IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 11, Issue 10 Ver. IV (October. 2017), PP 32-38
www.iosrjournals.org

Suitability of Aggregate Mine Wastewater as Soil Prospective Irrigation Water

Ikpe J. Udom[1] and Babatunde E. Olatunbosun[2]
[1, 2] *Department of Agricultural Engineering AkwaIbom State University IkotAkpaden, Nigeria*

Abstract: *The rising concern over the use of mine wastewater for irrigation of vegetables in Abak stream flood plain prompted this study which aimed at investigating the suitability of the aggregate mine wastewater as a source of irrigation water. The result of the analysis showed that the values for total suspend solids (TSS) of 125.4mg/l and turbidity of 44.00NTU for the mine drainage were high. This is presently beneficial to the sandy soil in improving its water holding capacity. Also, the values of sodium absorption ratio (SAR) of 0.53 and electrical conductivity of 3.86 mhos/cm, which is far lower than prescribed standards, indicates that use of the water possess no salinity hazard to the soil and crops at the moment. Magnesium-calcium ratio which was low at 0.75 indicates that use of the water will have no sodicity effect on the soil and crops. Thus, it is concluded that, the mine drainage is suitable for irrigation of vegetables in the Abak stream floodplain. It is however recommended that there should be continuous monitoring of these water quality parameters. Government legislation and enforcement of reclamation practices in mining activities are also recommended.*

Keywords:*aggregate mining, irrigation, water quality, mine wastewater, pollution*

Date of Submission: 10-05-2017 Date of acceptance: 18-11-2017

I. Introduction

The construction sector has grown over the years because of demands for real estate and housing and the provision of infrastructure to support economic and transportation needs of an increasing population size. Aggregates are a major basic raw material in the constructive industry [1]. The composite nature of floodplains as reservoir for aggregates and as fertile soil captivatingly suitable for agriculture makes floodplains the target of exploitation for aggregate and food amongst other uses. AkwaIbom state's 129 kilometers coast-line gives rise to numerous floodplains adjoining the courses of rivers and streams[2]. As a consequence, floodplain agriculture is a common practice in this area because the floodplains provide fertile soil and proximity to accessible good quality surface and groundwater in abundance for production of flood resistant and dry season crops under irrigation.

Floodplain agriculture is intensive and at its peak during the dry months when incidence of crop pests and diseases decline and the advantages of off-season production increases the returns on investment [3]. Concern over water quality suitable for irrigation becomes an important consideration when good quality supplies are not plentiful and readily available. Intensive pressure on good quality sources of water and the environmental impacts of human activities makes reliance on lower quality and less desirable sources of water inevitable [4].

Water that is intended for agricultural uses but in some way endangers agricultural activity can be defined as "unsuitable water" when they become unsuitable following the addition of substances other than those normally present. Conceptually, water quality refers to the characteristics of water supply that will influence its suitability for a specific use. That is, how well the quality of water meets the needs of the user.

Quality of water is defined by certain physical, chemical and biological characteristics and judged by the amount of suspended and dissolved materials it contains. Suspended materials include eroded soil particles, seeds, leaves and other debris. Dissolved materials include common cations in irrigation water such as calcium, magnesium, sodium and potassium. Bicarbonate, sulphates and chloride are the most common anions. Other solutes including nitrates, carbonates and trace elements such as boron, are occasionally present [5].

The amount of the above chemicals and physical characteristics determine the quality of irrigation water and its suitability for irrigation purpose. Crop irrigation with polluted water is disgustingly inferior and questions always arise on the safety of food produced from such waters [6]. Poor irrigation water quality can cause various soil and cropping problems to develop [7]. Pollution of irrigation water could be natural or man – influenced. The most important of the natural influences are geological, hydrological and climatic, since these affect the quantity and the quality of water available. Their influence is generally greatest when available water quantities are low and maximum use must be made of the limited resource.Thus, although water may be available in adequate quantities, its unsuitable quality limits the uses that can be made of it. Oni, [8] Miller and

Donalu, [9],Ayers and Wescot, [5],Meybeck et al., [10] Florescu et al., [11]have discussed alteration of irrigation water quality due to natural factors.

Man – influenced pollution includes sewage contamination and activities such as farming, animal rearing, industrial effluent and mining[12]; [13]; [14]. Mining supplies valuable materials such as sand and gravel (aggregates) that are used as building materials, and the geological domain of aggregate is that of stream (river).[15]. Stream-based (in stream or floodplain) aggregate are clean, durable and have the necessary hardness, chemical composition and low oil content which reduces the risk of concrete crumbling [16]. Although floodplain sand is of poor quality, floodplain gravel is of good quality and cheaper to mine than instream gravel.

Possible conflict between agriculture and floodplain mining activities includes loss of cultivable land and ecological and cultural values of floodplains and access to water resource for agriculture in terms of quantity and quality [17]. Input of mine wastes into water bodies through mine drainage leads to pollution of streams. Irrigation with mine wastewater has been widely practiced as reported in studies carried out to assess the effects of mine water irrigation on soil and crops. Jovanovic et al., [18] reported considerable increases in yield of irrigated crops in South Africa, when irrigated with lime – treated acid mine drainage compared with rain fed cropping. Annandale et al., [19] recommended the use of neutralized coal – mine drainage for irrigation of large variety of crops as they do not seem to have any deleterious effects on the soil environment.

Similarly,Murugappan et al.,[20] investigated the effect of using lignite mine drainage in Negveli, India for irrigation of crop and reported that the practice has no effect on soil to hamper crop growth.Garrido et al., [21] investigated the effect of irrigation with acid mine drainage from metal mining on soils and crops in Bolivia and reported greater concentrations of metals in soils and crops above reference soils and commercially sold vegetable guidelines respectively.Yen and Rohasliney, [22] investigated the status of water quality subject to sand mining in the Kelantan River, and concluded that certain physico-chemical parameters (such as TSS, turbidity and nitrate concentration) had increased to extremely high levels that exceed the prescribed national standards, as a result of sand mining activities.

Many streams and floodplains in AkwaIbom State are sources of aggregates (Figures 1 and 2),

Fig. 1: Floodplain mining

Fig. 2: Instream mining

Udom[23] identified 433 mining sites in 31 Local Government Areas (LGAs) of AkwaIbom State out of which 59% were located in floodplains. Incidentally, floodplains in AkwaIbom State also support intensive production of vegetables – okra, cucumber, pepper, tomato, maize, waterleaf and other leafy vegetables – under surface irrigation from mined stream and floodplain mine wastewater as irrigation water. Udom, [24] found permissible concentrations [25] of sodium, calcium, magnesium and electrical conductivity in the instream mine water and consequently recommended the Abak stream mine effluent as suitable for irrigation of vegetables in the floodplain.

Aggregate mining is not regulated in AkwaIbom State and intensive mining activity in the floodplain has made access to the stream difficult and abstraction of irrigation water impossible. This situation is observed to have affected the operation of some farms within the floodplain and, vegetable production on the floodplain has economic and social benefits The only option for farmers to continue production of crops on the floodplain is to abstract ponded mine wastewater from floodplain mines for irrigation.

Unlike the instream mine water, the floodplain mine water is fed by ground water and isolated from the self-purification mechanisms [26] of flowing waters and, the concern over its use for irrigation is rising.

Therefore the objective of this study is to examine the suitability of the Abak stream floodplain mine wastewater as prospective irrigation water by examining the physical and chemical parameters of the mine wastewater during the dry season which is the period when floodplain irrigation is prevalent in the study area.

1.1 Study Area Description

Abak stream in Abak town (4^0 59`N, $7^0$47`E), AkwaIbom State is a first order effluent stream located along Abak – Uyo road in the rain forest zone of Nigeria (figure1).

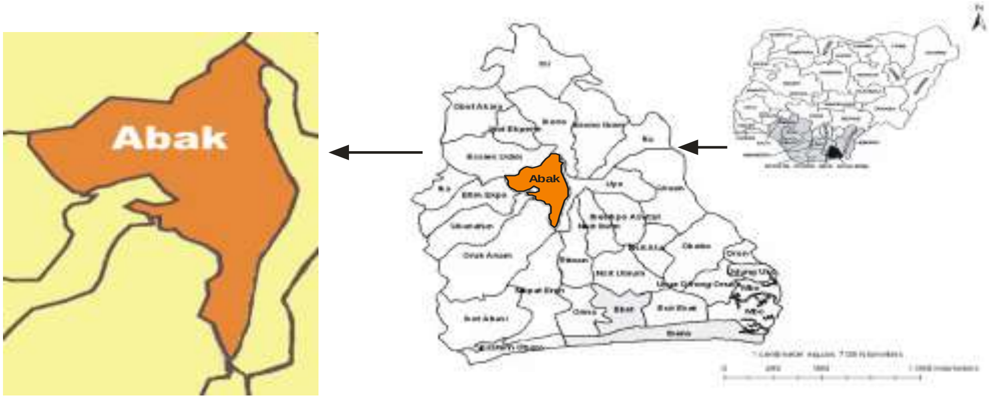

Figure 1: AbakLocal Government Area of AkwaIbom State

The stream flows through Abak and joins a tributary of Qua Iboe River at Ibagwa. Between Ediene and Oku Abak, the stretch of the water is commonly referred to as Abak stream. The stream has an average width of six meters and variable depth that has been affected by instream mining. The stream catchment is completely deforested and the floodplain of the stream is subjected to intensive mining for gravel as well as cultivation of vegetables.

II. Materials and Methods

During the dry season (November-March) of 2015 when there was no sediment contribution from the catchment, grab samples of mine drainage were collected from representative locations. The representative locations were instream location which was moderately affected by mining, floodplain location severely affected by mining and location 50m upstream of instream mine location which served as a control.

Samples were collected below the water surface using 1L clean plastic containers facing the direction of flow for instream locations in order to obtain representative samples. The bottles were filled to the brim and stoppered tightly. Samplings were timed to correspond to irrigation periods in the morning when pump suction induced abstraction and mixing of the mine drainage mostly in the floodplain mines. Samples were taken every forth night for the five months (November – March) during the dry season. A total of 30 samples were collected from 10 sampling campaigns.

Water temperature, pH, EC and TDS were measured on site using a portable meter (HANNA Instruments) before the samples were analysed at the AkwaIbom State Water Corporation (AKWC) laboratory, Uyo. The laboratory analysis was based on guidelines for interpretation of water quality for irrigation (TABLE 1), salinity tolerance level for vegetable crops (TABLE 2) and on Maximum Allowable Concentrations which affect the suitability of surface water sources for irrigation in Nigeria [25] given in TABLE 3

Table 1: Guidelines for Interpretation of Water Quality for Irrigation

Potential Irrigation Problems	Unit		Degree of restriction on use		
			None	Slight to Moderate	Severe
Salinity (affects crop water availability) EC TDS	 ds/m Mg/1	 or	 <0.7 <45 0	 0.7-30 450-2000	 >3.0 2000
Infiltration (affects infiltration rate of water into the soil,evaluatedusingEC and SARZtogether) SAR = 0-3 and EC= SAR = 3-6and EC= SAR = 6-12 and EC= SAR = 12-20 and EC= SAR = 20-40 and EC=			 >0.7 >1/2 >1.9 >2.9 >5.0	 0.7-0.2 1.2-0.3 1.9-0.5 2.9-1.3 5.0-2.9	 <0.2 <0.3 <0.5 <1.3 <2.9
Specific Ion Toxicity (affects sensitive crops) Sodium (Na) (for surface irrigation) SAR			 <3.0	 3-9	 >9.0
Chloride (Cl) (for surface irrigation) Boron	me/l mg/l		<4.0 <0.7	4-10 0.7-3.0	 >10.0

Bicarbonate (HCO_3) (overhead sprinkling only)	Mg/l		<5	5-30	>3.0 30
PH		Normal range 6.5-84			

Source: Murugappan et al, 2011

Table 2: Salinity Tolerance levels for Vegetable Crops

Crop	Yield Potential, EC_e				Maximum EC_e
	100%	90%	75%	50%	
Carrot	1.0	1.7	2.8	4.6	8
Cucumber	2.5	3.3	4.4	6.3	10
Pepper	1.5	2.2	3.3	5.1	9
Sweet corn	1.7	2.5	3.8	5.9	10
Tomato	2.5	3.5	5.0	7.6	13
Okra	NA	NA	NA	NA	NA
Waterleaf	NA	NA	NA	NA	NA
Fluted pumpkin	NA	NA	NA	NA	NA

Adapted from Ayers and Wescot, 1976

Table 3: Maximum Allowable Concentrations for Irrigation Water

Variables	Maximum Allowable Concentrations
Temperature	27-28
Iron (mg/l)	500
P.H	6.5-8.5
Turbidity	5.0
Electrical conductivity (mhos/cm)	1000
Sodium (mg/l)	200
Potassium	150
Sulphate (mg/l)	42-45
Phosphate	3.5
Alkalinity (mg/l)	100-200
Chloride (mg/l)	100-700
Total hardness (mg/l)	500

Source: FEPA (2001)

Properties commonly used as basis to evaluate water quality for prospective soil irrigation were those related to salinity, electrical conductivity, infiltration rate, sodium absorption ratio (SAR), sodicity and a group of other miscellaneous problems]27] . Analysis of sodium (Na) and potassium (K) was by flame photometry while calcium (Ca), magnesium (Mg) and iron (Zn) were by atomic absorption spectrophotometry (AAS) according to]28]. Sulphates were analysed using gravimetric technique by precipitating barium sulphate in an acidified solution.Phosphate was analysed by colorimetry using molybdenum blue as precipitating agent, chloride was analysed by titration against silver nitrate with potassium chromate as the indicator after neutralizing with calcium carbonate.

SAR was used to predict the potential for sodium to accumulate in the soil if sodium water was in constant use. The SAR is defined as (Jenson, 1980)

$$SAR = \frac{NA^{+}}{\sqrt{(Ca^{2+} + Mg^{2+})}} \quad 1$$

where,

Na = Sodium ions
Mg = Magnesium ions
Ca = Calcium ions

III. Results and Discussion

The physico-chemical characteristics of the stream and floodplain mine waters are presented in TABLE 5 as the means for the period under study.

Table 5: Physico-chemical characteristics of Abak stream irrigation waters.

Characteristics	Upstream of mining area	Instream mining area	Floodplain mines
Temperature	26.18	27.16	28.12
Iron	0.20	0.20	0.32
pH	6.30	6.32	6.45
Turbidity(NTU)	10.30	33.60	44.00

Electrical Conductivitymhos/cm	0.16	2.62	3.86
Sodium (mg/l)	1.75	1.90	2.08
Potassium (mg/l)	0.20	0.20	0.26
Sulphate (mg/l)	0.08	1.10	1.50
Alkalinity (mg/l)	2.82	2.75	2.78
Chloride (mg/l)	3.16	15.00	26.00
Total Hardness (mg/l)	19.25	22.75	27.00
Calcium (mg/l)	4.13	20.40	48.00
Magnesium (mg/l)	0.27	2.40	36.20
Acidity (mg/l)	1.00	1.00	3.00
TSS (mg/l)	6.50	27.50	125.4
TDS (mg/l)	10.02	10.83	45.43

3.1 Physical Parameters

The laboratory analysis revealed that the floodplain mine drainage has the highest value of turbidity and total suspended solids (TSS). Turbidity indicates the concentrations of suspended sediments in the water. Although sediments are a natural part of stream, excessive sediment is considered to be an indicator of surface water pollution. The Abak stream is not protected from polluting activities and the high turbidity results from intensive mining activities which release the colloidal and suspended particles from the mines into the stream water. The isolated mines showed the highest value of TSS and turbidity than the stream and the control due to absence of the diluting effect of the flow processes in the stream on the polluted water in the floodplain mine. Therefore the floodplain mine behaved as pond water.

The high value of turbidity may reduce the amount of light available for aquatic vegetation and hence their photosynthetic capabilities. High irrigation water temperature and reduced oxygen levels in the floodplain mine drainage is possible due to absorption of more heat from sunlight by the dark coloured water. Also closing of soil micro pores leading to reduced aeration and water within the soil is highly possible. For the floodplain sandy soil, the imminent risk of high TSS and turbidity is the increase in bulk density and water holding capacity of the soil due to decrease in pore sizes. The turbidity in the samples analysed in these study were respectively higher than the Nigerian Federal Environmental Protection Agency (FEPA) maximum allowable concentration for irrigation water. For now, 45.43 mg/l TSS recorded in the floodplain mine is far below values for potential irrigation problem from using the mine drainage. Induced physiological drought in the plants and a restrictive osmotic pressure will not therefore be a problem due to the use of the floodplain mine drainage.

3.2 Chemical Parameters

Both sodium absorption ratio (SAR) value of 0.53 and 0.50 and EC of 2.62 and 3.86 mhos/cm for the instream and floodplain mines respectively for the period of study indicated low salinity level of the mine wastewater. SAR is calculated from the ratio of sodium to calcium and magnesium and measures the suitability of water for use in agricultural irrigation. SAR is an expression of the sodium hazard of irrigation water. It is the measure of the proportion of sodium to calcium and magnesium in the water. The SAR is also an index of the sodium permeability hazard as water moves through the soil. The main problem with a high sodium concentration is its effect on the physical properties of soil. This breakdown disperses the soil clay and causes the soil to become hard and compact when dry and reduces the rate of water penetration when wet. A breakdown in the physical structure of the soil can occur with continued use of water with a high SAR value.

The effects of high SAR on the infiltration of irrigation water are dependent onthe EC of the water. Generally, if the SAR is more than 10 times greater than the EC,then poor water infiltration will occur.The low values of magnesium-calcium ratio of 0.12 and 0.72 respectively in instream and floodplain mines indicate that irrigation with the mine drainage will not cause soil sodicity hazard. The magnesium cation together with calcium is used to establish the relationship to total salinity and to estimate sodium hazard. Calcium and magnesium levels should always be higher than the sodium and chloride levels.

There was also marked variations between the values of sulphates, chlorides and calcium among the samples areas.Sulphate (SO4) is relatively common in water and has no major impact on the soil other than contributing to the total salt content. Irrigation water high in sulphate ions reduces phosphorus availability to plants. Chlorides contribute to the total salt (salinity) content of soils. It is necessary for plant growth in small amounts, while high concentrations will inhibit plant growth or be toxic to some plants.Irrigation water high in chloride reduces phosphorus availability to plants. The calcium cation is generally found in all natural waters. The calcium cation when adequately supplied with exchangeable calcium renders soils friable and usually allows water to drain easily. This is why calcium in the form of gypsum is commonly applied to improve the physical properties of tight soils. Sodium will be leached from the root zone when the Ca^{++} replaces the Na^{+} on the soil colloid. Irrigation water that contains ample calcium is most desirable.

For instream and floodplain mines areas, the variation probably resulted from the release of these chemicals into the mine drainage as the soil layers were opened up for mining activity, causing the release of these chemicals into the mines. The floodplain mines had the highest values of the considered chemicals. These were isolated ponds and the diluting power of groundwater was too weak since groundwater moves much more slowly. This quality of water can be accepted for irrigation of the sandy soil of the floodplain as the well-drained soil may not cause salt buildup in the soil.

The highest EC value of 3.86 mhos/cm in the analysis was recorded in the floodplain mine. This is far below the maximum allowable concentration for irrigation water in Nigeria. The higher the salt content, the greater the flow of electrical current.The desired ranges of values are less than 1.5mhos/cm and there is potential problem for values greater than 1.5 mhos/cm**.** As an indicator of the degree of salinity of water sample, the value of salinity in the mine drainage is low. The risk of dehydration of plants, yield decline and crop failure does not apply as a result of the use of this mine drainage for irrigation. Adverse effects of salinity on crop growth such as interference with nitrogen uptake and on soils such as flocculation effect on fine materials, venerability to erosion due to lack of surface cover and inability to absorb rainfall resulting in high rates of runoff which increases risk of flooding will not occur.

IV. Conclusion and Recommendations

This study has shown that the mine wastewater from the Abak stream floodplain is suitable as prospective irrigation water since the parameters for concern such as EC, TDS, SAR, etc. are all below maximum allowable concentrations for irrigation water in Nigeria.

However, since water quality can change rapidly, continuous monitoring of the quality of the mine wastewater is recommended.Increased use of crushed rocks as supplement to aggregates will reduce the intensity of mining activities and accompanying pollution in the floodplain.

Government legislation and enforcement of reclamation practices in mining activities to ensure that mining operations are conducted in manners that are compatible with the environment and the social and economic need of the people are recommended.Practices such as backfilling, grading, top soil replacement, stabilization and re-vegetation of disturbed areas to avoid pollution of the environment and loss of productive soil are advocated.

References

[1]. MEC. Informing and educating about the importance of minerals and mining. Minerals EducationCoalition, (https://mineraleducationcoalition.org). 2014
[2]. E.J. Usoro, and P.A. Akpan, AkwaIbom state: A geographical perspective. ImmaculatePublication Limited, Enugu, Nigeria, 2010.
[3]. I.J.Udomand C.C. Mbajiorju, Mining effects on the quality of irrigation water from an effluent stream. *International journal of environmental issues, vol. 4* pp. 50-56, 2006
[4]. FAO.Agricultural drainage water management in arid and semi-arid areas. FAO irrigation anddrainage.Paper 61 Italy, Rome,2002
[5]. R.S.Ayers and D. W. Westcott.Water quality for agriculture. FAO Irrigation and drainage paper, 1976
[6]. P. Drescheland B. Keraita, Irrigated urban vegetables production in Ghana: Characteristics, benefits and risks mitigation. International Water Management Institute, Sri Lanka,2014.
[7]. A. Murugappan, J. S. Sudarsan and A. Manoharan, Effects of using lignite mine drainage for irrigation onsoils – A case study of Perumal Tank command area in Tamilnadu State. *Jrnl of Industrial Pollution Control, vol. 22,* pp 151-160, 2006.
[8]. O.O. Oni. Water Quality and surveillance. Proceedings of national seminar on quality studies and monitoring programme. Prudence Hall. Eaglewood Cliffs. N. J. Jamie Bartram and Richard Ballance (Eds). United Nations Environment Programme and the World Health Organization, UNEP/WHO,1986.
[9]. R.W. Millerand R. L. Duane. Soils in our Environment 11th edition, Prentice Hall, 2007
[10]. M. Meybeck, E. Kusisto, A.Mäkelä and E. Mälkki, Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater, 1996
[11]. D. Florescu, R.E. Ionete, C. Sandru, A.Iordache, and M.Culea,The Influence Of Pollution Monitoring Parameters in Characterizing the Surface Water Quality from Romania Southern Area.*Rom. Journ.Phys., Vol. 56*, pp 1001-1010, 2011.
[12]. S. Caincross and R. G. Feachem, Environmental Health Engineering in the Tropics. JohnWiley and sons, New York, 1985
[13]. C.T. Agouridis, S.R. Workman ,R.C. Warner , G.D.Jennings, Livestock grazing management impacts on stream water quality: a review. *J. Am. Water Resour. Assoc., vol. 41*, pp. 591–606, 2005
[14]. S. Barnard, A. Venter and V. van Ginkel, Overview of the influence of mining-related pollution on the water quality of the Mooi River system's reservoirs, using basic statistical analyses and self organised mapping. Water SA,vol. 39, pp.
[15]. B.J. Skinner, Earth Resources. Prentice-Hall.Eaglewood cliffs. New Jersey, 1969
[16]. G.M. Kondolf, Geomorphic and environmental effects of in stream gravel mining. *Landscapes Urban Planning, vol. 28*, pp 225 – 243, 1994
[17]. A. R. Ladsonand Judd, D. A. A review of the effect of floodplain gravel on river stability, in Vietz, G.; Rutherfurd, I. D. and Hughes, R. (editors), Proc. 7thAustralian Stream Management Conference. Townsville, Queensland, 2014, pp. 249 – 259.
[18]. N.Z. Jovanovic, R.O. Barnard and N.F.G.Rethman and J.G. Annandale. Crops canbe irrigated with lime-treated acid mine drainage. Water SA, vol. 24, pp 113-122, 1998.
[19]. J.G.Annandale, Y.G. Beletse, R.J. Stirzaker, K.L.Bristow and M.E. Aken. Is irrigation with coal minedrainage sustainable? Proc. International Mine Water Conference. 19-23 October, 2009
[20]. A. Murugappan , A. Manoharan and G. Senthikumar. Effect of Lignite Mine Drainage on irrigated command areas- A case study. *Agricultural Engineering Research Journal, vol 1*,pp 12-19, 2011
[21]. A.E. Garrido, J. Condori, W.H. Strosnider and R.W.Nairn, Acid mine drainage impacts on irrigation water resources, agricultural soils and potatoes in Potosi, Bolivia. Proceedings America Society of mining and reclamation, pp 486-499, 2009.

[22]. Yen Tan Pak and H. Rohasliney. Status of water quality subject to sand mining in the Kelatan River, Kelatan. *Trop Life Sci Res., vol 24*, pp 19-34, 2013
[23]. I.J.Udom, Aggregate mining in AkwaIbom State: Emerging issues and effects on floodplain Agriculture. *International Journal of environmental issues, vol. 1*, pp. 24 – 36. 2011
[24]. I.J. Udomand A.I Essien. Agro – Environmental and economic dimensions of aggregate mining from stream channels and flood plains. *International journal of Economic development issues, vol. 4*, pp. 68-76,2006.
[25]. Federal environmental protection agency, Lagos, Nigeria, 2001.
[26]. R. K. Linsleyand J.B. Frazini, J.B. Water resources engineering. New York McGraw-Hill Book Company.1979.
[27]. American Public Health Association (APHA). Standard methods for examination of water and wastewater. 15thed. 1134p. 1980.