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Heavy Metals from Acid Mine Drainage in Coal Mines-A Case Study

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ABSTRACT

Acid drainage is most common problem or associated with almost all mines containing sulphide deposits and coal containing high pyrite. Acid drainage is caused when rain water and or seepage from rock formation interact with sulphur bearing minerals. It produces water of high acidity with higher metal concentration. Acid drainage is most susceptible to dissolve heavy metals particularly Iron, Zinc, Copper, Lead Mercury etc. The case study of surface coal mines of Northern Coal Fields Ltd., Singrauli is presented in this paper. Various techniques for decreasing the acidity of water in coal mine were experimented at laboratory scale. The pH value is ranging from more than 2.66 to 3.91.The ions and others content are also significantly higher than recommended permissible limit. There is waste water effluent treatments plant for arresting TSS in effluents coming from workshop. The marginal acidity in sump water is a major issue as for as water quality threat is concerned. The technique suggested in fields' application and effective to lower the pH value and others constituents present in water. It has been concluded that along with decrease in pH value, the concentration of iron is lowered significantly. However, the deposition of iron precipitates on surface rocks decreases the neutralizing capacity of rocks overburden used as acid neutralizer. The technique suggested for acid water treatment is field applicable and along with acidity it decreases the iron content of water of coal mine also.

Key words: Acid drainage, Coal Mines, pH value, TSS

INTRODUCTION

Acid mine drainage (AMD) formation has been widely recognized as one of the Major Environmental problems caused by mining worldwide, as evidenced by numerous studies[1,16]. Mining has been one of the most common activities since ancient times and continues to remain so in the modern world. The mining activities of certain minerals, including coal, copper, gold, and nickel, is associated with acid drainage problems that can cause long-term mutilation to natural water body and biodiversity. Metals mining industry also contain large quantities of hazardous toxic substances, such as heavy metals and cyanides, which have very serious human health and ecological implications [2, 24-27]. Acid water, also Known as acid Mine Drainage (AMD) is caused by the weathering of minerals such as iron disulphide (FeS_2), commonly known as pyrite, When pyrite is exposed to water and oxygen, oxidation and hydrolysis reactions produce sulphuric acid (H_2SO_4) and free hydrogen ions (H^+), acidifying the water [2].The Mining activity affects the water resources of the neighbouring mining area. They are disturbing the natural drainage pattern, lowering of water table, pollution of sub-surface and surface water bodies. Acid Mine Drainage (AMD) and its contaminants associated with it is the most hazardous environmental pollution. Characteristics of Acid Mine Drainage (AMD) vary mines to mines and site-to-site, the prediction of AMD can be very challenging and costly task [3]. Acid Mine Drainage contain low pH (2-4) and high Concentrations of heavy metals particularly Iron, Zinc, Cd, Copper, Lead, Mercury etc.

AMD can severely contaminate soils, surface and sub-surface water sources [4-5]. Every Mine produces AMD with different potential; about 40% of the AMD problems originated from active mines both surface and underground rest from others.[6-7] The nature and size of the associated risk and feasibility of mitigation options will also vary from mines to mines and site-to site. Disposal of AMD results in corrosion of mining equipments and pumps by pitting [8-10]. The risk of associated with AMD are the impacts upon water quality [11-14]. There are no any suitable methods for measuring and reducing the risk of acid water. Many factors like climate, geology and hydrological etc. Controlling the metal concentrations in polluted water resources and they have a harmful affect on the natural ecosystem of a river. In order to determine a cost effective treatment technology, it is necessary to identify the major sources of AMD.

ACID GENERATION IN MINES

Acid mine drainage (AMD) forms when sulphide minerals are directly exposed to oxidizing conditions in metal , coal mining, highway construction, and other large-scale excavations. There are many types of sulphide minerals. Iron sulphides is common in coal mine mortally pyrite and marcasite (FeS_2), but some other metals may also completed with sulphides forming chalcopyrite ($CuFeS_2$), covellite (CuS), galena (PbS), and sphalerite (ZnS). Pyrite commonly occurs with these other metal sulphides thereby causing AMD where Cu, Pb, and Zn are mined. Acidity in AMD is comprised of different minerals acidity (Fe, Al, Mn, and other metals depending on the specific metal sulphide) and hydrogen ion acidity. In general, sulphide-rich and carbonate-poor materials produce acidic drainage and shown by following reaction [23].

$$4FeS_2(s) + 15O_2(g) + 14H_2O(l) \rightarrow 4Fe(OH)_3(s) + 8SO_4^{2-}(aq) + 16H^+(aq)$$

These are various factors responsible for acid generation such as –

- pH value at the reaction sites
- Temperature at the reaction sites
- Flow rate and flow paths of water
- Chemical composition of pore water
- Degree of saturation with water
- Chemical activity of Fe_3C
- Bacterial activity
- Oxygen concentration in the water phase
- Surface area of exposed metal sulphide
- Oxygen content of the gas phase, when saturation is less than 100%
- Concentration, distribution, mineralogy and physical form of neutralising and other minerals
- Chemical activation energy required to initiate acid generation

The huge volume of mine water after treatment or untreated water can be used for various purposes such as Untreated acid mine drainage can be used for Mining (Gold mines),Neutralized ADM can be used for Agricultures, Mining, Industries, and Rivers, Neutralized and Desalinated ADM can be used for Domestic, Industries, and Rivers etc.

Global and Indian status

At present India have 84 minerals comprising 11 metallic, 49 non-metallic industrial, 20 minor minerals and 4 fuels [18]. In 1774, the first modern industrial mining activity started in India, when East India Company permitted to English Company for coal mining extraction in Raniganj area. In 1880, gold mining started by M/S John Tylor and Sons in Kolar goldfield in Karnataka. India is one of the leading producers and exporters of several natural minerals in the world and self-sufficient in most of the minerals which includes bauxite, barites, chromite, dolomite, fluorspar, gypsum, iron ore, limestone, lignite, magnesite , manganese ore, sillimanite, etc. In India more than 3100 locations mining activities are carried out for different minerals exploration. The total number of mineral deposits are 13,000, which is 0.21 percent of the total land of the country, which is about 0.7 million hectares. The Mining industry in India has been progressing at an annual rate of 4% to 5% during the last three decades. Thus it increased from 0.56 to3 percent in GDP [17, 19].

Indian mining industry provides huge employment to 1.1 million people with more than 16 percent share in India's export. India is Asia's third and worlds eleventh largest economy. It has natural resources of 12745 million tons of Iron ore, 76446 million tons of limestone; 2,525 million tons of bauxite, 233 million tons of magnesite, 176 million tons of manganese ore, 167 million tons of Lead & Zinc ore, 90 million tons of chromite and 70 million tons of barites, of the total known global resources of the minerals, the reserves of bauxite and manganese and iron ore accounts for nearly, 16 percent, 6 percent and 7 percent, respectively. The modernization of the mining industries has opened many opportunities for development of Country.

Case Study

The Churcha coal mine is located in Baikunthpur area of Sarguja district in Madhya Pradesh. The general geography around Churcha coal mine is very simple with high and low relief of 25 m. Churcha coal mine have many big and small water bodies. The Gej stream is situated very near to the Churcha coal mine and receives effluents from mines and ultimately discharges into Kewai River which is a tributary of Son River. The topography of the area lies in the range between 203m to 228m. The Climate of the area can be defined as a sub-tropical type with summer from April to June, monsoon season from July to September, post- monsoon from October to December and winter from January to March. The maximum and minimum temperature recorded 7○c winter and 48○c in summer seasons. The Baikunthpur area fully enriched with surface and ground water resources. The physico-chemical characteristics of mine water discharge from various locations in Churcha coal mine is summarized in table-1.

It may be observed from this table-1 and figures.(1 to 4) that quality of water in seam at location-1 ranges from 3.75-3.80 , location- 2, ranges from 3.91-3.94 and location- 7, ranges from 3.78-3.80,in water sample collected from location-3 to 6,ranges between 2.62 to 2.73, from the above pH values that pH of water discharge from location -5 is more acidic as compare to the other location in Churcha coal mine, and all the values are much below than the lower permissible limit of industrial effluent discharge (5.5-9.0) and hence it is highly objectionable for water quality. The total dissolved solids at different location from L-1to L-7 ranges between 2213 mg/l to 2908 mg/l which is higher than the permissible industrial limits of 2100 mg/l. The Iron (Fe) at different location from L-1to L-7 ranges between 22.02 mg/l to 65.8 mg/l which is higher than the permissible industrial limits of 3.0 mg/l. Hence it is highly objectionable for water quality. The values of TSS are much below than the lower permissible limit of industrial effluent discharge (100mg/l) at location-3 to location-7. Locations 1 and 2, have TSS are slightly higher than permissible limit of industrial effluent discharge (100mg/l).

Table -1 Physico-Chemical Characteristic of Mine Effluents of Churcha Coal Mine

Water quality parameters	Water sampling location							
	L- 1	L- 2	L-3	L- 4	L-5	L-6	L-7	Tolerance limit as per GRS(ISW)
Colour	Yellowish	Yellowish	Yellowish	Yellowish	Yellowish	Yellowish	Yellowish	Shall be colourless
Odour	Pungent	Pungent	Pungent	Pungent	Pungent	Pungent	Pungent	Shall be odourless
Temp.	29.8-30.2	29.5-30.2	30-39	33-34	29.1-30.2	31.7-32.3	32-34	Shall not be exceeding 5°c above the receiving water temp.
pH	3.75-3.80	3.91-3.94	3.75-3.80	2.73.-2.79	2.62-2.69	2.66-2.70	3.76-3.80	5.5-9.0
TSS	101-107	95-100	29.0-31.0	25.0-27.0	28.0-30.0	72-77	31.0-32.2	100.00
TDS	2215-2222	2213-2219	2684-2688	2900-2903	2501-2505	2280-2290	2908-2928	2100.00
DO	5.8-6.0	5.5-6.0	6.5-7.2	7.5-8.2	6.6-7.5	6.5-8.0	6.4-8.6	8.0at 25°c
BOD	8.5-9.6	8.7-9.3	10.6-11.0	10.8-11.2	9.7-10.1	8.9-9.5	14.5-14.9	30
Fe	22.02-23.8	29.8-32.02	43.1-44.02	45.4-46.8	41.8-42.6	39-44.7	60.2-65.8	3.0

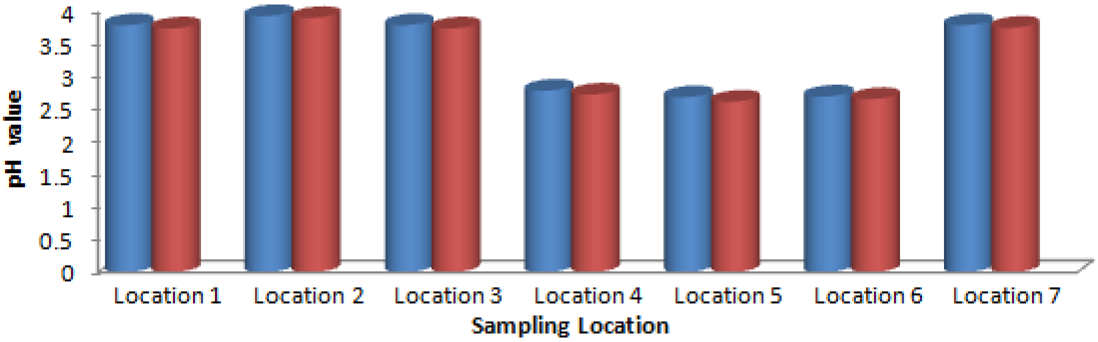

Fig. 1 pH value of sump water at various locations

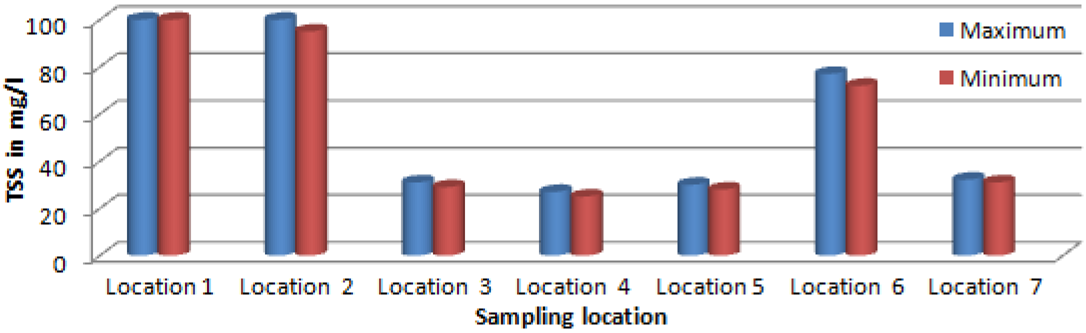

Fig. 2 Total Suspended Solids in sump water at various locations

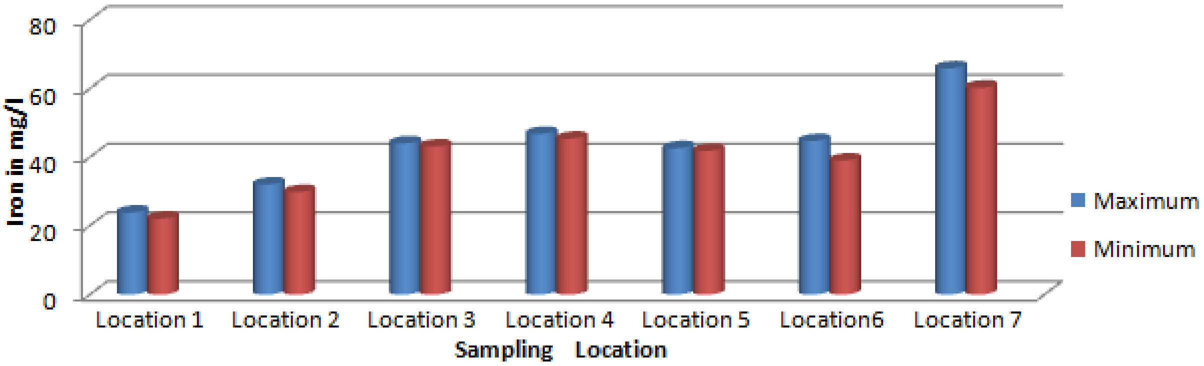

Fig. 3 Iron concentration in sump water at various locations

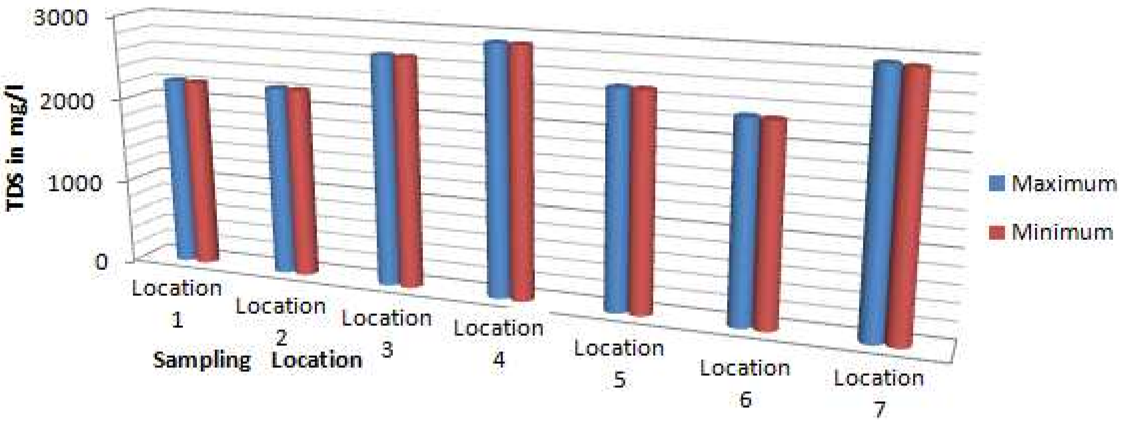

Fig. 4 Total Dissolved Solids in sump water at various locations

Existing methods and suggestive approaches for Acid Mine Drainage

Various techniques has been suggested for management of acid mine drainage in coal and metal Mines [20]. A few important one is given below –

- Dry covers
- Soil compaction
- Sealing with clay
- Covers with sludge
- Handling tailings
- Surface water diversion
- Application of chemicals
- Chemical neutralization plants
- "Inline system" plants
- Treatment plants by ion exchange
- Aerobic and anaerobic wetland
- Vertical flow reactors
- Reverse osmosis
- Anoxic lime drains

For management of acid mine drainage in coal mines, the technology suggested is discussed in subsequent paragraphs. The result of the experiment conducted on laboratory scale on drain model is presented here. The result is given in table-2.

Table -2 Changes in pH value verses rate of discharge

Time of observation	Rate of discharge(Liters/minute)			
	2.25	3.50	5.50	7.75
	Variation in pH value			
0 min	3.75	3.75	3.75	3.75
After 20 min	3.98	3.89	3.86	3.85
After 40 min	4.16	4.05	3.98	3.92
After 60 min	4.28	4.16	4.11	3.98
After 80 min	4.43	4.32	4.22	4.07
After 100 min	4.63	4.46	4.33	4.18
After1 20 min	4.81	4.65	4.48	4.23
After 140 min	4.91	4.77	4.56	4.31
After 160 min	5.02	4.90	4.67	4.42
After 180 min	5.12	4.92	4.89	4.51

From the table it can be seen that there is a gradual and at some times rapid increase in pH value of mine water flowing over the sand stones slabs laid in the drain at all rates of discharge. However, increase in pH value is more at lower rates of discharge. Initially, there is a rapid increase in pH value and with time, the rate of increase in pH value slowdown. The results indicate that the dissolution of basic components of the sandstones increases with more acidic water and as the pH of mine water increases, the rate of dissolution decreases. The initial rapid increase in pH value of mine water seems to be due to the availability of fresh minerals which release bases at the fast rate, but this rate slowdown with time. The sandstones help in liberation of bases and allow mine water to react with silicate minerals, [21]. The reaction involved in the neutralization of acid mine water may be shown below [22]

$$CaAlSi_2O_8+2H+H_2O \longrightarrow Ca_2+Al_2Si_2\,O_5\,(OH)_4\,(S) \tag{1}$$

$$KAl_2(AlSi_3O_{10}(OH)_4(S)+H^+ +3/2H_2O \longrightarrow K+3/2Al_2Si_2O_5\,(OH)_4\,(S) \tag{2}$$

$$KAl_3SiO_8(S)+2H+H_2O \longrightarrow K+2H_4SiO_4+1/2Al_2Si_2O_5\,(OH)_4\,(S) \tag{3}$$

$$NaAlSi_3O_8+H+9/2H_2O \longrightarrow Na+2H_4SiO_4+1/2Al_2Si_2O_5\,(OH)_4\,(S) \tag{4}$$

The experimental result strongly suggests that sandstone of the mine area have sufficient neutralizing capacity and can be economically used for acid mine water treatment by diverting the flow through a drain passing over the sandstones bed. The maximum neutralization capacity of sand stone can be obtained by increasing the length of drain, surface area of drain and monitoring rate of discharge with mine water.

CONCLUSION

The study reveals the problem of acid drainage in coal mines. The waste water is in acidic range fortunately, the occurrence of rocks associated with coal has acid neutralizing capacity. There is significant improvement in quality of water in terms pH value. The study is continued and impact of sandstone on metal content yet to be studies.

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REFERENCES

[1] M Kalin, A Fyson and WN Wheeler, The Chemistry of Conventional and Alternative Systems for the Neutralization of Acid Mine Drainage, *The Science of the Total Environment*, **2006**, 366 (23), 395-408.
[2] A Azapagic, Developing a Framework for Sustainable Development Indicators for the Mining and Minerals Industry, *Journal of Cleaner Production*, **2004**, 12 (6), 639 -662.
[3] PC Singer and W Stumm, Acidic Mine Drainage, The Rate-Determining Step, *Science*, **1970**, 167, 1121-1123.
[4] BM Thomson and RT William, Minerals and Mine Drainage Water Environmental, *Water Environment Federation*, **1996**, Vol. 68, pp. 542-546.
[5] H Olem, Coal and Coal Drainage, *Journal of Water Pollution Control Fed*, **1980**, 52(6), 1415-1424.
[6] H Olem, Coal and Coal Drainage, *Journal of Water Pollution Control Fed*, **1981**, 53(6), 814-824.
[7] MP Fillion, LL Sirois and K Feguson, Acid Mine Drainage Research in Canada, *CIM Bulletin*, **1991**, 82(931), 85-91.
[8] USEPA, *Technical Document of Acid Mine Drainage Prediction*, Office of Solid Waste, Washington, USA, **1994**, 48.
[9] G Singh, Impact of Coal Mining on Water Quality, *International Journal of Mining Water*, **1988**, 7 (3), 49-59.
[10] G Singh and DK Sinha, Impact of Coal Mining on Water Quality, *Third International Mining Water Congress*, Melbourne (Australia), **1988**.
[11] G Singh, Water Pollution Issues and Control Strategies in Mining Areas, *Minetech*, **1999**, 20(1), 45-53.
[12] A Jamal, *Environmental Impact of Opencast Coal Mining on Air and Water Quality and its Management*, PhD Thesis, Banaras Hindu University, Varanasi , India, **1989**.
[13] A Jamal, BB Dhar and S Ratan, Acid Mine Drainage Control in an Opencast Coal Mining Complex-A Case Study, *International Journal of Surface Mining and Reclamation*, **1991**, 5(2),83-88.
[14] A Jamal, BB Dhar and RK Tiwary, Prediction of Water Quality Drainage in Coal Mines- A Case Study, 6th *International Mine Water Association Congress*, B Led, Slovenia, **1997**.
[15] BB Dhar, Environmental Impact Assessment of Singrauli Mining Complex with Special Reference to Air and Water, *Proceeding of Indo-US workshop on Environmental Management Planning for Singrauli Coalfield*, NCL, Singrauli (MP), **1990**, 2, 47-57.
[16] T Saarinen, S Mohämmadighävam, H Marttila and B Klove, Impact of Peat Land Forestry on Run of Water Quality in Areas with Sulphide bering Sediments, How To Prevent Acid Surges, *Forest Ecology and Management*, **2013**, 293, 1728.
[17] V Sheoran and NK Tholia, Acid Mine Drainage, an Overview of Indian Mining Industry, *International Journal of Earth Sciences and Engineering*, **2011**, 4 (6), 1075-1086.
[18] TERI, Overview of Mining and Mineral Industry, TERI Project Report No. 2001EE42, **2001**.
[19] KS Raju, M Hasan and YG Kale, Status of Metalliferrous Mining in India: An Overview and Future Outlook, *Proceeding of 19th World Mining Congress*, **2013**, 403-414.
[20] RG Gaikwad and DV Gupta, Acid Mine Drainage, *Journal of Indust. Pollution Control*, **2007**, 23(6), 285-297.
[21] E Busenberg and CV Clemency, The Dissolution of Kinetics of Feldspars at 25°c and 1atm co2 partial Pressure, *Geochim, Cosmochim, Acta*,**1967**, (40), 41-50.
[22] A Jamal, S Siddharth and RK Tiwary, Management of Acid Mine Drainage in Coal Mines- Prediction of Water Quality Drainage in Coal Mines- A Case Study, *National Seminar on Status of Environmental Management in Mining Industry*, IT (BHU) Varanasi, **2003**, 141-150.
[23] DB Johnson and KB Hallberg, Acid Mine Drainage Remediation Options- A Review, *Science of the Total Environment*, **2005**, 338(1-2), 3-14.
[24] DA Marsden, RE DeWreede and CD Levings, Survivorship and Growth of Fucus Gardneri after Transplant to an Acid Mine Drainage-Polluted Area, *Marine Pollution Bulletin*, **2003**, 46, 65- 73.
[25] DS Cherry, RJ Currie, DJ Soucek, HA Latimer and GC Trent, An Integrative Assessment Of Watershed Impacted By Abandoned Mined Land Discharges, *Environmental Pollution*, **2001**, 111, 377-388.
[26] MO Aremua, DU Sangarib, EI Adeyeye and YY Ishalekua, Metal Concentration in Soils, Ponds and Associated Food Crops in Azara Derelict Baryte Mining Area in Nigeria, *EJEAF Che*., **2010**, 9(1), 10-18.
[27] HN Ezeh and E Chukwu, Scale Mining and Heavy Metals Pollution of Agricultural Soils: The Case of Ishiagu Mining District, South Eastern Nigeria, *Journal of Geology and Mining Research*, **2011**, 3(4), 87-104.
[28] Matthews Amune, Omono Christiana and Samuel Kakulu, Impact of Mining and Agriculture on Heavy Metal Levelsin Environmental Samples in Okehi Local Government Area of Kogi State, *International Journal of Pure Applied Science and Technology*, **2012**, 12(2), 66-77.