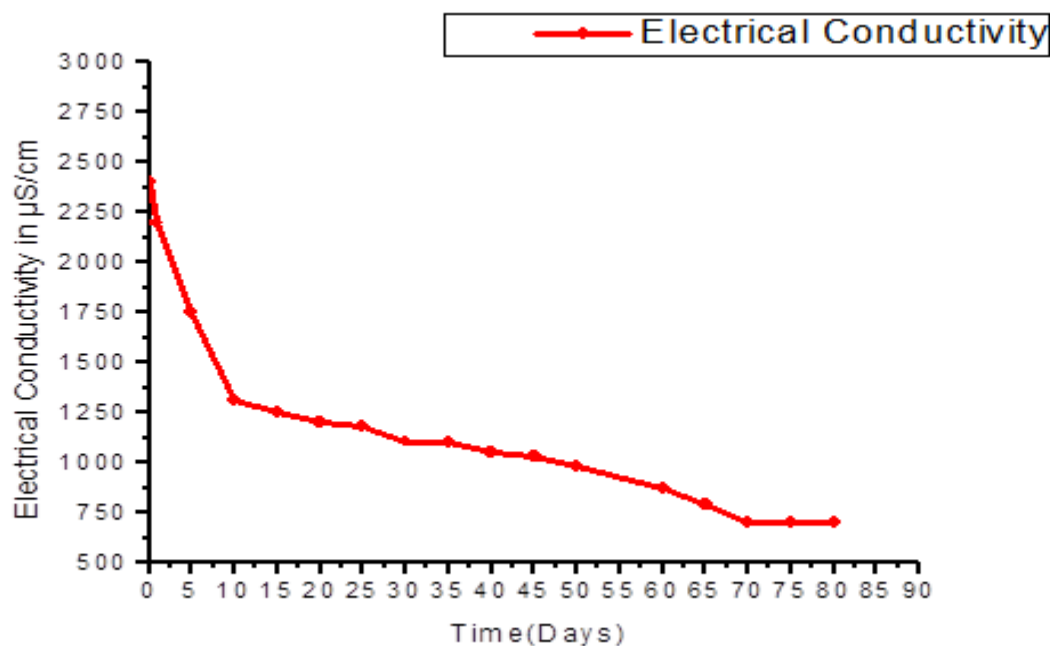


Fig.-3: Removal of electrical conductivity from mine water after treatment

RESULTS AND DISCUSSION

Water samples were collected from the inactive pits of Gorbi opencast coal mine. The water sample had the initial primary pH level of 2.48. Water sample passed through the sandstone column since the sandstone is alkaline in nature; the resulting water has high pH value of the water sample. Removal capacity of heavy metal and decrease in leachate pH was observed. The water sample of pH value 3.90 was established after 80 days of sample (AMD) treatment (Fig.-1); after 80 days the increase in pH attains

a saturated value of 3.90. The pH value of water sample was improved due to the composition of the sandstone ($\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$) and the calcium content.⁵⁵ This increases the pH value of the solution.

The water sample had initial electrical conductivity (EC) of 2400 $\mu\text{S}/\text{cm}$, at the starting of the treatment. The electrical conductivity of the treated water sample was reduced (Fig.-3), at the end of the experimentation, to 700 $\mu\text{S}/\text{cm}$. This was almost 71% of removal of initial Electrical Conductivity of the water sample, which shows the elimination of metals from mine water sample. The initial concentrations of total dissolved solids, 1450 mg/L was and salinity 1.12 PSU in the raw water sample. When the water sample was passed through the sandstone column, the total dissolved solids and salinity are subsequently decreased from the sample water (Fig.-2 and 4) to 390mg/L and 0.6 PSU respectively. The sandstone column was found to be extremely useful in eliminating toxic heavy metals from the AMD, 100 % of iron (Fe), 100 % of the lead (Pb), 100% of the cadmium (Cd) were removed after 60, 10 and five days of mine water treatment through sandstone column respectively (Fig.-5). The initial metals concentration in the raw water sample (acid mine drainage) was 75 mg/L iron (Fe), 00.066 mg/L lead (Pb), and 0.006 mg/L cadmium (Cd). The main concentration was Iron (Fe) in the water sample. After passing the water sample through the sandstone column, the initial metals concentration of the raw water sample has been decreased to 0.00 mg/L Fe, Pb, and Cd mg/L. The treatment through sandstone column was very efficient due to the composition of sandstone dominated (67.87%) by silicon oxide (SiO_2), (25.43%) Alumina (Al_2O_3), Ferric oxide (Fe_2O_3), (2.27%) and Calcium oxide (CaO) (1.70%), which provides better metal removal efficiency from metal-laden effluents.⁵⁴⁻⁵⁷

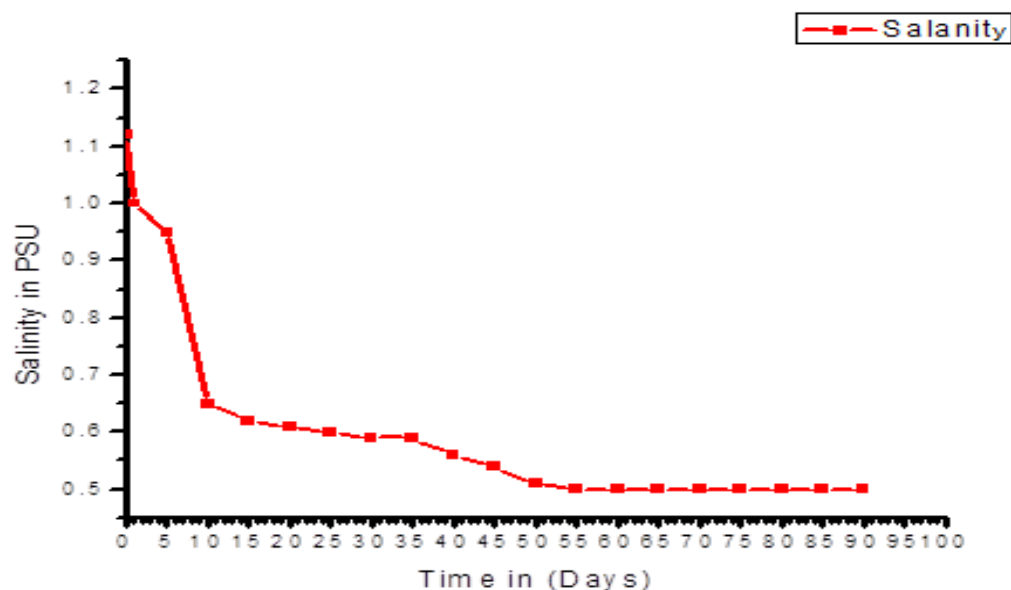


Fig.-4: Removal of salinity after treatment

CONCLUSION

Sandstone obtained from the local (NCL) mining area was found to be useful for the removal of lead, Cadmium and total iron from the Gorbipencast mine, effluents. The pH value of the raw water sample was improved from 2.48 to 3.90. The uptake of toxic heavy metals from water sample was found 100% total iron, lead, and cadmium with 71% reduction in electrical conductivity 73% TDS and 50% Salinity. The study results show that sandstone can be used as an economical material for the uptake of lead, cadmium, and total iron from mine water. A suitable field study is essential to estimate the relative economic treatment costs of both treatment process (active and passive) for the successful elimination of toxic heavy metals from the mining and industrial effluents.

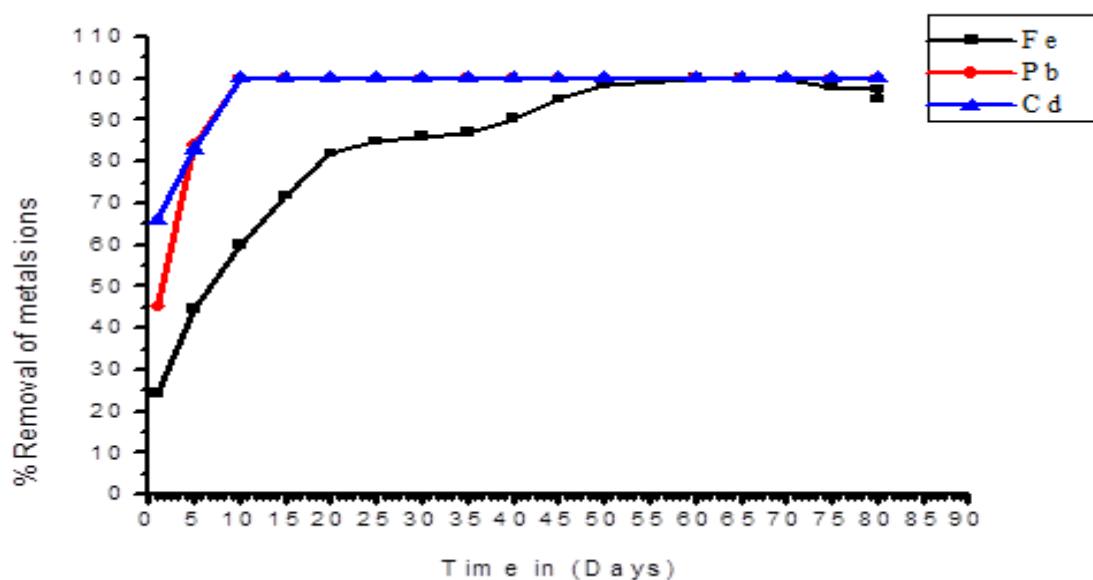


Fig.-5: Removal of heavy metals from mine water after treatment

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REFERENCES

1. E. Chockalingam, S. Subramanian, *Bioresour Technol.*, **100**(2), 615(2009).
2. E.R. Goetz, R.G. Riefler, *Chem Eng J.*, **240**,579(2014).
3. B. Prasad, R.J.G. Mortimer, *Water Air Soil Pollut.*, **218**,667(2011).
4. A. S. Sheoran, and V. Sheoran, *Miner. Eng.*, **19** (2), 105(2006).
5. D.B.Johnson, K.B.Hallberg, *Sci. Total Environ.*, **338**, 3(2005).
6. F. G. Bell, *Environmental Geology (Principles and Practice)*. Cambridge: Cambridge University Press (1998).
7. P.L.Younger, N.S.Robins, *Mine Water Hydrogeology and Geochemistry*. Geological Society of London, UK, 1-16 (2002).
8. R.W. Gaikwad, R.W, S.A. Misal, Dhirendra, D.V. Gupta, *Arab J. Geosci.*, **4**, 85(2011).
9. I.C. Montero, G.H. Brimhall, C.N. Alpers, G.A. Swayze, *Chem Geol.*, **215**,452(2005).
10. Asif Qureshi, Christian Maurice, Bjorn Ohlander, *J. of Geochemical Exp.*, **160**,44(2016)
11. H.L.Yadav and A. Jamal, *Int. J.of New Tech. in Sci. and Eng.*, **2**(3), 77(2015).
12. H.L.Yadav, and A. Jamal, *Int. J. of Advanced Research*, **3**(10),1009(2015).
13. H.L.Yadav, and A. Jamal, *Int. J. of Advanced Research*, **4**(6),310(2016).
14. B. Prasad, and H. Kumar, *Mine Water Environ.*, **35**, 553(2016).
15. A. Alcolea *et al.*, *Miner. Eng.*, **26**, 86(2012).
16. H. Davies, P.Weber, P. Lindsay, *J. Sci. Total Environ.*, **409**(15), 2971(2011).
17. P.L.Younger, Iron. In: D'Arcy, B., Ellis, J.B., Ferrier, R.C., and Jenkins, A., Dils, R. (Eds.). Terence Dalton Publishers, p. 95-104(2000).
18. H.F. Dallas, and J.A. Day, *Water Research Commission Report*, TT61/93, (1993).
19. D. M. Kargbo, D.S. Fanning, H. I. Inyang, R.W. Duell, *Environ Geol.*, **22**, 218(1993).
20. D. K. Nordstrom, C. N. Alpers, *Proc. Natl. Acad. Sci.*, **96**, 3455(1999).
21. D.S. Pelo, E. Musu, R. Cidu, F. Frau, P. Lattanzi, *J. Geochem. Explor.*, **100**,142(2009).

22. P. K. Sahoo, S. Tripathy, S. M. Equeendduin, M.K. Panigrahi, *J. Geochem. Explor.*, **112**,235(2012).
23. P.K. Goel, New Age International Publishers, New Delhi, (2006).
24. M. Delkash, Ebrazi, B. Bakhshayesh and H. Kazemian, *Micropor.Mesopor. Mater*, **214**, 224(2015).
25. A. E. Iakovlev, E. Makila, J. Salonen, M. Sitarz, S. Wang, and M. Sillanpaa, *Ecol. Eng.*, 8130(2015).
26. D. Bhattachayya, A. Jumawan, G.Sun, K. Schwitzebel, *AIChE Symposium Series, Water*; **77**, 31 (1980).
27. V. Bologo, J.P. Maree, and F. Carlsson , *Water*, **38 (1)**, 23(2012).
28. J.M.Hammarstrom, P.L. Sibrell, H.E. Belkin, *Appl. Geochem.*, **18**, 1705(2003).
29. D.C.Buzzi, L.S.Viegas, M.A.S. Rodrigues, A.M.Bernardes, and J.A.S.Tenorio, *Miner Eng.*, **40**, 82 (2013).
30. V. K. Gupta, P. J. M. Carrott, M. M. L.Ribeiro Carrott, and Suhas, *Environmental Science and Technology*, **39(10)**, 783(2009).
31. J. Landaburu-Aguirre V. Garcia, E. Pongracz, R.L. Keiski, *Desalination*, **240**,262(2009).
32. E.Sampera, M.Rodrigueza, M.A. DelaRubia D. Prats, *Sep. Purif. Technol.*, **65**,337(2009).
33. M.A.Barakat, *Arabian Journal Chemistry*, **4**, 361(2011).
34. M. M. Nia, P. Montazeri, H. Modarress, *Desalination* **217**,276(2007).
35. A. Criscuoli, M.S.I. Mozumder, M. T. Uddin, M.A., Islam, E. Drioli, *Water Res.*, **44**,97(2010).
36. H. Karami, *Chemical Engineering Journal*, **219**, 209(2013).
37. S. K. Nataraj, K.M. Hosamani, T.M.Aminabhavi, *Desalination* **217**,181(2007).
38. Q. Chang, G. Wang, *Chem. Eng. Sci.*, **62**, 4636(2007).
39. S.L.Daniels. AIChE symposium series. *Water*, **71**,265(1975).
40. A. G. ElSamrani, B. S. Lartiges, F. Villieras, *Water Res.*, **42**,951(2008).
41. B. Hadj, C. Messaoud, L. Angeliq, C. Michel, D.L Stephanie, *J. Nanostruct Chem.*, **4**, 98(2014).
42. S. Y. Bratskaya, A. V. Pestov, Y. G. Yatluk, V. A. Avramenko, *Colloid. Surf.*, **339**,140(2009).
43. Q.Chang, M. Zhang, J.X. Wang, *J. Hazard Mater.* **169**,621(2009).
44. J.C. Duan, Q.Lu, R.W.Chen, Y.Q.Duan, L.F.Wang, L. Gao, S.Y. Pan, *Carbohydr.Polym.*, **80**,436(2010).
45. M. Lundh, L. Jonsson, J. Dahlquist, *Water Res.*, **34**, 21(2000).
46. I. Heidmann, W. Calmano, *J. Hazard Mater*, **152**,934(2008).
47. A.G. Vlyssides, C.J., Israilides, *Env. Pollut.*, **97**,147(1997).
48. M. X. Guo, G.N. Qiu, W.P. Song, *Waste Manage*, **30**,308(2010).
49. A. Kongsuwan, P. Patnukao, P. Pavasant, *J. Ind. Eng. Chem.*, **15**,465(2009).
50. H. G. Park, T.W. Kim, M.Y. Chae, I.K., Yoo, *Process Biochem.*, **42**,1371(2007).
51. A. M. Youssef, S. El-Khouly, T.H. El-Nabarawy. *Carbon Lett.*, **9**, 8(2008).
52. M. Kalin, A. Fyson, and W.N. Wheeler, *Sci. Total Environ.*, **366 (23)** , 395(2006).
53. G. S. Simate, and S. Ndlovu, *J. Environ. Chem. Eng.*, **2(3)**, 1785(2014).
54. Vhahangwele, Masindi, Mugeru Wilson Gitari, Hlanganani Tutu and Marinda De Beer, *Water SA*, **41(5)** , 677 (2015).
55. S. D. Faust, O.M. Aly., Butterworth Publishers, Stoneham, (1987).
56. A.Mishra, and B.D.Tripathi, Toxicological & Environmental Chemistry, *Water SA*, **90(6)**, 1091 (2008).
57. H. Thorwarth, V. Stack-lara, S. Unterberger, & G. Scheffknecht, Proceedings of Air Quality V. Washington, D.C. (2005).

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