https://dx.doi.org/10.4314/dujopas.v10i1a.12
ISSN (Print): 2476-8316
ISSN (Online): 2635-3490
Dutse Journal of Pure and Applied Sciences (DUJOPAS), *Vol. 10 No. 1a March 2024*

Assessment of Chemical Characteristics of Bottom Sediments of Zobe Dam Reservoir, Katsina State, Nigeria

[1]Ibrahim Adesoji .A, [2]Jolly Byami . A. and [3]Tawey Mam. D

[1, 3] Department of Groundwater,
National Water Resources Institute,
Kaduna

[2]Deparment of Geology,
Ahmadu Bello University,
Zaria

Email: adesojiibrahim@yahoo.com

Abstract

Zobe Dam is one of the silted dams in Nigeria. It is located in the Dustin-ma area in Katsina State northwestern Nigeria. The bottom reservoir sediments of the dam were sampled during the bathymetric studies of the reservoir. The objectives are to: determine the status of mineral elements and their distribution; measure the anomalous elemental concentration, as a tool in search for solid mineral deposits; and determine the usefulness of such sediments when dredged out. A total of 15 samples were obtained and analysed at Federal Steel Council laboratory in Kaduna using a Scanning Electron Microscope which was then transferred electronically to EDX that revealed the elemental constituents of the samples in mg/kg. A total of 27 elements were examined, the order of enrichment is Si > Fe > Al > Hg> K > Pb > Ti > Ca > Cd….All the elements were several times greater than the world's mean crustal abundance. The preponderance of these elements could be attributed to the contamination from artisanal mining of polymetallic mineral associations in Jibia, Dandire, Mallam Tanko Kafur, Dutsin-Ma and other areas within the State; as well as the anthropogenic factors like organic fertilizer application by farmers. It is recommended that the erosion of sand into the dam be checked through the planting of trees and other environmental conservation practices.

Keywords: *Weathering, Sediments, Reservoir, Crustal abundance, Electron microscope*

INTRODUCTION

Earth's surface is in dynamic equilibrium, as a result of the balance between the internal geologic processes which create earthquakes, volcanic activity, and mountain ranges, and the external geologic processes that are responsible for shaping and modifying land relief, through weathering, erosion, transportation and deposition. The geologic agents of achieving these are the wind, the water, living beings and gravity; and one of the resulting actions is sedimentation. It is a process whereby soil particles are eroded and transported by flowing water or other transporting media and deposited as layers of solid particles in water bodies such as reservoirs and rivers (Tundu *et al.*, 2018). It is a complex process that may include temporary storage of eroded materials on hill slopes, stream courses, and in the long-term deposited in lower courses such as standing bodies of water, known as reservoirs.

Of particular concern are fine-grained silts and clays, which can degrade habitat, clog water supply intakes and fill reservoirs, and often carry phosphorus and/or contaminants harmful to humans and aquatic life (Larsen *et al.*, 2010). It also reflects the quality of surface water as

---

*Author for Correspondence

well as provides information on the transportation and fate of pollutants (Santchi, 1984). Research shows that about 1% of the total reservoir storage capacity of the world reservoirs is lost every year to sedimentation (Mahmood, 1987), and this can affect hydropower production or cause damage to the facility's mechanical components (Obialor *et.al.,* 2019). Reservoirs are designed for the assumption of a 50 - 100-year life span, after which depleted by sediment deposition over time. The amounts of sediment inflows from overland often make the useful life of a dam shorter because sediments are directly discharged into the dam and settled down as the velocity of water reduces near dyke as observed by Morris and Fan (2008). A World Bank study (Mahmood, 1987) illustrated that the average useful life of existing reservoirs in all countries of the world decreased from 100 to 22 years despite their significant contribution to flood control, by temporarily retaining flood water during peak flow, consequently reducing excess surface runoff along the streams contributing downstream (De Coning and Poolman, 2011; Elkhrachy, 2015).

A well-structured reservoir management approach will solve these myriads of reservoir sedimentation/siltation. The methods of managing sediment fall under three general categories: those that divert sediment around or through the reservoir, those that remove deposited sediments, and those that minimize the amount of sediment reaching the facility in the first place (Obialor *et al.,* 2019). The bathymetric survey is one of the methods employed to determine the volume changes caused by sediment deposits in various reservoirs. It allows for measuring the depth of a water body as well as mapping the underwater features (Menna, *et al.*, 2018).

The previous researches available on Zobe dam are on the controlling foundation-related seepages in 1983,1985,1986,2005, and 2009 (ESIA,2020), the efficacy of Zobe dam for hydroelectricity generation, (Nuhu and Abdul,2020), water quality assessment (Ibrahim, *et al.*, 2014; Sadauki *et al.,* 2022), measurement of radiation activity, (Najib *et al.*, 2014; Oluwole *et al.*,2020). However, the bathymetric study and bottom sediment sampling analysis of the Zobe Dam are the first of its kind since the dam was constructed. This report therefore serves as baseline information for future studies. The objectives of sediment bottom sampling are to: determine the status of metals and heavy metals, as well as solid non-metal distribution in bottom sediments; measure the anomalous elemental concentration of elements, as a tool in studying environmental pollution and search for secondary solid mineral deposits.

Location of the study area

The Zobe Dam is situated on the coordinates 1202137.69″ N, 702753.98″ E in the Dutsin-Ma local government area of Katsina State of Nigeria (Fig.1a). It is an earth-fill structure with a height of 19 m and a total length of 2,750 m. The dam has a storage capacity of 177 million cubic meters and an irrigation potential of 8,000 hectares. Zobe Dam was conceived in the late 1970s and was planned to supply 50% of drinking water to Katsina State (ESIA Report, 2020), while also supporting irrigation farming in the Dutsinma area and nearby towns and villages along the dam spillway discharge (Fig.1b).

Geology of the Area

Dutsin-Ma and its environs are underlain by two formations (Akor *et al.,* 2017): the Illo-Gundumi formation of the Sokoto Basin covers 20% of the total geology of Katsina. The remaining 80% parts of where Zobe Dam is located is underlain by Basement Complex Rocks: the ancient biotite-mica-rich older granites older than 650 million years (commonly called the Pan-African granite suites), and the granite-gneiss-migmatite with minor bandings and augen structures in occasional place types (Kankara, 2020), in association with meta-sediments (Akor *et al.*,2017). However, within the surroundings of Zobe Dam are exposed lateritic hard pans.

In some parts of the area, the rocks have changed over time as a result of weathering and erosion effects (Kankara, 2020).

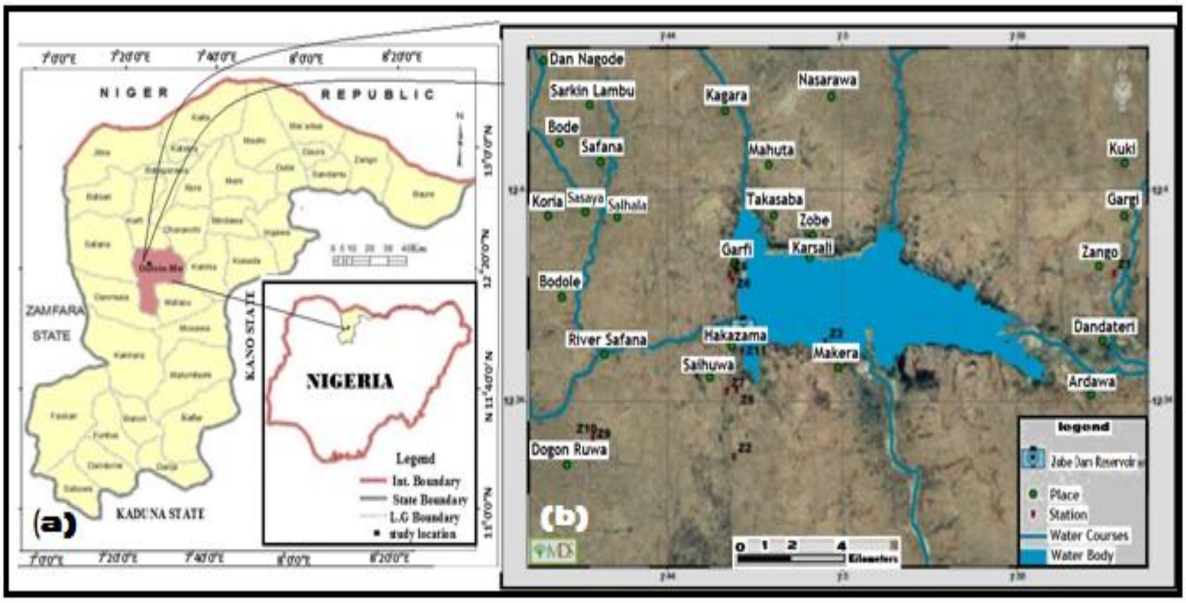

Fig.1a. Location map of Dutsin ma in Katsina state (source: Gnes/Spot Image, (2014), and
Fig.1b. Location of Zobe Dam and the adjoining settlements in Dutsin-Ma LGA (source: ESIA Report, 2020)

MATERIALS AND METHODS

Sample collection

A total of fifteen samples were collected within the reservoir in December 2021. Their locations are shown in Fig.2. These samples were later grouped as either single or composite samples based on their proximity and tributaries, according to the established network during bathymetric studies. In the end, six samples were analysed, these are ZEB 01, ZEB 05,(as single samples), ZEB 3 representing sample locations 3, 6,8, and 10; ZEB 14 representing locations 14 and 16; ZEB 12, representing locations 11, 12 and 18; and ZEB 22, representing, 22, 23, 28 and 35 (as composite samples). The samples were collected using a fabricated dredger. The wet samples were wrapped into black polythene bags, labelled and transferred to the Federal Steel Council laboratory, Malali in Kaduna, where they were air dried at room temperature (26^{o} - 27^{o}C) for three weeks.

Laboratory Analyses

These Samples were then pulverized to a particle size of about 0.15 microns or about 100mesh, using equipment such as a Jaw Crusher, Disc miller, and vibrating cup miller. The samples were later run through a Scanning Electron Microscope (SEM-PHENOM PRO X MODEL). The images are adjusted for sharpness, necessary zooming and refocusing. This was then transferred electronically to EDX (Energy dispersive X-ray spectroscopy) The EDX coupled with Elemental Identification Software automatically characterized the major, minor and trace percentage elemental constituents of the sample. The machine is capable of carrying out elemental analysis of samples and expressing the results in percentage atomic weight, % weight conc., and oxides of the element in % stoichiometry concentration.

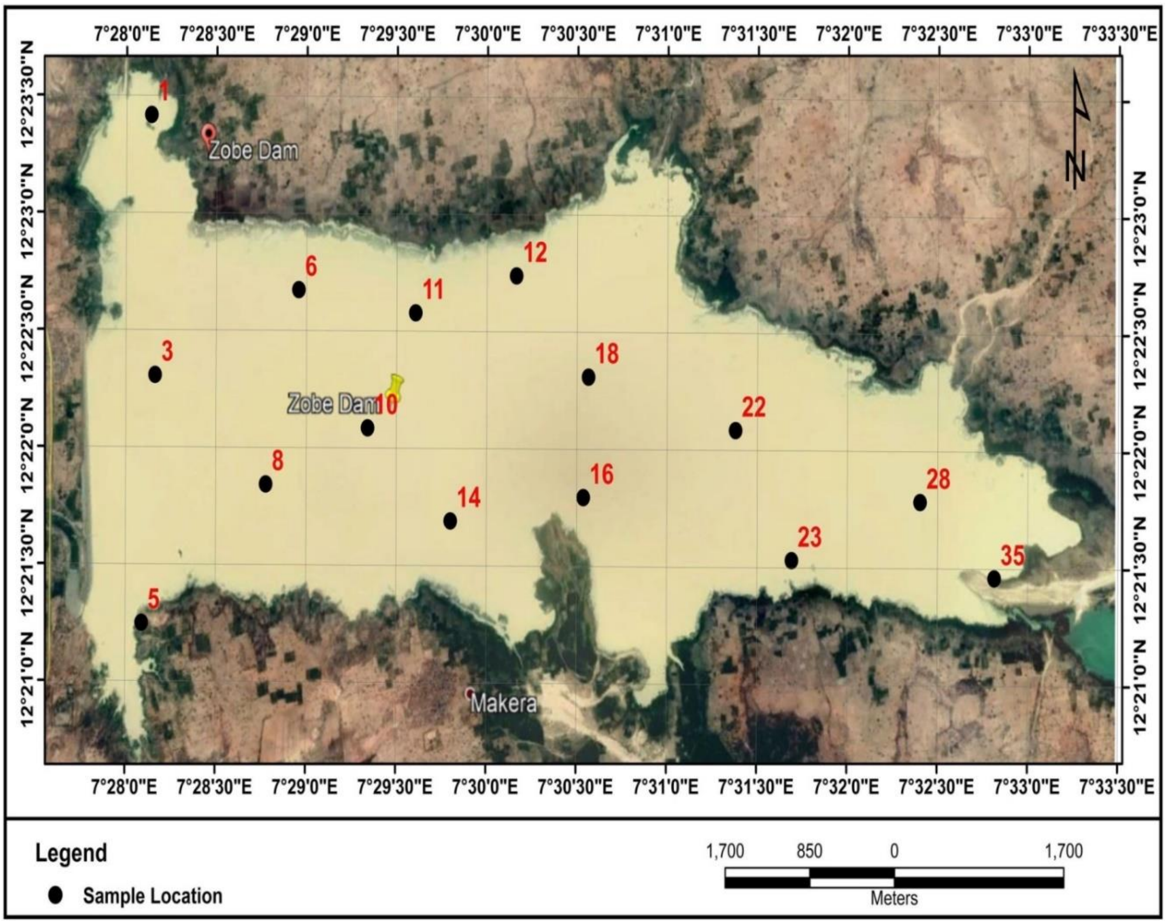

Fig. 2 Sample locations within the Zobe Dam Reservoir

RESULTS AND DISCUSSION

Description of Bottom sediment of Zobe Dam

The sediments are silty to fine-grained sands (mostly quartz) and the textures vary from very fine to fine, while the colour is from greyish-black to brown, depending on the location. Those at the periphery of the dam are brown, while those at the centre are greyish to black. The sediments are also rich in organic matter, especially remains of decayed aquatic weeds (mainly Typha grass). The colour could be attributed to an anoxia environment and the presence of organic matter.

Chemical Analysis of Sediment of Zobe Dam

A total of twenty- seven elements were examined from the bottom sediments collected at Zobe Dam, these elements are grouped as Heavy metals; macro and micro nutrients for plant growth; and those that are referred to as commonly found elements in the earth's crust. From the descriptive statistics of the concentration and distribution of these elements (Table 1), it was observed that all the elements present are several times higher than their crustal abundance. Those with relatively lower values of concentration are sodium, 12.7%, Magnesium, 30.7%, and Calcium, 55.8%. This could be due to chemical alteration, as explained by Thomas *et al*., (1996) that when chemical alteration exceeds mechanical erosion, the most soluble elements are carried in the dissolved phase as ions (Ca^{2}+, Mg^{2}+, Na+ K+) and dissolved SiO_2, whereas the least soluble ones (Al, Fe, Ti, Mn) remain in the soil which gradually becomes more enriched.

Also, Katsina State is endowed with several solid minerals, these include Nickel, Copper, Cobalt, Vanadium, chromite- a polymetallic association in Jibia and Chromate found with asbestos at Dandire and Mallam Tanko. Tantalite/Columbite occurs in many locations and artisanal mining is being carried out in 15 LGAs, Iron ores occur in 5 locations (Katsina State Investors Handbook, (2016). The weathering and other surficial processes could also assist in the concentrations of these minerals, as well as their associates. Other activities could be attributed to anthropogenic activities, such as agricultural practices. Agricultural activities have caused 70% of water pollution worldwide (Sagasta *et al.*, 2017). Watts (2010) stated that pesticides and fertilizers from agricultural activities have contributed 43% of chemical oxygen demand, 67% phosphorus, and 57% nitrogen from waste to the rivers.

Table 1: Descriptive statistics of the distribution of elements in the bottom sediment of Zobe dam

Element Symbol	Range (Mg/Kg)	Mean (Mg/Kg)	Mean± SD	**Crustal Abundance weight (Mg/Kg)	Percentage greater than crustal abundance
Si	320200 -94100	359883	±335906.6	277200	129.8
Fe	167300 -81600	214867	±157192.4	5000	429.7
Al	160000 -15400	188600	±165192.4	81300	232
K	37900 -40900	43867	±39352.73	25900	169.4
Pb	0 - 36700	19700	±5985.19	15	131333.3
Cu	0 - 5600	933	±1353.19	70	1333.3
Ti	19800 -28900	24767	±21758.57	4400	562.9
Cd	8200 - 21600	13088	±8015.56	0.2	6544165
Ca	16800 -23700	20250	±17719.58	36300	55.8
Ag	10700 -18500	13667	±10509.36	0.1	1366670
Co	0 - 12600	6267	±567.99	23	27246.4
Mn	2900 -14700	6433	±1491.62	1000	643.3
Zn	0 - 10400	5950	±2019.73	130	4576.9
Se	3100 -10400	6533	±3959.55	0.09	7259256
Mg	1700 -10400	6417	±3378.31	20900	30.4
Nb	8500 -17200	11867	±8851.26	24	49444.5
Cl	5000 -7700	6400	±5514.56	320	2000
Ni	0 - 10200	4000	±754.68	80	5000
Y	8200-20800	12217	±7763.05	40	30541.7
Na	2500 -4800	3600	±2616.13	28300	12.7
As	4800 -3400	6383	±4260.4	2	319166.5
P	1300 -3400	2333	±1548.99	1180	197.7
Cr	0 - 5800	1450	±976.31	200	725
C	1300 -4900	2617	±1389.94	320	817.7
S	0 - 5900	2133	±371.13	520	410.3
N	900 -2300	1400	±926.71	50	2800
Hg	0 - 90200	15033	±14664.01	0.5	30066

**Crustal abundance adapted from (Mason, 1952)

Heavy metals that are released and transported from land environments can easily accumulate in the sediment and, under certain conditions, permeate the water layer (Duman and Koca, 2004), and this could have severe consequences for the users of such water. For Instance, since Cd has bioaccumulation capacity (Norvell et al., 2000), it is one of the most toxic substances for all human populations mostly from plant-derived food and the intake of contaminated food. Moreover, in part of the valley of the River Jinzu in Toyama Prefecture, Japan, paddy-rice-growing soils had been contaminated by a Pb-Zn mine upstream and some of the population suffered death and severe disability from Cd toxicity (Alloway and Steinnes,1999).

CONCLUSION

The elemental composition of the bottom sediments of the Zobe Dam reservoir analysed using the SEM-EDX technique shows that the reservoir is rich in metallic and non–metallic mineral elements. The order of enrichment is Si > Fe > Al > Hg> K > Pb > Ti > Ca > Cd….All the elements were several times greater than the world's mean crustal abundance. The preponderance of these elements could be attributed to the contamination from artisanal mining of polymetallic mineral associations in Jibia, Dandire, Mallam Tanko Kafur, Dutsin-Ma and other areas within the State, as well as the anthropogenic factors like organic fertilizer application by farmers. It is therefore recommended that:

- Activities like artisanal small-scale gold mines that use Mercury, Arsenic cadmium and Lead should be seriously monitored to curtail further pollution of the dam;
- The use of cow dung as a remediation of heavy metals like chromium and arsenic should be encouraged especially among farmers, via organic manure, as it has been proven (Mohan and Gupta, 2014) that cow dung can achieve 73.8% removal of chromium from aqueous solution;
- Watershed management concerning planting of trees, to reduce soil erosion and transportation of sand particles should be encouraged in the region.

REFERENCES

Akor, M., Akpaneno, A.F. and Afuwai, G.C. (2017). Geoelectrical Investigation of Groundwater potential of Administrative Block at permanent site, Federal University Dutin-Ma, Katsina State, Nigeria, *FUDMA Journal of Sciences* (FJS), Maiden Edition, Vol. 1, No.1, 161- 169

Alloway, B.J. and Steinnes, E. (1999). Anthropogenic Additions of Cadmium to Soil, Ch. 5. In McLaughlin, M.J. and Singh, B.R. (Eds.), Cadmium in Soils and Plants, Kluwer Academic Publishers, London, pp. 1-28

De Coning, E. and Poolman,E. (2011). South African Weather Service Operational Satellite-based Precipitation Estimation Technique: Applications and Improvements. *Hydrology and Earth System Sciences*, 15(4): pp 1131-1145.

Duman F, Koca, F.D. (2004). Single and combined effects of exposure concentration and duration on biological responses of Ceratophyllum demersum L. exposed to Crspecies. *Int. J. Phytorem*. 16: 1192-1208.

Elkhrachy, I. (2015). Flash Flood Hazard Mapping using Satellite images and GIS tools: a case study of Najran City, Kingdom of Saudi Arabia (KSA). *The Egyptian Journal of Remote Sensing and Space Science,* 18(2): 261-278.

Environmental and Social Impact Assessment (ESIA) Report, (2020). ESIA Report for Zobe Dam and Associated Infrastructures Rehabilitation Works, (FMWR/WB/IR/CQS/12/2), sponsored by Triming, World Bank and Federal Ministry of Water Resources, Abuja

Gnes/Spot Image, (2014). In Ibrahim, Y.E and Nuraddeen, A. M, (2016): An Assessment of Some Water Quality Properties of Groundwater in Dutsin - Ma Metropolis, Nigeria, *Int.J.Curr.Microbiol.*App.Sc.p.7.

Ibrahim, A. (1990). Geology and Geochemistry of the Area Around Kankara Kaolinitic, http: www. Researchgate.net

Ibrahim, Y. E. and Nuraddeen, A. M. (2014). An Assessment of Some Water Quality Properties of Groundwater in Dutsin - Ma Metropolis, Nigeria, *Int.J.Curr.Microbiol*.App.Sci. 3(5): 644-649.

Ibrahim, Y.L, Abdu, Y. and Kabir, I. (2018). Soil Resources in Katsina State, https://www.researchgate.net/publication/328314936

Kankara, A.I. (2020). On the Use of Kriging Model Concept to Detect Groundwater Potential Zones in Hilly, Dutsin-Ma, Northwestern Nigeria, *International Journal of Strategic Research in Education, Technology and Humanities*, Vol. 8 No. 1. Pp 1-18

Katsina State Investors' Handbook, (2016). Mineral inventory of Katsina State, Table 1, p20

Larsen, M. C., Gellis, A. C., Glysson, G. D., Gray, J. R., and Horowitz, A. J. (2010). Fluvial sediment in the environment: a national problem. *Proceedings, Second Joint Federal Interagency Conference, Las Vegas, NV, June 7 – July 1, 2010.*

Mahmood, K. (1987). Reservoir sedimentation: impact, extent and mitigation. *Tech. Pap*. No. 71, World Bank. Washington, D.C.

Mason, B., (1952). Principles of geochemistry, 276 p. New York, John Wiley, and Sons.

Menna, F. P. Agrafiotis and Georgopoulos, A. (2018). State of the art and applications in archaeological underwater 3D recording and mapping. *Journal of Cultural Heritage*, 33: 231-248.

Mohan, L., Gupta, D. (2014). Study on removal of chromium from aqueous solution using dry cow dung powder. *J Chem Pharm.* Res 6:1066–1070.

Morris, G.L. and Fan, J. (1998). Reservoir sedimentation handbook, McGraw-Hill, New- York.

Najib, M. U., Zakari Y. I., Sadiq U.,Bello I. A. and Ibrahim G. G.(2014). Measurement of radioactivity in water of Zobe Dam Dutsinma, Katsina State, Northern Nigeria, *Archives of Applied Science Research, 6 (6):28-33.*

Nuhu,I. and Abdulsalam, H. (2020).An Efficacy of Zobe Dam for HydroelectricityGeneration in Katsina State, *Nigeria. Nigerian Journal of Technology* (NIJOTECH), Vol. 39, No. 4.

Norvell, W.A., Wu, J., Hopkins, D .J. and Welch, R. M. (2000). Association of cadmium in durum wheat grain with soil chloride and chelate-extractable soil cadmium, *Soil Science Society of America Journal*, vol. 64, no. 6, pp. 2162–2168

Obialor,C. A., Okeke, O. C., Onunkwo, A. A., Fagorite, V. I, and Ehujuo, N. N. **(**2019).Reservoir Sedimentation: causes, effects and mitigation, *International Journal of Advanced Academic Research | Sciences, Technology and Engineering* Vol. 5, Issue 10, | ISSN: 2488-9849.

Oluwole, J. O., Mark, O.A., Theophilus, A., Olayinka, B. P. (2020).Risk assessment of drinkable water sources using gross alpha and beta radioactivity levels and heavy metals, *Heliyon 6* e04668.

Sadauki, M.A., Bichi, A.H., Dauda, A.B., Geidam, M.B. (2022). Assessment of Assessment of Assessment of Assessment of Water Quality Parameters of Zobe and Ajiwa Reservoirs, Katsina State, Nigeria, *African Scientist* Vol. 23, No. 1.

Sagasta, J.M., Zadeh, H. and Turral. (2017). Water pollution from agriculture: a global review. FAO and IWMI, Rome. P.29

Santchi, P.H. (1984). Particle flux and trace metal residence time in natural waters. *Limnol. Oceanogr*. 29:1100-1108.

Thomas, R. and Meybeck, M. (1996). The use of particulate material, Chapter 4, In Water Quality Assessments - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring - Second Edition, UNESCO/WHO/UNEP.

Tundu, C., Tumbare, M. J. and Onema, J. K. (2018). Sedimentation and Its Impacts/Effects on River System and Reservoir Water Quality: case Study of Mazowe Catchment, Zimbabwe. *Proc. IAHS*, 377, 57–66.

Watts, J. (2010). Chinese farms cause more pollution than factories, says official survey [available on the internet at http://www.guardian.co.uk/environment/2010/feb/09/ china-farmspollution].