IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 9, Issue 12 Ver. II (Dec. 2015), PP 35-45
www.iosrjournals.org

Impact of Coal Mining In Enugu Area of Nigeria on the Surrounding Water Quality

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Abstract: *This study examined impact of coal mining in Enugu on the surrounding water quality.Mine tunnels empty their discharged water into Nyaba and Ekulu Rivers within the Enugu coal mined area. Twenty five (25) water samples from the tunnels and the two Rivers wereanalyzed in an attempt to reflect the impact of coalmining on the surrounding water quality. Various physico-chemical characteristics of mine water as analyzed include, pH,alkalinity, acidity, hardness, total solids, sulphate, chloride, magnesium, calcium and iron. Trace metals analyzed include, Cd, Pb, Ni, Cr, Co, As,Cu,Mn,Zn and Fe. Concentration trend of metals follows the order Fe>Ni>Zn>Pb>Cd>Co>Cr>As>Cu>Mn. The concentrations of Fe (1, 89 mg/l), Cd (0.33mg/l), Ni (0.97 mg/l) and Pb (0.53 mg/l) exceeded the recommended values for potable water. This is a great risk to the consumers as the Water is not fitfor drinking and cooking but could be used for washingand other purposes. This research revealed that coal mining activities, markedly pollute the surrounding waters.*

Key Words:*Toxic elements, As, Cd, Cr and Pb, WHO tolerable limits.*

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I. Introduction

There is relatively little knowledge about the post-mining of coal in Enugu area and its effects on the surface and groundwater quality. Water pollution caused by either by mining activities or natural geochemical processes such as the oxidation of pyrites, is a significant problem in several countries. However, it is generally understood that the influence of mine on site abandonment has adverse effects on the quality of water. The study is aimed at determining the Impact of coal mining in Enugu area on the surrounding water quality.
This major aim is achieved through the following objectives:-

a) To determine the chemical characteristics of water samples from the study area
b) To determine the physical characteristics of water samples from the study area
c) To determine whether the physical and chemical compositions of the water samples from the study area meet the NAFDAC and WHO maximum permissible standards.

II. Materials And Methods

Field and laboratory studies were applied in this study to investigate the impact of coal mining in Enugu on the surrounding water quality.Site localities were identified on 1:50,000 Geological Survey of Nigeria topographic maps, sheet 301, part of Udi NE and recorded using a standard Gamin eTrex HC global positioning system (GPS) instrument. Samples identification numbers with 'ON' were collected from Onyeama mine areas while those with 'OK',came from Okpara mine areas.Twenty five (25) water samples were collected. Water samples collected came from the tunnels, Ekulu and Nyaba Rivers (Figure 1). Sample numbers ON-11, OK-13, OK-15, OK-23 and OK-25 (Table 1) were collected from the tunnels (in asterisk) are referred to as mine water. Mine water here is defined as water that collects due to groundwater seepage or flow from surface water or precipitation and comes out through the mined tunnels [Uma, 2005]. Eleven samples (ON 1—ON11) were collected from the Onyeama mine areas and fourteen (Ok-12 - OK-25) came from the Okpara mine areas.Standard samplingprotocols described by [Classen, 1982] and [Barcelona et al.,1985] were adhered to during sample collections. Water samples were collected using one-litre polypropylene plastic bottles sterilized with dilute hydrochloric acid. Water samples were also collected at 400-500 meter intervals down the slopes of Ekulu and Nyaba rivers. The pHreadings were taken in the field using Philips model PW 9418 pHmeter with immersion electrodesafter the meter had been calibrated with standard buffers of pH 4.0, 7.0 and 9.0.All samples were stored in a refrigerator ready for various physio-chemical analyses. The quantitative analyses of trace metals were done using an Atomic Absorption Spectrophotometer, model 210 VGP.

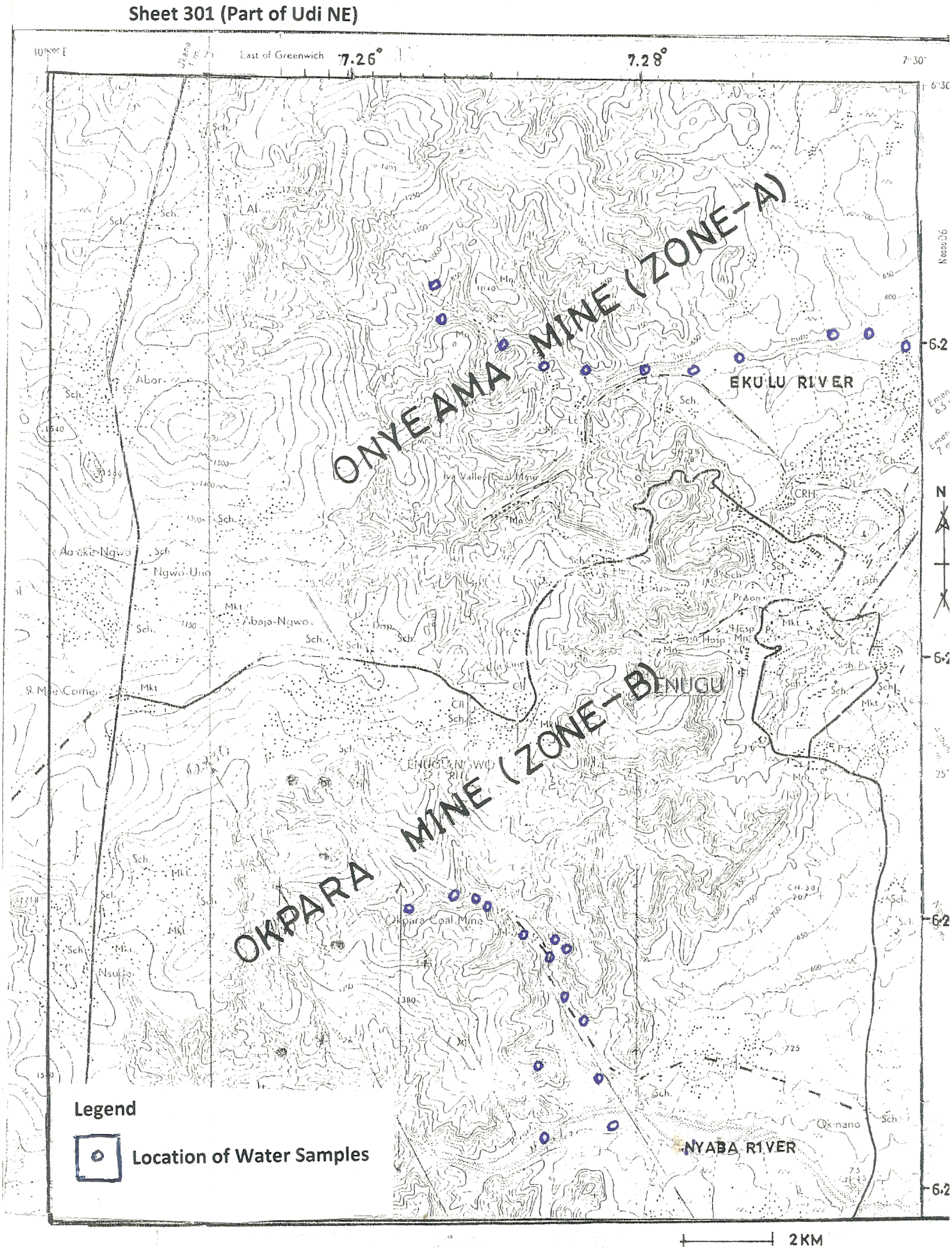

Fig 1. Location of Water Samples

Table 1: Location of Water Samples

Sample ID	Zones	Latitude N(deg)			Longitude E(deg)		
ON – 1		06	27	436	07	28	836
ON - 2		06	27	899	07	28	355
ON - 3		06	27	910	07	28	550
ON - 4	Zone	06	27	818	07	27	458
ON - 5		06	28	295	07	27	389
ON - 6	A	06	28	146	07	28	852
ON - 7		06	28	100	07	28	836
ON - 8		06	28	251	07	29	977
ON - 9		06	28	030	07	26	035
ON- 10		06	28	479	07	26	820
ON-11*		06	28	327	07	26	789
OK- 12		06	24	167	07	26	802
OK- 13*		06	24	161	07	26	944
OK - 14		06	23	915	07	27	153
OK-15*		06	23	541	07	27	197
OK -16		06	23	716	07	27	284
OK -17	Zone	06	23	052	07	27	328
OK- 18	B	06	23	495	07	27	430
OK- 19		06	23	392	07	27	518
OK- 20		06	22	147	07	27	409
OK- 21		06	22	756	07	27	877
OK- 22		06	22	687	07	27	617
OK- 23*		06	24	067	07	26	996
OK- 24		06	24	084	07	26	991
OK- 25*		06	23	090	07	27	219

Note: * Mine water from tunnels; Zone A is OnyeamaMine Area; Zone B is Okpara Mine Area.

Water Samples Analysis:

Water samples (30ml) were filtered with Whatman grade A filter paper for estimation of dissolved content.Water samples generally do not require preparation other than to re-suspend any settled material by agitating the sample prior to analysis.

Alkalinityof water was determined by titrimetric method. This method is applicable to drinking and surface water, domestic and industrial wastes, and saline waters [Bryant, 2005].It is suitable for all concentration ranges. 10ml of unfiltered portion of each water sample was titrated potentiometrically with 0.01M HCI solution using methyl orange as indicator.

Chloride was determined by titrating 10ml of the sample with a standard solution of 0.1N silver nitrate solution using solution of potassium chromate as indicator.

Total solids (TS) and total dissolved solids (TDS) were determined by volumetric method.

Hardness of water was determined by calculation method. Hardness as sum of $CaCO_3$ equivalents (mg/l) obtained by multiplying concentration (mg/l) found of cations by a given factor. Factors for calculating hardness using given cations by [Bryant, 2005] are Ca (2.497), Mg (4.116),Sr(1.142), Fe (1.792),Al(5.564),Zn (1.531) and Mn(1.822). Parameters determined by volumetric analysis involved measuring initial and final burette readings. The titre values (TV) used for calculating the concentrations of the parameters in mg/l.

The water samples were quantitativelyanalyzed for trace metals: lead (Pb), zinc(Zn),nickel(Ni),copper(Cu),cadmium(Cd),cobalt(Co),iron(Fe),manganese(Mn),chromium(Cr) and arsenic(As)usingBuck Scientific Absorption Spectrophotometer (AAS) model 210 VGP. Concentration of the trace elements were extrapolated from plotted curve [Vogel, 2007].

III. Results And Discussion

Results of chemical analysis of water samples (mg/l) are shown in Table 2.These reflect the geochemical system of the coal seams and overlying strata form which the water samples have been collected. These underground mine waters are neutral to slightly alkaline in nature and pH values lie within permissible limit.Trace metals analysis of Water samples in mg/l are presented in Table 3. Combined physio-chemical characteristics of drinking water standards from World Health Organization [WHO, 2011] National Agency for Food, Drug Administration and Control (NAFDAC) and Standard Organization of Nigeria [SON, 2003] is presented in Table 4 for comparison.

Trace metal ion concentrations in water samples were compared with WorldHealth Organization (WHO) standards, Table 5.The comparisons of the trace metal ions as compared with world health standards concentration guideline are demonstrated as shown in the histograms for total solids(TS), chloride, alkalinity, cadmium, chromium, copper, nickel, manganese, iron, zinc and zinc in Figures 2,3and 5.In the demonstrated Figures, Onyeama mine area is Zone A while Okpara mine area is Zone B.

Table 2: *Chemical Analysis of Water Samples (mg/l)*

Sample ID	Total hardness as $CaCO_3$	Total solids (TS)	Total dissolved solids (TDS)	Chloride	Calcium	Magnesium	Alkalinity	Sulphate	PH
ON 1	104.00	401.00	120.00	61.70	50.15	20.00	100.00	215.00	5.0
ON 2	520.00	120.00	21.80	35.40	17.10	19.40	75.00	NIL	5.5
ON 3	340.00	650.00	100.00	74.00	33.00	8.60	67.00	100.00	5.5
ON 4	220.00	320.00	110.00	141.00	21.30	5.40	NIL	490.00	6.5
ON 5	440.00	310.00	73.00	160.30	9.75	16.80	110.00	160.00	6.0
ON 6	100.00	110.00	90.80	80.05	33.40	NIL	75.00	90.30	5.5
ON 7	95.00	440.00	520.00	27.90	12.12	9.60	35.00	700.00	4.5
ON 8	47.90	120.00	87.90	42.75	16.70	3.40	105.00	120.30	5.0
ON 9	76.00	312.00	63.40	106.00	4.75	6.70	75.00	225.00	5.5
ON 10	150.00	175.00	140.00	153.30	19.20	13.40	Nil	140.00	5.5
ON11*	115.00	420.00	320.00	35.40	8.01	2.43	100.00	20.00	5.0
Total	**2207.9**	**3378.0**	**1646.90**	**917.86**	**225.51**	**106.73**	**748.00**	**2260.30**	**59.5**
Ave.	**200.71**	**307.09**	**149.71**	**83.44**	**20.50**	**10.57**	**82.44**	**226.03**	**5.4**
OK 12	38.75	176.00	91.60	95.30	19.00	6.70	73.40	307.00	6.5
OK 13*	67.70	330.00	63.75	175.00	35.70	Nil	95.00	175.00	4.5
OK 14	80.10	320.00	210.00	38.75	11.60	12.04	125.00	215.00	4.5
OK 15*	50.50	375.00	87.25	68.30	32.00	9.50	Nil	Nil	5.5
OK 16	85.70	430.00	105.00	180.05	42.40	16.70	Nil	69.10	5.5
OK 17	140.00	220.00	110.00	156.40	13.60	17.90	87.00	215.00	6.5
OK 18	21.75	540.00	81.00	25.73	12.02	5.50	90.00	89.30	5.0
OK 19	45.00	220.00	55.00	37.80	65.00	Nil	25.00	320	5.0
OK 20	150.00	110.00	76.50	104.70	8.10	11.80	37.00	210.00	4.5
OK 21	65.10	75.00	67.80	135.00	29.10	7.00	80.30	200.20	5.5
OK 22	95.00	520.00	315.00	87.00	30.60	5.60	90.00	100.30	4.5
OK 23*	140.00	51.75	60.00	57.80	32.48	3.41	25.00	430.00	6.5
OK 24	61.00	140.00	320.00	75.00	23.70	Nil	75.00	320.00	5.0
OK 25*	49.00	605.00	105.00	61.00	25.60	9.46	Nil	570.00	5.0
Total	1089.6	4112.7	1747.80	1297.83	380.90	105.01	802.70	3220.40	74.0
Average	**77.82**	**293.76**	**124.85**	**92.70**	**27.20**	**9.54**	**72.97**	**247.70**	**5.3**
Mean	**139.26**	**300.42**	**137.28**	**88.07**	**23.85**	**10.05**	**77.70**	**236.86**	**5.4**
WHO Limit	**100.00**	**500.00**	**1500.00**	**200.00**	**75.00**	**20.00**	**100.00**	**500.00**	**7-8.9**

***Water from tunnels (mine water)

Table 3: *Trace Metals Analysis of Water Samples (mg/l)*

Sample ID	Cd	Cr	Cu	Mn	Ni	Pb	Co	Fe	Zn	As	pH	
ON 1	0.32	0.02	0.03	0.02	0.60	0.03	0.13	0.64	0.87	ND	5.0	Onyeama Mine
ON 2	0.45	0.01	0.05	0.03	0.37	0.01	0.11	0.88	1.02	0.01	5.5	
ON 3	0.18	ND	0.04	0.05	0.98	0.05	0.42	0.61	0.99	0.10	5.5	
ON 4	0.16	ND	0.07	0.11	0.10	0.10	0.07	0.37	1.29	ND	6.5	
ON 5	0.14	0.04	0.03	0.02	1.11	0.02	0.17	0.45	1.06	ND	6.0	
ON 6	0.40	0.02	0.03	0.08	1.55	0.07	0.10	0.42	1.12	ND	5.5	
ON 7	0.47	0.01	0.12	0.03	1.10	0.03	0.05	0.96	0.90	0.01	4.5	
ON 8	0.56	0.01	0.07	0.07	0.11	0.04	0.15	0.83	0.78	ND	5.0	
ON 9	0.35	ND	0.06	0.10	0.86	0.06	0.19	0.81	1.06	ND	5.5	

ON 10	0.31	ND	0.08	0.02	0.19	0.08	0.06	0.35	0.57	ND	5.5	
ON 11*	0.46	0.02	0.04	0.49	0.07	0.10	0.12	0.97	0.03	0.09	5.0	
Total	**3.80**	**0.13**	**0.62**	**1.02**	**7.04**	**0.59**	**1.63**	**7.29**	**9.69**	**0.21**	**59.5**	
Average	**0.34**	**0.01**	**0.05**	**0.09**	**0.64**	**0.05**	**0.14**	**0.66**	**0.88**	**0.05**	**5.4**	
OK 12	0.21	ND	0.70	0.04	0.70	0.03	0.17	0.68	0.94	0.01	6.5	Okpara Mine
OK 13*	0.37	0.02	0.06	0.03	1.04	0.02	0.09	0.80	0.80	0.01	4.5	
OK 14	0.23	0.01	0.06	0.08	0.65	0.04	0.13	0.73	1.61	ND	4.5	
OK 15*	0.15	ND	0.09	0.06	0.03	0.03	0.06	0.39	0.68	ND	5.5	
OK 16	0.22	0.01	0.05	0.02	1.12	0.03	0.18	0.54	0.77	0.01	5.5	
OK 17	0.12	0.01	0.03	0.01	3.91	0.07	0.07	0.71	1.11	ND	6.5	
OK 18	0.44	0.01	0.10	0.07	1.22	0.05	0.15	0.48	0.51	0.01	5.0	
OK 19	0.39	ND	0.11	0.11	1.14	0.08	0.04	0.67	0.79	0.01	5.0	
OK 20	0.62	0.01	0.04	0.04	1.61	0.06	0.12	0.81	0.56	0.01	4.5	
OK 21	0.51	ND	0.06	0.10	0.49	0.04	0.08	0.71	1.38	ND	5.5	
OK 22	0.44	ND	0.09	0.03	1.25	0.02	0.03	0.77	0.95	0.01	4.5	
OK 23*	ND	0.10	ND	0.07	1.86	5.50	0.30	27.1	0.58	0.50	6.5	
OK 24	ND	ND	ND	0.23	0.70	2.00	0.05	1.40	0.03	ND	5.0	
OK 25*	ND	0.80	ND	0.50	2.50	6.30	0.40	8.10	0-60	ND	5.0	
Total	**3.70**	**0.97**	**1.39**	**1.39**	**18.22**	**14.27**	**2.37**	**43.89**	**11.31**	**0.57**	**74.0**	
Average	**0.33**	**0.12**	**0.12**	**0.09**	**1.30**	**1.01**	**0.16**	**3.13**	**0.81**	**0.07**	**5.3**	
Grand Total	7.50	1.10	2.01	2.41	25.26	14.86	4.00	51.18	21.00	0.78	133.5	
Mean	**0.33**	**0.06**	**0.08**	**0.09**	**0.97**	**0.53**	**0.15**	**1.89**	**0.84**	**0.06**	**5.4**	
WHO Limit	0.003	0.05	0.50	0.10	Nil	0.01	Nil	1.00	0.01	0.01	7.0-8.9	

NB: ND = Not Detected
* = Water from tunnels (mine water)

Table 4: ***Current Drinking Water Standards.***

	Parameter	NAFDAC Maximum allowed limits	SON standards	WHO (2011) standards Highest desirable	WHO (2011) standards Maximum permissible
1	Colour	3.0 TCU	3.0 TCU	3.0 TCU	15 TCU
2	Odour	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
3	Taste	Unobjectionable	Unobjectionable	Unobjectionable	Unobjectionable
4	pH at 20^o C	6.50-8.5	6.50-8.50	7.0-8.9	6.50-9.50
5	Turbidity	5.0 NTU	5.0 NTU	5.0 NTU	5.0 NTU
6	Conductivity	1000 (us/cm^{-1})	1000 (us/cm^{-1})	900(us/cm^{-1})	1200(us/cm^{-1})
7	Total solids	500mg/L	500mg/L	500mg/L	1500mg/L
8	Total Alkalinity	100mg/L	100mg/L	100mg/L	100mg/L
9	Phenolphthalein Alkalinity	100mg/L	100mg/L	100mg/L	100mg/L
10	Chloride	100mg/L	100mg/L	200mg/L	250mg/L
11	Fluoride	1.0mg/L	1.0mg/L	1.0mg/L	1.5mg/L
12	Copper	1.0mg/L	1.0mg/L	0.5mg/L	2.0mg/L
13	Iron	0.3mg/L	0.3mg/L	1mg/L	3mg/L
14	Nitrate	10mg/L	10mg/L	10mg/L	50mg/L
15	Nitrite	0.02mg/L	0.02mg/L	0.02mg/L	3mg/L
16	Manganese	2.0mg/L	0.05mg/L	0.1mg/L	0.4mg/L
17	Magnesium	20mg/L	0.20mg/L	20mg/L	20mg/L
18	Zinc	5.0mg/L	5.0mg/L	0.01mg/L	3.0mg/L
19	Selenium	0.01mg/L	NS	0.01mg/L	0.01mg/L
20	Silver	----	----	NS	NS
21	Cyanide	0.01mg/L	0.01mg/L	0.01mg/L	0.07mg/L
22	Sulphate	100mg/L	100mg/L	250mg/L	500mg/L
23	Calcium	75mg/L	750mg/L	NS	NS
24	Aluminum	0.5mg/L	NS	0.2mg/L	0.2mg/L
25	Potassium	10.0mg/L	10.0mg/L	NS	NS
26	Lead	0.01mg/L	0.01mg/L	0.01mg/L	0.01mg/L
27	Chromium	0.05mg/L	0.05mg/L	0.05mg/L	0.05mg/L
28	Cadmium	0.003mg/L	0.003mg/L	0.003mg/L	0.003mg/L
29	Arsenic	0.01mg/L	0.01mg/L	0.01mg/L	0.01mg/L
30	Barium	0.05mg/L	0.05mg/L	0.05mg/L	0.07mg/L
31	Mercury	0.001mg/L	0.001mg/L	0.001mg/L	0.001mg/L
32	Antimony	NS	NS	----	0.02mg/L

33	Tin	----	----	----	1-µg/L
34	Nickel	----	----	----	0.02mg/L
35	Total Hardness ($CaCo_3$)	100mg/L	mg/L	100mg/L	500mg/L
36	Vinyl Chloride	0mg/L	0mg/L	0mg/L	0.003mg/L

Source: [8]

Metal	Zone A	Zone B	WHO Limit
Total Solids(TS)	307.09	293.76	500mg/l
Chloride(Cl)	83.44	92.70	200mg/l
Alkalinity(Alk)	82.44	72.97	100mg/l

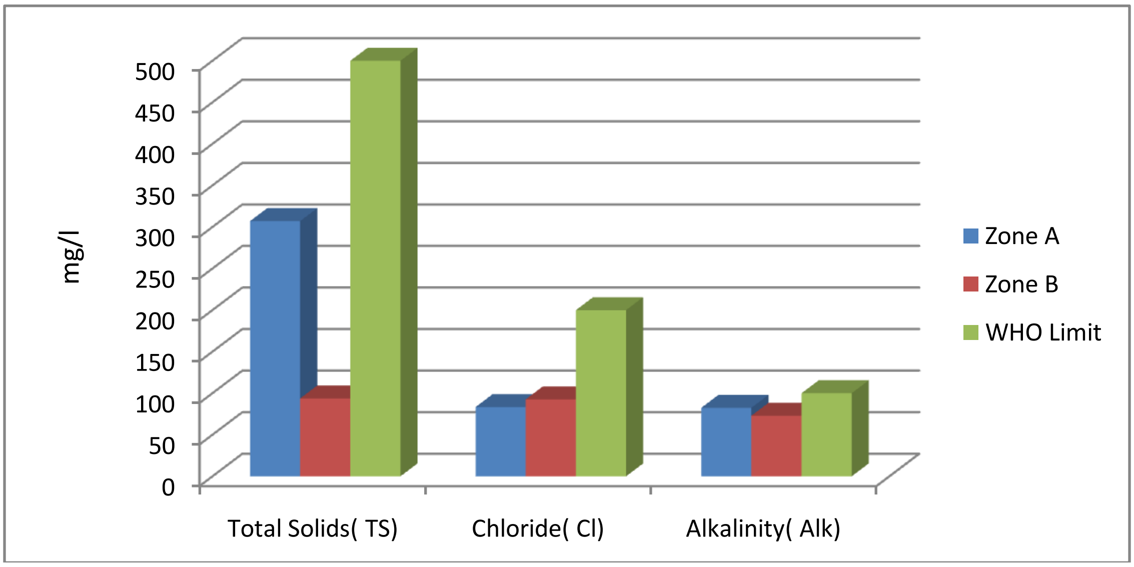

Fig 2: Averages TS, Cl and Alkalinity Concs.of Water samples in Zones A and B compared with [6] limits.

Metal	Zone A	Zone B	WHO Limit
Cd mg/l	0.34	0.33	0.003
Cr mg/l	0.01	0.12	0.05
Cu mg/l	0.05	0.12	0.50

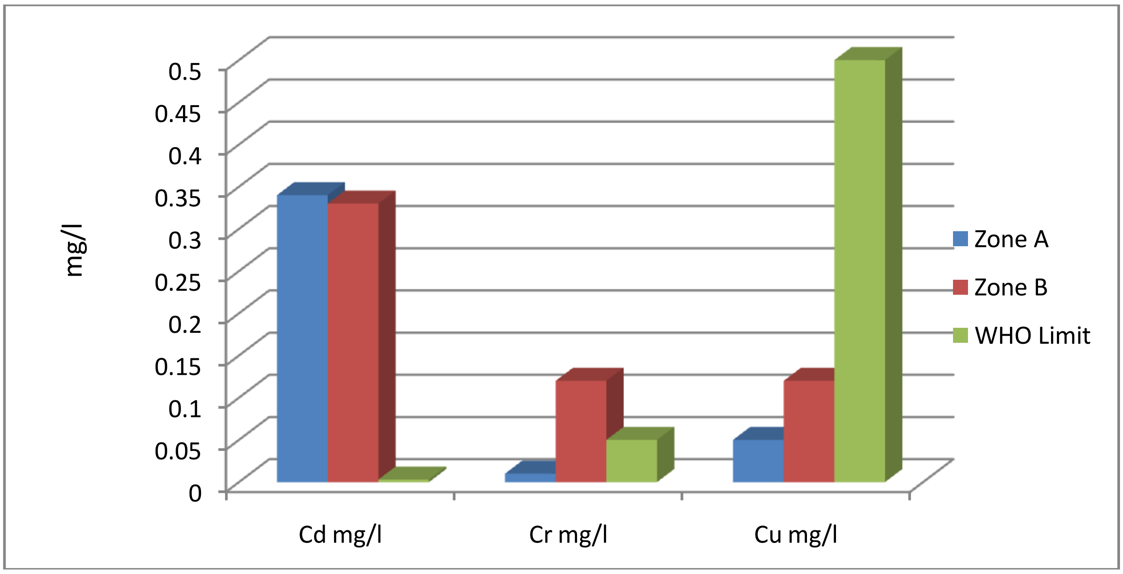

Fig3: Averages Cd, Cr, Cu Concs.of Water samples in Zones A and B compared with [6] Limit.

Metal	Zone A	Zone B	WHO Limit
Ni mg/l	0.64	1.30	0.01
Mn mg/l	0.09	0.09	0.10
Pb mg/l	0.05	0.01	0.01

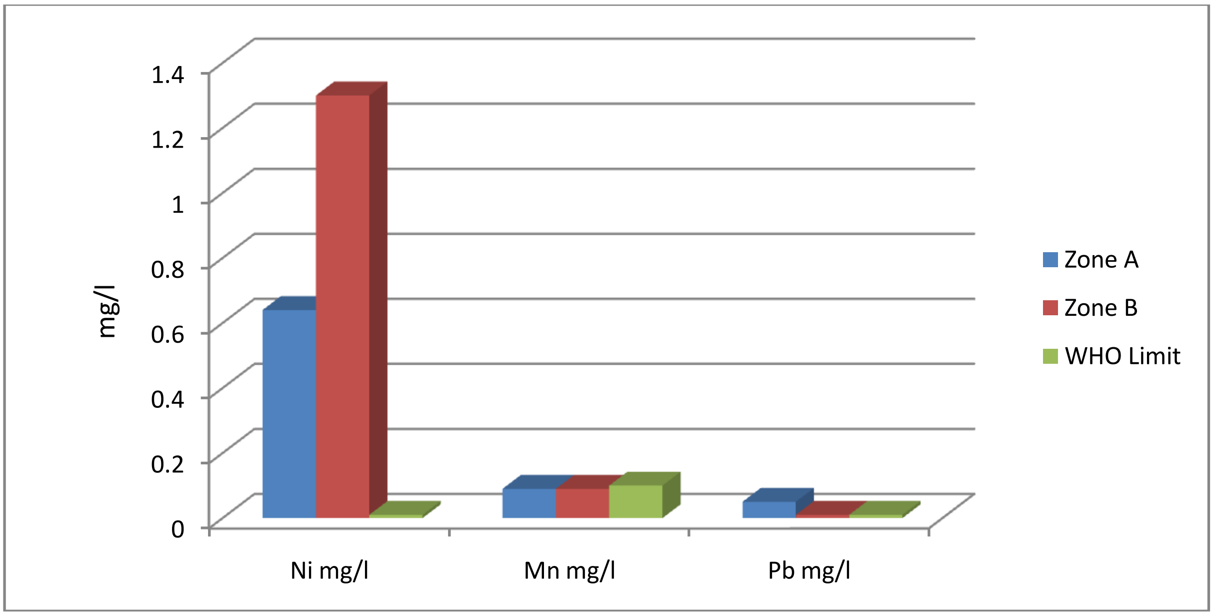

Fig.4: Average Ni, Mn, Pb Concs.of Water samples in Zones A and Bcompared with WHO [6] limits.

Metal	Zone A	Zone B	WHO Limit
Fe mg/l	0.66	3.13	1.00
Zn mg/l	0.88	0.81	0.01
As mg/l	0.05	0.07	0.01

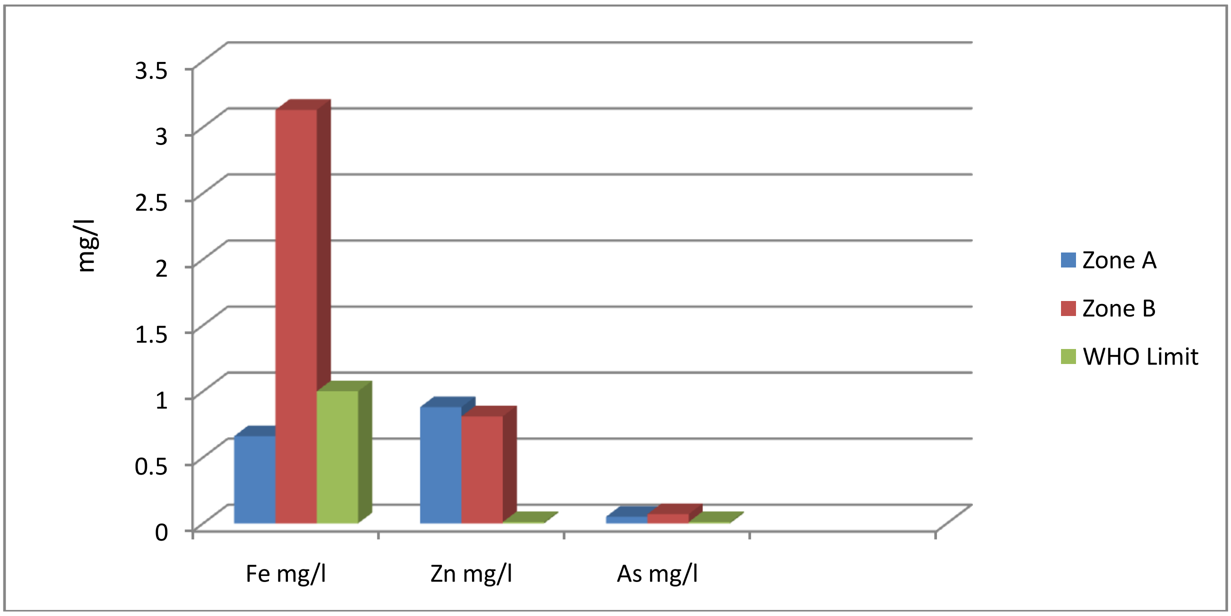

Fig 5: Average Fe, Zn and As ion Concs.of Water samples in Zones A and B compared with [6]limits.

Table 5: Compared Pollution Condition Assessment of the examined medium

		Metals									
Medium	Parameters	Cd	Cr	Cu	Mn	Ni	Pb	Co	Fe	Zn	As
	ZoneAaver.mg/l	0.34	0.01	0.05	0.09	0.64	0.05	0.14	0.6	0.88	0.05
	Zone B aver.mg/l	0.33	0.12	0.12	0.09	1.30	1.01	0.16	3.3	0.81	0.07
Water	Mean of A& B	0.33	0.06	0.08	0.09	0.97	0.53	0.15	1.8	0.84	0.06
	HRL	5	2	3	0	3	4	3	0	1	3
	WHO Limit mg/l	0.003	0.05	0.05	0.10	Nil	0.01	Nil	1.0	0.01	0.01
	Pollution Level	Hy	Low	Unp	Unp	lnter	High	low	low	Unp	Unp

Note:
HRL = Health Risk Level Unp =Unpolluted Hy = Heavy
Low = slightly polluted Zone A = Onyeama Mine Area
Inter = Intermediate levelZone B=Okpara Mine Area

Characteristics of Water Samples medium

Rivers are known to serve as a medium for transportation of pollutants from source to receptors [UNESCO/UNEP/WHO, 1992]. They can therefore be used to detect pollutants that could escape coal waste dump and soil analysis and provide information about critical sites of water under consideration [Horsfall and Spiff, 1999].Chemical and trace metal characteristics of water samples from zones A and B are given in Table 2 and 3 respectively. The results reflect the geochemical systems of the coal seams and overlying strata from which the water samples were collected. Heavy metals, and in particular those in the first row of transition elements including Cr, Mn, Fe, Co, Ni, Zn and Cu are natural constituents of river sediments [Adekola and Saidu, 2005]. Pollutant indicators are compared with permissible limits of World Health Organization [WHO, 2011], National Agency for Food and Drug Administration and Control (NAFDAC) and Standard Organization of Nigeria (SON) standards for potable water. The results are shown in Figures 2, 3, 4 and 5.

The values of total dissolved solid (TDS) 21.80 – 520 mg/l and total solids (TS) 51.75 – 605.00 mg/l are high, though below WHO standard 1500 mg/l maximum permissible level. Such values, according to [Adekunle and Mojisola, 2009] have serious negative impact in the entire aquatic environment. The mean value 300.42 mg/l for total solids (TS) is below WHO, SON and NAFDAC standards of 500.00 mg/l. Two sites (ON-3 and OK-25) that had 650.00 mg/l and 605.00 mg/l respectively were the highest yet below the 1500 mg/l desirable limit. Alkalinity ranged from <25.00 – 125 mg/l with 77.70 mg/lmean value. The mean 77.70 mg/l fall below the maximum desirable level of 100mg/l by [6] standard. Chloride concentrations are in general low (25.75 – 180.05 mg/l) with mean 88.07 mg/l and fall within permissible 200 mg/l limit. Sulphate concentration ranged from <20.00 – 570 mg/l, averaged 236.86 mg/l with one local enrichment at ON-7 that had 700 mg/l. Total loads of calcium (4.75 – 65.00 mg/L) with mean 23.85 mg/l and magnesium (2.43 – 2.00 mg/l) with mean value 10.05 mg/l are low when compared with WHO and SON standards. The mean values of Ca (23.85 mg/l) and Mg (10.05 mg/l), according to [Rawat and Gurdeep, 1983] and [Gurdeep, 2006] indicate low level of metal pollution. None of the pH values (4.5 – 6.5) fall within WHO and SON maximum permissible level range 7 – 8.9. The mean pH 5.4 indicates some level of acidity. The lower pH of water, according to [Adekunle and Mojisola, 2009] is likely to be corrosive to the household metals and may cause the leaching of the clay pot water containers.

Determined trace metal concentrations for Water samples are shown in Table 3. It is seen from these data that the concentration trend of metals in water medium follows the order Fe > Ni > Zn >Pb > Cd > Co > Cr > As > Cu >Mn. The concentration of toxic elements such as Mn (0.01 – 0.50 mg/l) with average of 0.09 mg/l, Pb (0.01 – 6.30 mg/l) with average of 0.53 mg/l, Cr (0.01 – 0.80 mg/l) with average 0.06 mg/l, Cd (0.12 – 0.62 mg/l) with average 0.33 mg/l and As (0.01 – 0.50 mg/l) with 0.01 average are high compared with [WHO, 2011] permissible limits, Figs 2,3,4 and 5.

Toxic metals are more soluble at low pH (Tables 2 and 3) as a result of secondary reactions between iron sulphate compounds in nearby clays and shales [Gurdeep, 2006]. Obtained results indicate below detection limits of Cd, Cu, and As in some locations (Table 3). However, high arsenic (As) value 0.5 mg/l at OK-23 **(mine water**, Table 3) is in excess of its normal load and thus demands special attention. Arsenic has been found to have an effect on the liver by causing a disease called cirrhosis [Huttan, 1987]. In Chile and Taiwan, 0.2 mg/l arsenic in drinking water and taken for a long time has been calculated as threshold for skin cancer [Finkelman and Zhang, 1999].

Mean values of Pb (0.53 mg/l), Zn (0.84 mg/l), Cd (0.33 mg/l), As (0.06 mg/l) and Ni (0.97 mg/l) in Table 3are present at significant levels and exceed public health standards. Trace metals at these levels in drinking water, are highly toxic and undesirable, do not support aquatic life, destroy mining equipment and result in land damage which pose environmental problems [Huttan, 1987].

Chromium (Cr)

The maximum permissible level of Cr in drinking water is 0.05 mg/l [UNESCO/UNEP/WHO, 1992] and [WHO, 2011]. Concentration in the sampled water ranged from < .01 – 0.10mg/l except one locality (OK-25) from the tunnel (mine water) that had 0.8 mg/l.

Copper (Cu)

Copper is highly complexed with carbonate and hydroxide ions in natural waters and as aresult, free copper ion is usually low in concentration. The highest desirable concentration of copper in drinking water is 2.0mg/l standard. Concentration of copper in the examined water samples ranged from 0.03 – 0.70 mg/L,(Table 3). The average value 0.08 mg/l is far below 2.0 mg/l permissible level by [WHO, 2011], Fig 3.

Manganese (Mn)

Manganese dissolved or suspended matter at concentrations below 0.02mg/l [Warren, 1973] .Surface water sources investigated in this study had Mn concentrations from 0.01 – 0.50 mg/l and mean 0.09 mg/l. The highest readings 0.49 mg/l and 0.50mg/l came from the tunnels (mine water) ON-11 and OK-25 respectively, Fig. 10 presents mean values of metals compared with [WHO, 2011] guideline value. It shows Mn below the recommended target value of 0.01mg/l. According to CSP Fact sheets 2003 report, a manganese concentration of 0.75mg/l in a drinking water supply had no apparent adverse effect on the health of its consumers.

Nickel (Ni)

The highest desirable concentration of Ni in drinking water is 0.02 mg/l, by [WHO, 2011] standard. This study shows that all the water samples contain Ni much higher (0.03 – 3.91 mg/l) than the prescribed 0.02 mg/l value (Table 3, Fig.4) presents compared mean values of trace metals with [WHO, 2011] guideline value. The higher Ni concentrations measured in the water samples, especially (OK-23 and 25) from mine tunnels, range 1.86 – 2.50 mg/l. It may have resulted from mineral water interactions within the aquifer [Zhang et al., 2003].

Lead (Pb)

Lead in the environment is due to human activities such as refining and burning fossil fuels, mining, smelting, coal, gasoline and manufacturing. Lead in air may travel thousands of kilometers from the originating source before settling to ground. In the surface water, atmospheric fallout, runoff and waste water are major sources. The maximum permissible concentration of Pb in drinking water is 0.01 mg/l according to [WHO, 2011], Table 4. In water samples, Pb concentration ranges from 0.01 – 6.30 mg/l with average value of 0.53 mg/l. The average value exceeds the allowable level (0.01mg/l), Fig.4. This implies that the mine water is contaminated by Pb traces and makes Ekulu and Nyaba rivers that truncate the study area, unsafe as drinking water.

Iron (Fe)

The permissible concentration of Fe in drinking water is 0.3 mg/l (NAFDAC and SON) and 1 mg/l by [WHO, 2011]standards,Table 4.The concentration of Fe in sampled water ranges from 0.37 – 27.10 mg/l with average value 1.89 mg/l.(Table 3) The average exceeds the established 1 mg/l [WHO, 2011] limit. Local high concentrations 8.10 mg/l and 27.10 mg/lwere found in tunnel locations OK-25and 23 respectively. It may be inferred that the relatively high iron found in the two locations may be due to the mineral water interactions and oxidation – reduction reactions taking place in the system. According to [Biagioni, 2003] at levels above the standard for drinking water quality of 0.3 mg/l, iron may be associated with the development of neoplasm in animals.

Zinc (Zn)

Zinc is an abundant element and constitutes approximately 0.004 percent of the earth's substance [Browing, 1969].According to NAFDAC and SON standards, desirable concentration of zinc in pure water is 5.0mg/l but with [WHO, 2011], it is 3.0 mg/l.Water containing zinc at concentrations above 5.0 mg/ltendsto be opalescent,develops a greasy film when boiled,and has an undesirable astringent taste [Browing, 1969]. In the sampled water, concentration of Zn ranges from 0.03 – 1.38 mg/l, averaging 0.84 mg/l (Table 3). The investigated values are far below the maximum permissible 3 mg/l limit of NAFDAC, SON and WHO. It implies that theinvestigated water medium is free from zinc pollution and could be considered as safe.

Arsenic (As)

The allowable concentration of As in drinking water is 0.01 mg/l by [WHO, 2011] standard. In water samples, As concentration ranges from <0.01 – 0.50 mg/l with 0.06 mg/l mean value. One sample location (OK-23 fromtunnel, mine water) had 0.5 mg/l highest concentration. The arsenic content in the water samples was below the accepted drinking water standard of 0.01 mg/l[WHO, 2011] and does not appear to be an important factor.

Impact Assessment

Water in the examined environment, particularly samples from mine tunnels (mine water) were polluted by Cd (mean 0.33 mg/l) as against 0.003 mg/l WHO limit, Fe (mean 1.89 mg/l) as against 1.00 mg/l WHO and NAFDAC limits and Pb (mean 0.53 mg/l) as against 0.01 mg/l [WHO, 2011] standard. Other heavy metal concentrations- As, Cd, Cr, Mn and Cu are in accordance with or even lower than those reported in earlier work carried out by [Adaikpoh et al., 2005] in coal and sediments from River Ekulu in Enugu. The presence of toxic elements such as As, Cd, Pb and Cr in water could be detrimental to human beings and aquatic life. Most trace metals are toxic. When metallic toxicants find their way into the body, they attack the proteins, notably the enzymes [Adaikpoh et al., 2005]. Water medium is slightly polluted by Co, Pb and Fe, Ni but not by Cu and Mn.

Based on the results of water analysis, the toxic elements Cd (0.33mg/l mean), As (0.06 mg/l mean), Pb (0.53mg/l mean), Cr (0.06 mg/l mean) and pH (5.4 mean) values, all exceeded the maximum permissible levels of [WHO, 2011], (Figures 3, 4 and 5) and this according to [Gurdeep, 2006] seriously worsened the water quality. The high levels of total dissolved solids (TDS) (21.80 – 520 mg/l) though below WHO permissible level of 1500 mg/l has serious negative impact in the entire aquatic environment according to [Adekunle and Mojisola, 2009] Zn, Ni and Fe (Figures 2 and 3) also exceeded the allowable concentration levels. Trace metals at these levels are highly toxic and undesirable and result to land damage which pose environmental problems [Huttan, 1987]. Water pollution in the study area, though at low level renders the water unsafe as drinking water. Large volume of water is lost daily due to Enugu coal mining. According to [Uma, 2005], about 1800m^2 of water is pumped out daily from the mines into the nearby streams and that the source of the enormous volume of water has been established based on the hydrodynamics and hydrology of the area.

The mine tunnels in the examined area are left open even after the coal mining had ceased. Coal mines release methane gas and other hydrocarbons from coal seams disturbed during the extraction process. According to [Sage and Creedy, 2003], if the mine entries are sealed, the gas emission rate can be reduced significantly but the risks of uncontrolled emissions can arise. It is probable that the unsealed tunnels in the examined area are contributing to environmental degradation through methane release. Methane release is detrimental to the environment because of its high global warming potential [Elder, 1972, Kessell, 1974 and [Sutherland, 2000]. Methane gas affects the environment undesirably, influencing plant vegetation and enlarging the greenhouse effect [Sutherland, 2000].

IV. Conclusion

Water in the examined environment ,particularly samples from tunnels (mine water) were polluted by Cd (0.33mg/l) as against 0.003 mg/l WHO limit, Fe (mean 1.89mg/l) as against 1.00mg/l WHO and NAFDAC limits and Pb (mean 0.53 mg/l) as against (0.01mg/l) WHO standard.Other heavy metal concentrations namely: arsenic, cobalt, chromium, manganese, and copper have similar concentrations with or a times lower than those in the earlier research carried by [Adaikpoh et al., 2005] in and sediments from Ekulu river.Dictation of toxic elements such as arsenic, lead and chromium in water could be detrimental to human beings and aquatic life. According to [Adaikpoh et al., 2005],when metallic toxicants find their way into the body,they attack proteins, notably the enzymes. The environment was slightly polluted by cadmium, lead and iron but not by copper and manganese. The similarity of the heavy metal concentrations from Onyeama (Zone A) and Okpara (Zone B) mines shows that the mines are of the same geologic formation and chemical composition.

References

[1]. Uma, K.O (2005). Origin of Acid Mine Drainage in Enugu. J. Environ. Geo.Vol. 20 (3), pp 181- 194.

[2]. Classen, T.H (1982). Guidelines and Techniques for obtaining water samples that accurately represent the quality of an aquifer. U,S Geological Survey Open File Report 82-102 p49.

[3]. Barcelona, M; Gibb, J.P; Helfrich, J.A and Garke , E.E (1985) Practical guide for ground water sampling. IIinnois State Water Survey ISWS contract Report 37.

[4]. Bryant, M (2005).Water and Soil. In Official Methods of Analysis of AOAC International, 18th edition, 2005, Current through Revision 4, 2011, pp1-32.

[5]. Vogel, A.I (2007).Quantitative Inorganic analysis including elementary Instrumental analysis (3rd ed). Longmans, Green & Co Lit, USA 375P

[6]. World Health Organization (2011). Guidelines for drinking water quality [Electronic Resource] .Incorporating 1st and 2nd Addenda, Vol.1 Recommendations. 3rd ed Geneva 608p.

[7]. SON (2003). Standard Organization of Nigeria Safe Drinking Water Regulation.

[8]. Adekunle, A. I and Mojisola, A. A. (2009). Physico-Chemical analysis of well waters in Minna and its Environs, Niger State, Nigeria. Journal Chemical Society of Nigeria, Vol. 32 (2), pp 122-1.

[9]. UNESCO/UNEP/WHO, (1992). Water Quality Assessments, Chapman and Hall, London, pp 62-64.

[10]. Horsfall, M and Spiff, A.I (1999). Bull Chemical Society Ethiopia, 13.1.

[11]. Adekola, F. A and Saidu, M. M. (2005). Determination of pollution level of water and sedimentsamples of Landzu River, Bida Nigeria. Journal of Chemical Society of Nigeria, Vol. 30, No 2, pp 18.

[12]. Rawat, N.S and Gurdeep S. (1983). Chemical, Geological and Biological aspects of acid mine drainage. Journal of Sci. Industrial Resource.Vol.42 pp.448-455.

[13]. Gurdeep, S (2006). Impact of Coal mining on Water Quality. Inter. Journal Min. Water, Vol. 7 (3), pp 49-59. www.imma.info.

[14]. Huttan, M. (1987). Human health concern for lead, mercury and arsenic in land: Mercury, cadmium and arsenol in the Environment. Wiley Scope, pp 85-89.

[15]. Finkelman, R.B and Zheng , B. (1999). Health Impacts of Domestic Coal use in China. National Academy of Science proceedings, Vol. 96, pp. 3427-3431.

[16]. Warren, H. C (1973) Some of trace elements in various environments. In Environmental Medicine. G.M Howe and J, A Lorrine (eds) William Heinemann Medical Books London, UK. p9.

[17]. Zhang, Chao-Ian and Bai, Hou-yi (2003) Application fuzzy mathematics assessment on soil heavy metals. Pollution, (J) Guanxi Science of agriculture biology, vol, 22 (1) pp 54-57.

[18]. Biagioni, K (2003). The public effects of abandoned coal mine workings on the residents in South Wellington, Nanaimo. Proceedings of the Third International Conference on Environment and Health. Chenmai, India. pp 23-31.

[19]. Browing, E (1969). Toxicity of industrial metals.2nd edition. Butterworths, London. 348p.

[20]. Adaikpoh,E. O., Nwaeji, G.E and Ogala, J. E. (2005). Heavy Metals Concentration in Coal and Sediments from River Ekulu in Enugu, Coal city of Nigeria, Journal of Applied Sciences and Environmental Management, Vol.9, No 3, pp 5-10.

[21]. Sage, P.W and Creedy D,P (2003). Reducing the Environmental Impacts of abandoned Coal mines in China. www.Coalline.fo.net.on/coal bed/meeting.

[22]. Elder, J.L. (1972). The gasification of Coal. In Lowry, H.H (ed),Chemistry of Coal Utilization, Suppl. Vol. pp 1041-1080.

[23]. Kessell, F.N. (1974). Peak Methane concentration during Coal mining. U.S Bureauof Mines. Report of investigation, p78.

[24]. Sutherland, R.A (2000). Bed Sediment-associated Trace Metals in an Urban Stream, Hawaii Environ.Geo.39, pp 611-627.