GEOSPATIAL MODELLING OF GROUNDWATER QUALITY IN JOS SOUTHLOCAL GOVERNMENT AREA OF PLATEAU STATE, NIGERIA

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CERTIFICATION

This is to certify that this research work was carried out by**EGUAROJEOnoshi Ezekiel(SCP11/12/H/1329)** in partial fulfilment of the requirements for the award of**Doctor of Philosophy** (Ph.D.) Degree in Ecology and Environmental Science of theObafemiAwolowo University, under our supervision.

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DEDICATION

I dedicate this research work to God Almighty (The Source and Provider of Living Water) and to my Lovely Children. I also dedicate this research work to all those who are working tirelessly to improve and provide quality and safe water to Humanity.

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LIST OF ABBREVIATIONS AND ACRONYMS USED

‰	parts per thousand
a.m.	ante meridian (before noon)
A.P.H.A.	American Public Health Association
AAS	Atomic Absorption Spectrophotometer
ADEQ	Arizona Department of Environmental Quality (USA)
Ag	Silver
$AgNO_3$	Silver nitrate
AL	Action Level
Amsl.	Above mean sea level
ANOVA	Analysis of variance (Statistics)
APHA	American Public Health Association
As	Arsenic
ASDC	Atmospheric Science Data Center
AWWA	American Water Works Association
B	Bottom
Ba	Barium
Be	Beryllium
BOD5	Biochemical Oxygen Demand (over 5 days)
BS	Base Saturation
C	Carbon
Ca	Calcium
CaCO3	Calcium carbonate
Cd	Cadmium
C_d	Degree of Contamination
CEC	Cation Exchange Capacity
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
C_f	Contamination Factor
Cl^-	Chloride
Cl	Chlorine
cm	centimetre
cm^3	centimetre cube
Cr	Chromium
Cu	Copper
CV	Coefficient of variation
D	Distance
DDT	Dichlorodiphenyltrichloroethane
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DS	Dry Season
E	East of Greenwich Meridian
E.D.T.A.	Ethylene-diamine-tetra-acetic acid
e.g.	*exempli gratia* (for example, for instance)

EC	Electrical Conductance
ED	Early Dry
EDTA	Ethylene-Diamine-Tetra-acetic Acid
EQS	Environmental Quality Standard
ER	Early Rain
ER	Enrichment Ratio
ESPS	Environmental Statement for Port of Southampton
et al.	*etalli*(and others)
etc.	*etceteria* (and others)
F	Fischer (Statistics)
FAAS	Flame Atomic Absorption Spectrophotometer
FCC	False Colour Composite
Fe	Iron
FEPA	Federal Environmental Protection Agency (Nigeria)
FES	Flame Emission Spectrophotometer
FFG	Functional Feeding Groups
Fig.	Figure(s)
Formulae	
g	gram
GPS	Global Positioning System
h	hour
H	Hydrogen
ha	Hectare
HCo_3	Carbonic acid
HCl	Hydrochloric Acid
Hg	Mercury
i.e.	*idest*(that is)
IEB	Ionic Error of Balance
IITA	International Institute of Tropical Agriculture
ISSS	International Society of Soil Science
K	Potassium
kg	kilogram
km	Kilometre
kW	kilowatt
L	Litre
LD	Late Dry
LGA	Local Government Area
LR	Late Rain
LSRCA	Lake Simcoe Region Conservation Authority
LULC	Land use Land Cover

m	metre
m/s	meter per seconds
m^2	meter square
Max	Maximum value
MCM	million cubic metres
MDNR	Maryland Department of Natural Resources (USA)
meqL-	1millequivalent per litre
Mg	Magnesium
Mg	Magnesium
mg	milligram
min	Minimum value
ml	millilitre
mm	millimetre
Mn	Manganese
Mo	Molybdenum
N	Nitrogen
N	North of the Equator
Na	Sodium
NASA	National Aeronautics and Space Administration (USA)
ND	Not determined / No data
NFESC	Naval Facilities Engineering Service Center (USA)
Ni	Nickel
nm	Nanometer
NO_3^-	Nitrate
NOAA	National Oceanic and Atmospheric Administration (USA)
NPRB	North Pacific Research Board
NTU	Nephelometric Turbidity Unit
O_2	Oxygen
^oC	Degree Celsius
OC	Organic Carbon
OM	Organic Matter
Op. cit.	*Opere citato* (in the work cited)
Org	Organism
Org/m^2	Organisms per meter square
P	Phosphorus
p	Probability value (Statistics)
p.m.	Post meridian
PAHs	Polycyclic Aromatic Hydrocarbons
PAST	Palaeontological Statistics
PASW	Predictive Analytic SoftWare
Pb	Lead
PCA	Principal Component Analysis
PCBs	Polychlorinated Biphenyls
PEL	Probable Effect Level
pH	*potential Hydrogeni*(potential of hydrogen)

PO_4^{3-}	Orthophosphate
POC	Particulate Organic Carbon
Pp	Pages
ppm	Parts per million
PSWC	Plateau State Water Corporation
Pt-Co	Platinum cobalt unit
QA/QC	Quality Assurance / Quality Control
r	Correlation coefficient
RR	Rain
RS	Rainy Season
RV	Reference Value
s	Second
S	Sulphur
S.A.R	Sodium Absorption Ratio
s.d.	Standard deviation (of the mean)
S.E.	Standard error (of the mean)
S.E.M.	Standard error of the mean
s.g	Specific gravity
S/N	Serial number
SO_4^{2-}	Sulphate ion
spp	Species (Plural)
SPSS	Statistical Package for the Social Sciences
SWCSMH	Soil and Water Conservation Society of Metro Halifax (Canada)
TDS	Total Dissolved Solids
TEL	Threshold Effect Level
THC	Total Hydrocarbon
TIN	Triangulated Irregular Network
TLES	Threshold Level Effect in Sediments
TOC	Total Organic Carbon
TOM	Total Organic Matter
TS	Total Solids
TSS	Total Suspended Solids
TV	Target Value
U	Uranium
UAE	United Arab Emirates
UK	United Kingdom
UNEP	United Nations Environmental Program
USA	United States of America
USDA	United States Department of Agriculture
USEPA	United State Environmental Protection Agency
V	Vanadium
W	West of Greenwich meridian
WEF	Water Environment Federation

WHO	World Health Organisation
WQI	Water Quality Index
Zn	Zinc
DEM	Digital Elevation Model
3D	3 dimension Visualization
DTM	Digital Terrain Model

ABSTRACT

This study established the landuse pattern and determined the physio-chemical properties of the groundwater of Jos South Local Government Area, Plateau State, Nigeria over a period of two years, 2013-2015. It also determined the variation of the physic-chemical parameters in relation to space, depth, season and geology of the study are. This was with a view to providing information on the groundwater quality of the study area.

The field period was divided into early dry, late dry, early rain, and rainy seasons. Sixty four (64) sampling stations generated from grid demarcation were established. At each of the sampling station, water samples were collected from wells and boreholes. The geographical coordinates of each sample location were recorded using hand-held GPS device. Physical water quality parameters such as; temperature, conductivity, well and water depth, and pH were determined in the field. Parameters determined by Titrimetric methods include DO and BOD, organic matter, TOC and COD, total alkalinity and total acid, Ca^{2+} and Mg^{2+} and Cl^{-}. Parameters determined by instrumental methods include SO_4^{2-} , NO_3^{-}, colour, Na^{+}, K^{+} and turbidity. Heavy metals (Mn, Pb, Fe, Cr, Zn, Cd, Co, Ni, Cu) were analyzed using Atomic Absorption Spectrometery (AAS). The data obtained were analyzed using descriptive statistics, ANOVA, correlation analysis, cluster analysis and Principal Component analysis (PCA). The results were also integrated in a GIS environment and relevant thematic layers (terrain, geology, land use/ land cover e.t.c) generated

The groundwater was classified as slightly buffered and bicarbonate with an observed ionic order of dominance of the form:Ca^{2+}> Na^{+}> K^{+}>Mg^{2+}. This cations order occurred in therainy season with the dry seasons cationic order of Ca^{2+}> Na^{+}>Mg^{2+}> K^{+}. The results also revealed definite pattern of significant variation ($P \leq 0.05$) in majority of the elements tested. Among the parameters investigated, water depth, apparent colour, truecolour, turbidity, TS and TSS were higher in concentrations in the dry season than in the rainy season while water temperature was higher in the dry season. Most ofthe major ions (HCO_3^{-} ,Cl^{2-},SO_4^{2-}, Ca^{2+}, Na^{+} and K^{+}) were higher during the rainy season thanin the dry season whereas nitrate, Mg^{2+} and phosphate were higher during the dry season. The overall sequence of metals concentrations in the groundwater were in the order ofMn>Pb>Fe>Cr>Zn>Cd>Co>Ni>Cu. The concentrations of the tested heavy metals weregenerally lower and within the permissible limit of WHO. The mean coliform abundance of 141.96 cfu100m/Lrecorded for the study area was higher than the maximum of 3 coliforms per 100 ml recommended by the WHO.The groundwater quality index of the study area fell between 0 and 65 which classified the groundwater quality into bad, fair and good.

The study concluded that the geology of the study area, terrain characteristics, anthropogenetic activities and landuse pattern remain dominantfactors affecting the groundwater quality. Although the physicochemical parameters of the groundwater were within permissible limits recommended by the WHO, the waters had elevated coliform concentration levels.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Water is life. It is required by all living things for metabolism (Ayedun*et al.,* 2011). It is second only to air as the most essential natural resource for the survival of man. According to the World Health Organization (WHO), the minimum water requirements for developing and developed countries per person per day are 120 and 400 litres respectively due to difference in infrastructure for water development(WHO, 2012, GLAAS, 2012). Water is a vital resource upon which most human activities such as agriculture, industry, transportation, domestic use and recreation depend (Nwankwoala and Nwagbogwu, 2012). The importance of water depends on its unique properties assingular universal solvent. "The available water supply is a boundary line beyond which no society or nation, agriculture or industry can go" (Daramola, 2004). There are different sources of water namely; atmospheric, surface and groundwater. Surface water occurs as either fresh or saline. Saline water is found mainly in seas, oceans and occasionally as fossil water trapped within rocks. It constitutes about 97% of total earth water. Fresh water, which constitutes less than 3%, occurs either as solid in ice caps (68.70%), or liquid found as groundwater (30.10%). Surface water (1.20%) which occurs as streams, rivers, lakes e.t.c. is readily available for daily use, while groundwater is available and accessed through wells, springs and boreholes (Oyebode, 2005; Ajewole, 2005; Hefkes *et al.,* 1981).

Besides, the current level of urbanization and development has placed additional pressure on water quality even in those areas where surface water is available. As a result of this, there is a need for alternative sources. Groundwater sources provide the most readily available alternative.

Groundwater is an accumulated pool of water which occurs beneath the earth's surface. It constitutes an important source of water for domestic, agriculture and industrial production (Ranjana, 2009).

The use of groundwater has increased significantly in the last decades due to its widespread occurrence. About 2 billion people depend directly upon aquifers for drinking water. About 40% of world's food is produced by irrigated agriculture that relies largely on groundwater (Morris *et al.,* 2003).

Naturally, groundwater contains mineral ions. These ions are slowly dissolved from soil particles, sediments and rocks as the water travels along mineral surface in the pores or fractures of the unsaturated zone and the aquifer. Generally, metals associated with the aqueous phase of soils are subject to movement with soil water, and may be transported through the vadose zone to groundwater (Pierce *et al.,* 1998). They are referred to as dissolved solids. Some dissolved solids may have originated from the precipitation water or river water that recharges local aquifers. More importantly, it is the dissolved solids and pollutants by man as a result of different anthropogenic activities that account for greater pollution effect. Such contamination from anthropogenic factors is increasingly affecting the quality and limiting groundwater use. It has been established that once pollutants enters the subsurface environment, it may remain concealed for many years, becoming dispersed over wide areas of groundwater aquifer and rendering groundwater supplies unsuitable for consumption and other uses (Sunder*et al.,* 2010). Therefore, understanding the potential influences of human activities and the impact of natural interaction on groundwater quality is important for protection and sustainable use of groundwater resources (Jehangir*et al.,* 2013).

The assessment of groundwater suitability for various purposes such as drinking, domestic, irrigation and industrial production requires the determination of the concentrations of some important parameters to show if they conform to appropriate guidelines stipulated by World Health Organization (WHO) and other national and international water regulatory organizations (Srinivasamoorthy*et al.,*2009). Evaluation of water quality prior to its use will assist in water treatment and disease prevention. It will also guide farmers in preventing probable deleterious effects on plant productivity as well as protecting industrial equipment against incrustation and corrosion.

Previous groundwater assessment involves various elemental analyses which are subjected to different statistical computation either aimed to check for variance or trend. This method though still in use produces numerous results that are sometimes difficult to interpret and inadequate for spatial analysis. Based on this, the Water Quality Index Computation and the use of GIS (Geospatial techniques) have been introduced to provide an easy assessment of spatial distribution of water quality in different areas and multi-spatial criteria analysis combine physicochemical parameters, landuse indices and geology to determine the quality of groundwater in such a way that highlights visible indicators of groundwater quality. Kavita and Vineeta (2010) used this method to evaluate and develop WQI for drinking purposes in Singhbhum District, India. Similarly, Babaei*et al.*(2011) used similar method to outline the status of water quality of Karoon River in Iran. In another study, Yogendra and Puttaiah (2008) also used WQI to determine the suitability of different water bodies for urban water supply in Shimoga town, Karnataka, India.

Similar studies have not been carried out in Nigeria especially in the Jos Plateau area which has a peculiar geology in Nigeria. Surface water sources are generally seasonal in this area for which reason most residents depend on groundwater.

1.2 Statement of ResearchProblem

The concern that physico-chemical elements in drinking water present a potential health hazard if they exceed certain concentrations has prompted several statutory bodies such as the World Health Organization (WHO) and Standard Organization of Nigeria (SON) to establish maximum allowable concentrations of trace elements in drinking water supplies. This concern has heightened in recent times considering the long list of diseases and health disorder caused by unclean water. In