Industrial and Technological Waste Mismanagement and Its Implications for the Present and Future Geology of the Earth: A Field Study of the Ekulu River in Enugu Metropolis, Southeastern Nigeria

Original Research Article

ABSTRACT

Aim: Field study of the Ekulu River in the coal mining and industrialized part of the Enugu Metropolis was done in order to evaluate the impacts of industrial and technological waste mismanagement on the present and future geology of the Earth.

Methodology employed include field observation, sampling and description of nature and composition of the sediments from the ancient/abandoned and present/active river channels.

Result shows incorporation of non- decomposable particles such as nylon, plastics, leather, chicken feather, pieces of broken bottles, electrical wire, coal chips, aluminum foil, cloth materials, metallic containers, coal tar and chippings scraped off from failed road etc as part of the present river channel sediments in an active areas such as Onyeama Mine and surroundings and Abakpa Bridge.

Conclusion: Occurrence of these debris referred to as "Technofossils" in the sediments and sedimentary rocks that is or will be preserved in these fluvial settings now and in the near future will serve as one of the evidences of human impacts on the Earth System through the use of technological inventions and industrial revolution. These anthropogenic materials in the present river channel sediments are markers which support the argument on a clear shift in geologic time from Holocene to Anthropocene, a proposed human influenced geologic epoch.

Key Words: Ekulu River, Tectnofossil, Enugu, Anthropocene, Abandoned channel and Active channel bar

1. INTRODUCTION

Anthropocene, a proposed human- influenced geological epoch is the subject of global discussion (Zalasiewicz *et al*., 2008; Steffen *et al*., 2011; Sample, 2014; Haff, 2014; Davlin, 2015; Lewis and Maslin, 2015; Vaughan, 2016; Davies, 2016; Waters *et al*., 2016; Macfarlane, 2016; Rees, 2016; Carrington, 2016; Finney and Edwards, 2016; Nielson, 2017; Zalasiewicz *et al*., 2017; Cooke *et al*., 2018). The concept of Anthropocene is suggesting that the earth is moving away from its current epoch (Holocene) and already into a new one which is quite different in characteristics from the Holocene. Human activities are thought to be largely responsible for the exit (Steffan *et al*., 2011) and thus there is an expectation of

a change in the earth's geology which will reflect activities/impacts of humans on earth at present and in near future. Large- scale technology (referred to as technosphere) has been noted as a factor that contributed to the shift from the Holocene to Anthropocene (Haff, 2014). Perez (2009) defined technological revolution as a major upheaval of the wealth- creating potential of the economy, opening a vast innovation opportunity space and providing a new set of associated generic technologies, infrastructures and organizational principles that can significantly increase the efficiency and effectiveness of all industries and activities.

An increasing rates of change in human activity occurred since the beginning of the industrial revolution. A sharp increase in the rate of every indicator of human activity such as population increase, rise in economic activities among others around 1950 was reported by Steffen et al. (2011). With increasing human activities and technology on the Earth, many wastes are being generated on daily basis. While some of these waste are disposed on dumpsites at close proximity to the seas, rivers, lakes and streams, some others are emptied directly into the water body, drainage channels and water ways. Accumulation of these waste in seas, rivers and streams are not only an environmental threat but also a factor that may lead to change in the geology of the Earth System.

Coal mining and industrialization in Enugu Metropolis are veritable sources of waste products that can impact on present and future geology of the Earth. River channels and bars are repositories for waste products generated by human and technological activities. This paper will document the physical nature of the sediments of the Ekulu River in active and less active areas of the Enugu Metropolis in order to key into, and test current ideas on how waste products can impact the present and future geology of the Earth.

1.1 The Study Area

Enugu Metropolis is an industrialized and commercial city known mostly for its coal deposits and coal mining. The city is accessible through the east- west running Enugu- Onitsha and north- south trending Enugu- Port Harcourt expressways. There are also road networks which connect different parts of the metropolis. Major settlements in the town include Coal Camp, Uwani, Ogui, New Heaven, Emene, Abakpa Nike, Awkunanwu, Akwuke, Ugwuaji, Agbani, Independent layout, Trans Ekulu etc (Fig. 1).

Enugu metropolis is situated at the western foot of the scarp slope of the N – S trending segment of the Enugu – Awgu Cuesta (Nwajide, 2022). The lowlands are underlain by the Enugu Formation whereas the sandstones of the Mamu and Ajali formations underlie the scarp face and tops of the escarpment respectively. The tributaries of the Ekulu, Nyaba, Ogbete and Asata Rivers flow westwards into the Cross River Drainage System. The Ekulu River is noted as the largest water body in the city (Adaikpo *et al.,* 2005) and provides part of the domestic water supply in the metropolis (Egboka, 1985).

Enugu lies within the humid tropical rain forest zone with a derived savanna (Sanni *et al*., 2007). The annual rainfall has been estimated to range from 1,600 to 2000 mm (Ofomata, 1965; Inyan, 1978; Egboka *et al*., 1989). Warm day temperatures of between 27°C and 32°C and moderately cool nights of 17°C and 28°C are characteristics of the city.

Two main seasons mark the area; rainy and dry seasons. Rainy season starts from March and lasts till October, with an August break. Most of the rainfall in this season is heavy and often accompanied by thunderstorms, resulting in heavy flooding and soil loss. Relative humidity is about 65 to 80% and highest during the rainy season. Dry season commences from early November till February and is characterized by cold and dusty weather (harmattan) caused by the northeast trade winds.

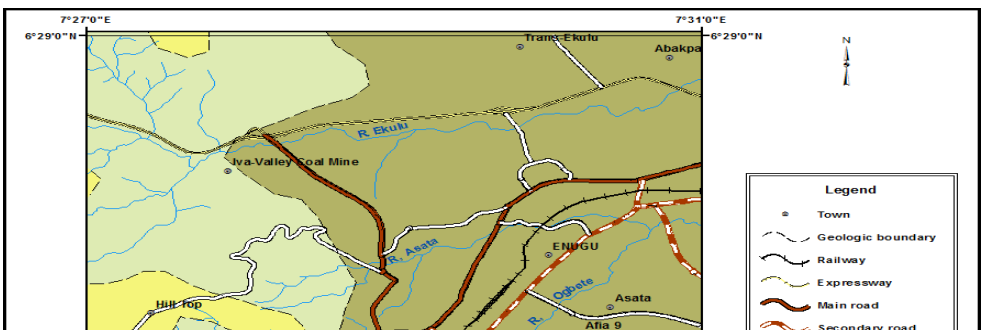

Fig. 1: Map of the Study Area

2. METHODOLOGY

Field study was carried out on the Ekulu River around the Onyeama Mine/Proda Bridge, Abakpa Trans Ekulu and Golf Estate Bridge within Enugu Metropolis. The ancient/abandoned channel and present/active channel sediments of the river in these localities were studied (Table 1). Samples were carefully collected with clean sample bags and well labelled to avoid mix up. Photographs of significant features were taken and presented as figures under result section. The sediment were studied based on nature, composition and texture. Sorting was estimated by the use of grain size comparator and hand lens.

Table 1: Various sampling points in the study area

S/N	Locality	Coordinate	Elevation

			(m)
1.	Onyeama Mine (Proda Bridge)	N06°28'13.4" E007°27'24.3"	213
2.	500 m away from Proda Bridge along Enugu-Onitsha expressway	N06°27'88.7" E007°27'67.8"	195
3.	Below Trans Ekulu Bridge	N06°28' 13.4" E007°29' 74.7"	175
4.	Below Abakpa Bridge	N06°28' 47.3" E007°30' 81.2	162
5	Below Golf Estate Bridge	N06°28' 07.0" E007°28' 84.5"	180

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Depositional Settings and Sedimentation Processes in the River

The east flowing Ekulu River in the study area has two distinct channel types; the meandering and the braided channels. At 500m away from the Onyeama Mine/Proda Bridge along Enugu- Onitsha expressway and below Abakpa Bridge, both channels occur within a stretch of length and are flanked by terraces representing the ancient/abandoned channel deposits. The Enugu Formation constitutes the underlying lithostratigraphic unit.

For the braided channels, the longitudinal bars are the common feature exhibited by the river (Fig. 2). The bars are oriented with their long axis parallel (longitudinal) to the flow direction. These bars are one of the sediment depositional sites in the river. They tend to be submerged during rainy season owing to rise in water level caused by flooding, and are however, exposed during the dry season when there is fall in water level.

The meandering channels consist principally of the main meander channels and the point bars (Fig. 3), which are building outwards (lateral accretion) on the inside bend of meander loops. Point bars and main

meander channels constitute the major depositional sites of the meandering river. Abandoned channel deposits also occur.

Erosion of the river banks and surrounding areas and the deposition of the eroded materials on these depositional sites (the main meander channel, point bars and braid bars) are on- going processes in the river and occur mostly during the flood stage when current strength is high. Refuse dumped at the proximity of the river and surroundings are also being moved down with sands, pebbles and plant debris into the depositional sites of the river by flowing water during the rainy season.

Fig. 2: Braided channels of the Ekulu River showing the longitudinal bars

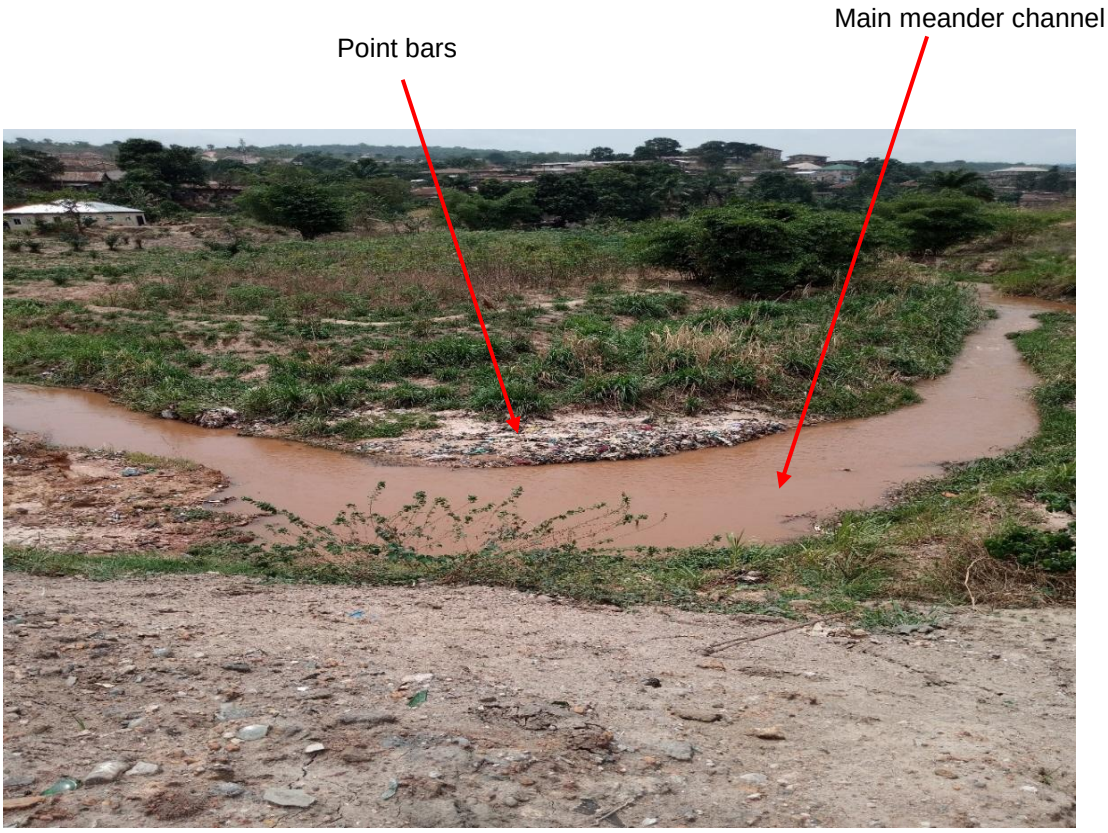

Fig. 3: Meandering channel of the Ekulu River showing the main meander channel and the point bar

3.1.2 Description of the Sampled Localities

Location I: Onyeama Mine/Proda Bridge

Anthropogenic activities on and around the Ekulu River channels (ancient and present) in this locality include (a) abandoned mine dump above the ancient terraces of the river (b) technological waste dumped at the proximity of the river. These wastes however, are being washed down into the present river channel by rain and consist of materials such as automobile tyre, pieces of broken bottles, nylon, plastic bottles and containers, clothes, stem and roots of plants, metallic containers, pieces of leather materials, coal tar and chippings from failed road etc. Most of these materials have been incorporated and deposited along with sands and pebbles on the present river channel (Fig 4).

Fig. 4: On- going activities on location 1; (a) Abandoned coal mine waste dumped above the ancient and present terraces of the river that is being washed down the river channel by rain (b) Waste dump at the margin of the river also being moved down into the river channel especially during the rainy season (c &d) Exposed on- going sedimentation at the present river channel situated below the dumpsites. These sediments are exposed owing to fall in water level due to dry season.

Location II: 500 m away from Onyeama Mine along Enugu- Onitsha Expressway

Both meandering and braiding channels of the Ekulu River are exposed at close intervals in this locality. The channels are flanked by sedimentary units of the ancient river channels. Micro- water falls were found developing on the underlying Enugu Formation. Technological waste dumped at the proximity of the river together with vegetable farming on the ancient terraces of the river are observed human activities in this location. Some of the refuse dumped around the river were moved down by current during the rainy season and were already deposited as part of sediments on the point bars and braid bars of the present river channels. Such materials include nylon, clothes, plastic bottles, can, woody debris etc (Fig. 5).

Location III: Below Trans Ekulu Bridge

This is a less active area as farming activity (vegetable garden) on the ancient terrace of the river is the only on- going human activity in the locality. No waste dump was found at the proximity of the river, thus the present river deposits consist mostly of sands.

Location IV: Below Abakpa Bridge

Braiding and meandering channels are also present within a stretch of length in this locality. Vegetables were planted on the ancient terraces of the river. Nylon particles, plastic containers and woody debris were found deposited as part of sediments on the present river channels (Fig. 6).

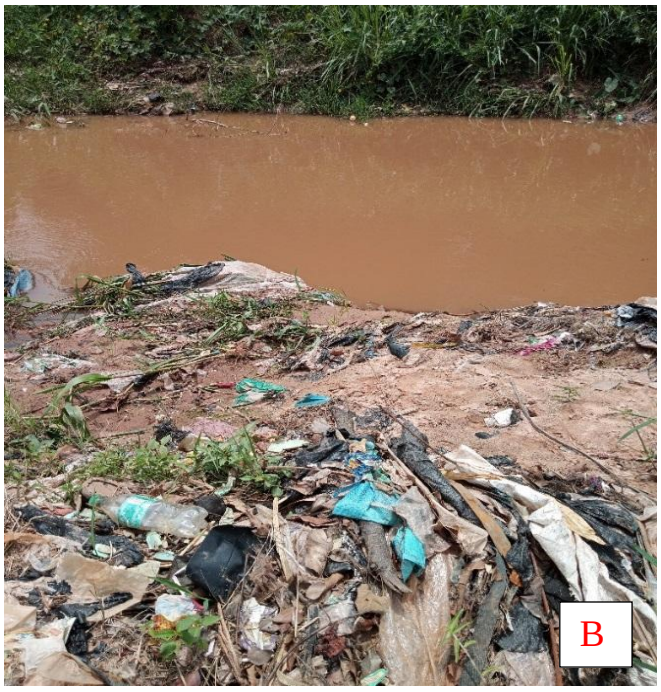

Fig. 5(a &b): Fluvial sedimentation on the outer and inner (point bars) parts of the present meander channel. The sediments are exposed due to fall in water level during dry season (c& d) Exposed braid bars sediments of the present river

Fig. 6: Ekulu River in a less active area (below Abakpa Bridge). Nylon, plastic containers and wood debris were deposited as part of sediments on the present channels and bars of the river

Location V: Below Golf Estate Bridge

This is another less active area. Meandering is the typical characteristic of the river with minimal vegetable farming activity on the ancient terrace of the river. No refuse dump was also found around the river channels.

3.1.3 Sediment Characteristics

Sediment samples from the active areas consist of sands with grain size that ranges from very fine to very coarse and pebbly. Large pebbles also occur. Clay, quartz and coal pebbles are present especially in areas around Onyeama Mine. Sediment sorting varies from well sorted to very poorly sorted sands with sub- rounded quartz grains. Debris consisting of cloth and nylon particles, pieces of broken bottle, chicken feather, woody particles, coal chips, leather material, pieces of electric wire, aluminum foil and plastic particles etc were incorporated in the sediments of the river in active areas. Apart from the

occurrence of woody debris, other particles were not found in the sediments obtained from the channels of the river in less active areas such as below Trans- Ekulu Bridge and Golf Estate Bridge.

3.2 Discussion

Field study and sediment characteristics of the Ekulu River from active areas such as Onyeama Mine/Proda Bridge and nearby environments as well as below Abakpa Bridge entail that improper management of industrial and technological wastes by human is already affecting and seriously modifying the present and future geology of the Earth System. The nature and composition of the sediments exposed on the present river channels in active areas of the metropolis are quite different from the ones preserved on the ancient/abandoned channels. The present channel sediments are the sedimentary units that will be preserved as meandering and braid channel bar deposits of tomorrow. Materials such as nylon, broken bottles, leather, automobile tyres, clothes, plastics, metallic cans and containers, materials scrapped off from the tarred roads etc which are parts of these present channel sediments are not decomposable, thus their debris/particles are being preserved in the sedimentary units of the river as fossils. These are part of what Zalasiewics et al. (2014) referred to as “Technofossils” (i.e technological fossils).

Ekulu River and its tributaries discharges some of these non- decomposable wastes into the Cross River, which will eventually empties most of these gathered wastes from all its tributaries into the Atlantic Ocean.

Nylon bags and plastics are ubiquitous and are common household materials. They are also being widely used for packaging of food and drinks in restaurants, event centres, industries, among others. Previous studies have reported the accumulation of plastic debris as part of sediments in an open ocean, on shorelines and in deep seas (Derraik, 2002; Thompson et al., 2004; Barnes, 2005; Weiss et al., 2006; Barnes et al., 2009). Sources of these plastic debris in these environments were stated to include direct dropping and dumping of litter on land or sea, blowing from landfill sites, losses in transport and accident (Barnes et al., 2009). The pattern of the distribution of the plastic debris in the sea was also documented (e.g Coe et al., 1997; Barnes, 2005; Santos et al., 2005; Barnes and Milner, 2005; Demeron et al., 2007). Babu et al. (2007) and Ongondo et al. (2011) discussed the global environmental problem and the management of electrical and electronic wastes.

This study anticipates the modification of the present and future geology of the study area in particular when these incorporated non- decomposable materials are buried and converted to rock. The presence of these anthropogenic materials in present sediments have been enlisted as markers to identify the new geologic epoch, and thus suggesting a shift in geologic time scale from the Holocene to the "Anthropocene Epoch" (Zalasiewics *et al*., 2014, 2017; Carrington, 2016; McKie, 2016; Vaughan, 2016).

4. CONCLUSION

Study of the Ekulu River in the industrialized part of the Enugu Metropolis have shown that mismanagement of industrial and technological wastes impacts on the present and future geology of the Earth System. Present sediments are already documenting technofossils as one of the evidences of human activities on Earth. This is in support of the proposed new human influenced geologic epoch called "The Anthropocene"

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COMPETING INTERESTS

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AUTHORS CONTRIBUTIONS

Authors worked together and approved the submission of the manuscript.

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