IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 7, Issue 5 Ser. II (Sep. – Oct. 2019), PP 09-15
www.iosrjournals.org

Groundwater Flow and Contaminant Transport from Municipal Solid WasteDumps in Bida, Central Bida Basin, Nigeria

Michael Chimezie Okeke, *Nuhu Musa Waziri; Idris-Nda Abdullahi; Isah Aliyu Goro; Thomas Agbor Ako& MusaTenimu Suleiman
Department of Geology, Federal University of Technology, Minna, PMB 65, Minna, Nigeria.
**Corresponding Author: Nuhu Musa Waziri*

Abstract: *In some part of Bida metropolis, the amount of solid wastes generated is on the increase due to population growth and due to the absence of modern engineered landfill. The wastes are dumped on the land surface without proper knowledge of the hydrochemistry, hydrology and geology of the dumpsites with regards to the movement of contaminants into the subsurface. The transport of contaminants from selected dumpsites into the groundwater body in Bida is the aim of this study and was undertaken by carrying out groundwater inventory studies for 130 hand dug wells identified in the area combined with sieve analysis of soil samples collected beneath the dumpsites.The groundwater inventory results revealed the average depth of wells in the area is approximately 11.0m signifying that wells in the area are shallow.The groundwater flow direction is predominantly towards the south-eastern part of the town.The flow pattern in the aquifer system therefore suggests that the eastern regions of the study area are more vulnerable to groundwater pollution with respect to differences in hydraulic heads. The maximum contaminant travel distance from the dumpsites down to the unconfined aquifer along groundwater flow directions in the hand dug wells range from* 2.69×10^{-5} *to* 3.92×10^{-5} *m.The implication of this result is that the dumpsites may pose no threat presently to the unconfined aquifer due to the low contaminant travel distances observed, but nevertheless still remain a potential threat in the nearest future. It is therefore recommended that the dumpsites conditions be improved to minimise further leachate migrations from the sites.*

Key words: *Groundwater flow, Groundwater contamination, Dumpsites, Bida Basin.*

Date of Submission: 07-10-2019 Date of acceptance: 23-10-2019

I. Introduction

Water contained in the subsurface column below the water table where all pore-spaces (whether primary or secondary pores) are completely filled under hydrostatic pressure is called groundwater. Groundwater supplies are usually obtained from aquifers, which are hydrogeologic units with adequate porosity and permeability that enable them to store, transmit and yield significant amount of water to wells or springs. The aquifer system in the study area like in most part of the Nupe Basin is a multi-aquifer system and occurs in three aquifer levels which are unconfined, semi-confined and confined aquifers[1, 2].

Groundwater in its natural state is invariably moving and is often governed by hydraulic properties such as hydraulic head which is a driving force for groundwater flow and hydraulic conductivity; a combined property of fluid density, viscosity and permeability of the porous medium. The flow of groundwater in aquifer does not always reflect the flow of water on the surface. Groundwater flows from a higher static level to a lower static level [3].

The starting point for understanding groundwater contamination issues is usually based on prediction of flow rates and directions in confined and unconfined aquifers. Once natural water is contaminated, it becomes difficult if not impossible to reverse it. Sources of groundwater contamination are widespread and include industrial, municipal and agricultural waste containing fertilizer residues, pesticides, sewage, nutrients, plastics and chemical wastes[4]. Generally three processes can be distinguished which govern the transport of contaminants in groundwater: advection, dispersion and retardation. Contaminant transported at the same groundwater velocity (advection), are described as the non-reactive solute[5], while others spread as stream or discrete volume (dispersion) through the subsurface[6]. Dispersion is a mechanism for dilution and its differences with density/viscosity may accelerate contaminant movement, while retardation processes such as oxidation, biological degradation and sorption can slow the rate of movement.

In the study area, improper solid waste management still form a major environmental problem in the area caused due to ignorance or individual attitudes to waste disposal followed by insufficient human resources and equipment among others. The type of waste disposal system practised is the open dump waste disposals system upon which solid wastes are dumped on the land surface and are not evacuated for a long time. The solid wastes are dumped on the land surface without proper knowledge of the geology and hydrology of the dumpsites with regards to the movement of contaminants into the subsurface. Very little, if any, research has been carried on contaminant transport into groundwater in the area. Recently, Sidi *et al.*[7] studied the transport of contaminant metals into groundwater around Badegi (near the present study) and concluded that the metals travel at much lower velocity compared to water. The aim of this work therefore is to study the transport of contaminants from selected dumpsites in Bida metropolis into groundwater in the area.

II. The Study Area

The study area is located in Bida, Central Nigeria and it is bounded by latitude 9°02'44" N and 9°06'47" N and longitude 5°58'07"E and 6°02'14" E with a total surface area of 57 km^2(Figure 1). The area is drained by several rivers all of which empty into River Niger. Rainfall in this area varies considerably from station to station with maximum rainfall per year varying from 900.6 to 1340 mm for different location (NCRI Agro Met, 2014). The vegetation of the area belongs to the sub arid type with few tress distributed across the area which disposes the soil to erosion. Along the river channels, the vegetation becomes more wooden and acquires some forest notations. The people are particularly known both nationally and internationally for traditional brass, bass, copper goblets, and glass bead works which has generated a lot of tourist attraction to the town.

Groundwater in the area occurs within the sedimentary intergranular spaces. The Nupe Sandstone is slightly cemented but the dominantly fine grained sandstones and interbedded clays, mudstones and siltstones through much of the sequences reduce groundwater potential[8]. Overall, borehole yields are poor to highly variable, but where sandstones dominate, borehole yields of approximately 2 to 4 l/s are seen and coarser conglomerate beds at the base of the sequence may support higher yields[9]. The mineral resource found around the area are silica and sand commonly used for white wall and table ware (Niger State Bureau of Statistics, 2012).

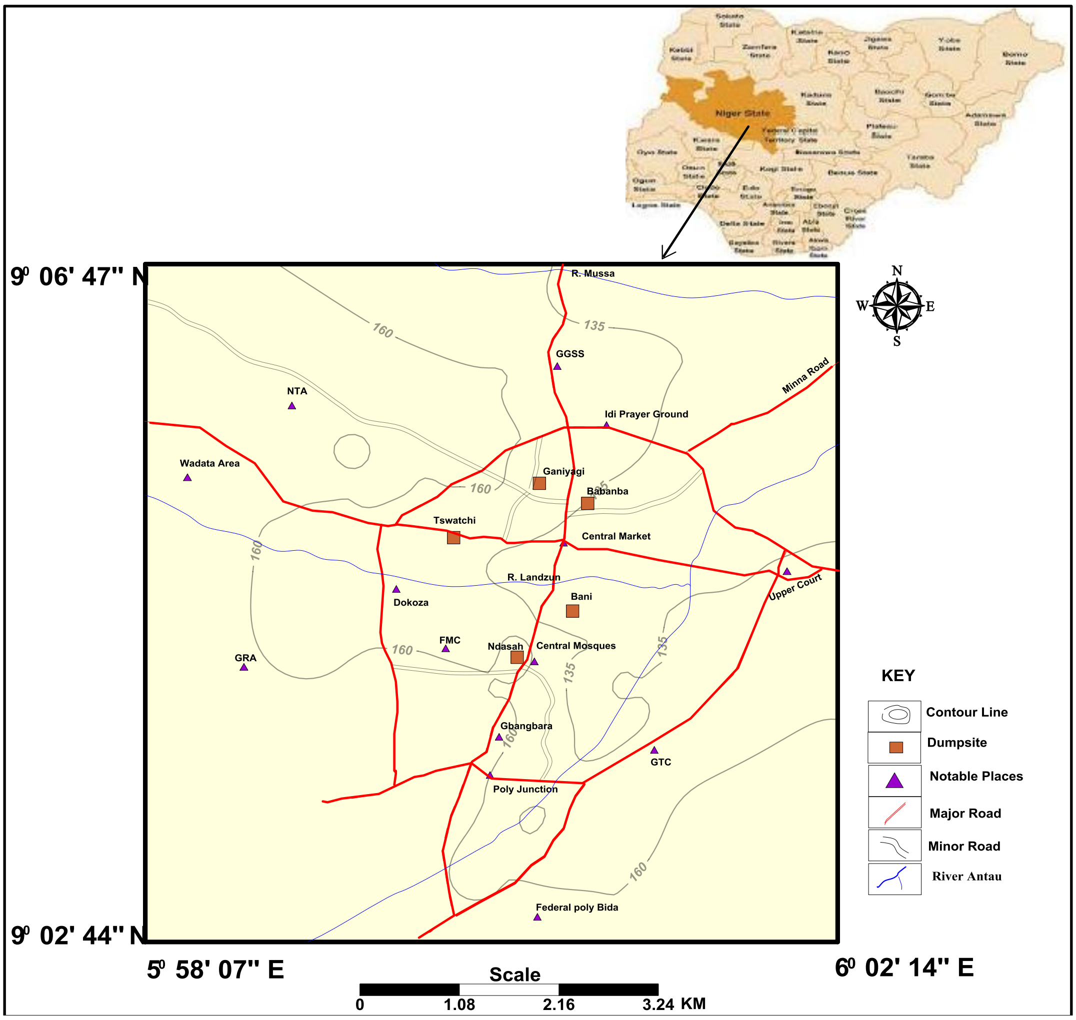

Figure 1: Location of the Study Area

III. Methodology

3.1 Hydrogeological mapping and dumpsites delineation

Groundwater inventory of the area was conducted by identifying 130 hand-dug wells during the period of April, 2017. The coordinates of the wells were obtained using Garmin eTrex Legend handheld Global Positioning System (GPS) device. The water level variations in the wells and well depths were determined using measuring tape with a padlock attached to one end. The measuring tape was gently lowered into the well until the padlock touches the bottom of the well. To this effect, the measuring tape is rewound and the length of the water column marked on the tape is subtracted from the total length of the tape to obtain the depth to water level in the well. Hydraulic heads were equally computed from the differences in the surface elevations and the depths to water levels in the wells. The hydraulic head values combined with the well coordinates were then used to generate the water level elevation map upon which groundwater flow direction and possible leachate migration were deduced.

The dumpsites mapping was also conducted by identifying five massive dumpsites in the area and taking their area extents, heights above the ground surface and surface elevations, distinctive compositions and relative ages. The dumpsites relative ages were determined through the use of questionnaires and oral interview from the custodians. For the purpose of assessing hydraulic properties of the aquifer material beneath the dumpsites, 5 trial pits were constructed for soil sample collection. The pits at "Babanba, Ganiyagi, Ndasah, Bani, and Tswatchi" were constructed with a pick axe, digger, measuring tape and shovel to the depths of 0.8 m, 1.54 m, 1.06 m, 2.30 m and 1.15 m respectively. A total number of 10 soil samples were collected from the middle and base of the pits for various analyses.

3.2 Evaluation of contaminant travel distances in the study area

Hydrogeological information normally required for assessing contaminant migration from a point source (dumpsite) to groundwater body includes stratigraphic, hydraulic conductivity and hydraulic head data. The general form of this equation according to Darcy equation combined with the standard continuity equation is expressed inform of:

$$\bar{\upsilon} = -K\,i/\eta \qquad (3.1)$$

Where $\bar{\upsilon}$ = average linear groundwater velocity
K = hydraulic conductivity (cms^{-1})
i = hydraulic gradient (dimensionless)
η = effective porosity

Adjusting velocity and distance travel for non-reactive contaminant, equation (3.1) becomes

$$d = -K\,i\,t/\eta \qquad (3.2)$$

where (d) is the distance from the source point to the point of interest and (t) represents the contaminant travel time.

3.3 Estimation of hydraulic conductivity (K)

The hydraulic conductivity (K) of the soil samples were estimated from the grain size distribution curve using an empirical formula by Bear[10]. The formula has a general form of:

$$K^* = Cd^2 \qquad (3.3)$$

where:
K* = the intrinsic permeability
d = the effective diameter of the grain usually taken as d_{10} and;
C = a single dimensionless coefficient based on the nature of geologic environment [11].

The coefficient C, which depends on the nature of geologic environment has an established value of 6.0 for unconsolidated and poorly cemented sandy materials, while moderately consolidated/cemented rocks, C = 3.8, and for fairly well compacted and cemented rocks, C = 2.0. The K* (cm^2) computed from equation (3.3) is converted to hydraulic conductivity K (cms^{-1}) by noting:

$$K\ (cms^{-1}) = 1.0\ cms^{-1} = K^*\ (cm^2) = 1.02 \times 10^{-5}\ cm^2$$

3.4 Determination of effective porosity for the dumpsites samples

The bulk densities of the samples beneath refuse dumps were determined according to the procedures described by Smith[12]. A cylindrical cutter about 6.3 cm diameter and 10.4 cm long is carefully driven into the soil, dug out, cleaned, trimmed and weighted. The weight of the cutter and its internal dimensions are readily determined, hence:

$$\text{Bulk density } (\rho b)\ (g/cm^3) = \frac{\text{Weight of cutter and soil} - \text{Weight of cutter}}{\text{Internal volume of cylinder}} \qquad (3.4)$$

Similarly, the particle density for all the samples was determined by oven drying the samples at 105 ^{0}C over a period of 24 - 48 hours. Assuming the water is removed from the soil and the volume of the sample remained unchanged, therefore particle density was then obtained using the relation;

$$\rho p = w_s/v \qquad (3.5)$$

where:

ρp = particle density (g/cm^3)

w_s = weight of dry sample (g)

v = volume of sample

The loss in weight in the original samples (weight of water) after drying compared with the weight of solid provide $_{\text{insight}}$ to moisture content (m_c) of the samples. According to Rawls *et al.*[13], the relation in equation (3.4 and 3.5) can be used to determine the effective porosity (n) for all the samples;

$$n = \frac{\rho b}{\rho p} - m_c \qquad (3.6)$$

IV. Results and Discussion

4.1 Hydrogeology of the study area

The summary results of groundwater inventory from 130 hand dug wells identified in the study area are presented in (Table 1). The depth of wells range from 2.0m to 28.8m while depths to which groundwater is at equilibrium with the atmospheric pressure range from 1.6m to 19.0m. The average depth of well is approximately 11.0m signifying wells in the area are shallow.

Table 1: Summary Results of Groundwater Inventory of Hand dug wells in Bida

	Surface elevation (m)	Well depth (m)	Depth to water (m)	Hydraulic Heads (m)
Min	111.0	2.0	1.6	106.7
Max	194.0	28.8	19.0	175.7
Mean	145.0	11.0	10.0	135.1

The water elevation contour map of the study area showing various trends in the flow direction is presented in (Fig. 2). The result revealed that groundwater flow is dominantly from north-western corner through the central regions to the south-east. The consequence of this with respect to groundwater quality degradation is that the south-eastern part of the aquifer is more susceptible to receive transported contaminant from the north-western/ central part of the study area.

The main recharge region occurs around Ilorin Garage area, Chenyen ward northwestern region of the study area. From the recharge area, groundwater flow towards the central part of the area toward Etsu Musa Central Palace area. Major recharge of groundwater is also seen around Federal Poly Bida area, Government Technical College area, and Eyagi area.

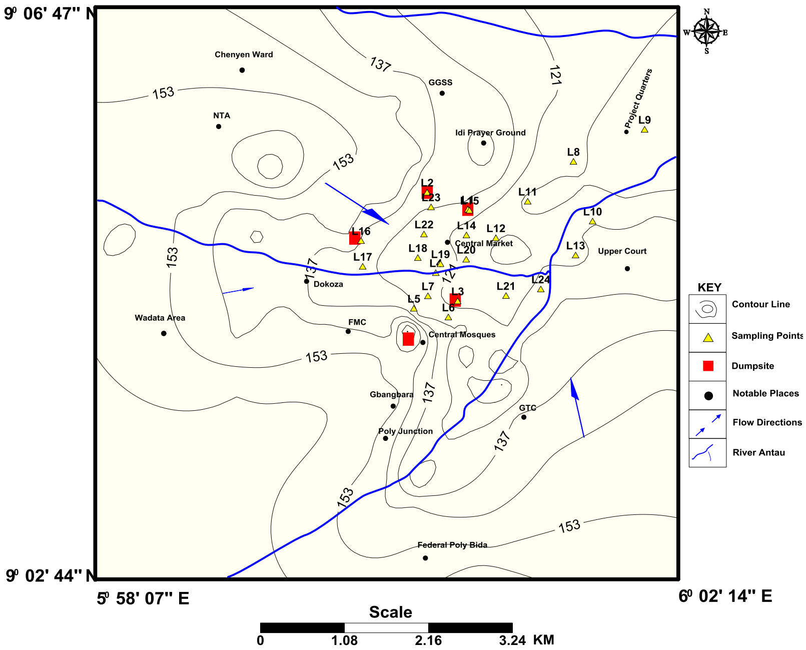

Figure 2: Water Level Elevation Map in Bida Metropolis

Groundwater flow is also toward the eastern part of Wadata area, Social Welfare, and Ganiyagi Area. The main discharge area occurs in the central part of the study area around Tswatamokun, Celima and State Library area. These areas are drained by Landzu River which flows north-eastward of the study area. Discharge area also occurs around Dokoza and off Federal Medical Centre axis while in the south-eastern side of the study, discharge occurs around Gbangaye area, Bantwa Cirico down Project Quarters.

4.2 Contaminant travel distance in the study area

The contaminant travel distance was considered from the dumpsites (Plate 1) down to the unconfined aquifer along groundwater flow directions in the hand dug wells. The ages of the dumpsites which is also equivalent to the contaminant travel time from refuse dumpsites in the study area range from 46to 67years while the hydraulic conductivity of aquifer materials obtained beneath the dumpsites revealed values from 1.43×10^{-7} - 7.29×10^{-7} cms^{-1} (Table 2). The horizontal hydraulic gradients in the aquifer based on the groundwater slope from northwest-southeast flow direction revealed an average value of 0.81.

Plate 1: The studied dumpsites in Bida metropolis, Nigeria. (a) Ganiyagi Dumpsite contain ing thick solid waste with a dimension of about $3000m^2$ and a height of 9.2m above the ground surface; (b) Babanba Dumpsite with a dimension of about $2650m^2$ and a height of 6m above the ground surface; (c) Tswatchi Dumpsite containing thick solid layer wastes with a dimension of about $556m^2$ and (d) Ndasah Dumpsite containing solid waste with a dimension of about $882m^2$ and a height of 4.6m above the ground surface.

Table 2: Parameters used in the Computation of Contaminant Migration (meters) along Groundwater Flow Direction in the Hand-dug Wells

Location	Longitude	Latitude	Dumpsite Age (yrs)	Bulk density (g/cm^3)	Particle density (g/cm^3)	Moisture content (%)	Effective porosity (n)	Hydraulic conductivity (cms^{-1})
Babanba	6° 0' 45.0"	9° 5' 21.2"	52	1.43	1.29	10.8	1.003	$3.435x10^{-7}$
Ganiyagi	6° 0' 27.6"	9° 5' 28.2"	56	1.49	1.32	11	1.018	$1.425x10^{-7}$
Ndasah	6° 0' 19.8"	9° 4' 26.2"	67	1.29	1.15	9.7	1.02	$7.29x10^{-7}$
Bani	6° 0' 39.7"	9° 4' 42.5"	50	1.5	1.37	9	1.004	$1.61x10^{-7}$
Tswatchi	5° 59' 57.1"	9° 5' 9.0"	46	1.31	1.19	10	1	$2.945x10^{-7}$

Consequently from the data on hydraulic gradient (ὶ), effective porosity (η), and hydraulic conductivity (K), values of the average linear groundwater velocity (ῡ) in the northwest-southeast direction were computed to be in the range of $1.15×10^{-7}$ to $5.85×10^{-7}$ m yr^{-1}. Aggregating the average linear groundwater velocity values with the ages of the dumpsites reveals minimum frontal leachate migrations of $5.27 × 10^{-6}$ to $7.68 × 10^{-6}$from the dumpsites into the under groundwater sourcewhile the maximum frontal leachate migration ranges from $2.69 × 10^{-5}$ to $3.92 × 10^{-5}$(Table 3).The implication of this result indicated that the dumpsites may pose no threat presently to the unconfined aquifer due to the low contaminant travel distances observed but nevertheless still remains a potential threat in the nearest future. Consequently, the unconfined aquifer will experience a longer time for it to be affected by the most reactive contaminants.

Table 3: Frontal Leachate Migration from the Dumpsites along Groundwater Flow Direction in the Wells

Dumpsites	Minimum frontal leachate migration (m)	Maximum frontal leachate migration (m)
Babanba	$5.96 × 10^{-6}$	$3.04 × 10^{-5}$
Ganiyagi	$6.42 × 10^{-6}$	$3.28 × 10^{-5}$
Ndasah	$7.68 × 10^{-6}$	$3.92 × 10^{-5}$
Bani	$5.73 × 10^{-6}$	$2.93 × 10^{-5}$
Tswatchi	$5.27 × 10^{-6}$	$2.69 × 10^{-5}$

The movement of contaminant from the source (dumpsite) to the degree of its impairment of the groundwater quality will depend largely on the amount of precipitation or moisture available, nature of the contaminants and the hydraulic properties of the geologic materials obtained beneath the dumpsites.

V. Conclusion

The result of this study has shown that the flow pattern in the aquifer system is principally sloping towards the eastern region of the town such that indiscriminate solid waste disposal in the region would be more detrimental for inhabitants living within this area.This study has also shown that the underground water resources in the area are yet to be contaminated by the frontal leachate migrations from the dumpsites but nevertheless still remain a potential threat in the nearest future. It is therefore recommended that the dumpsites conditions be improvedto minimise further leachate migrations from the sites.

Acknowledgements

The authors would like to acknowledge the contribution of Yahaya Dogara in the data collection for this work. The equipment used for this research work was partly made available by the Department of Geology, Federal University of Technology, Minna, Niger State, Nigeria.

References

[1]. Olaniyan, I. O. & Oyeyemi, S. M. (2008). Geophysical Exploration for Groundwater Potential at Hayin Danmani Area of Kaduna, Nigeria. *Global Journal of Engineering and Technology*, 1(4), 413-418.

[2]. Idris-Nda, A., Salihu, H. D., Jimada, A. M. & Babadoko, A. (2016). Groundwater Quality in Shallow Unconfined Sedimentary Aquifers in Bida, Nigeria. 39th WEDC International Conference, Kumasi, Ghana. Briefing Paper 2339.

[3]. Delleur, J. W. (1999). Elementary Groundwater Flow and Transport Processes, In Handbook of Groundwater Engineering, pp. 41

[4]. Pawari, M. J. & Gawande, S. (2015). Ground water Pollution and its Consequences. *International Journal of Engineering Research and General Science*, Volume 3, ISSN 2091-2730.

[5]. Freeze, R. A. & Cherry, J. A. (1979). Groundwater. Prentice Hall, Inc. Englewood Cliffs, New Jersey. 803p.

[6]. Mary, P. A. (1984). Movement of contaminants in groundwater: Groundwater Transport- Advection and Dispersion. Studies in Geophysics. National Academy Press, pp 37- 45.

[7]. Sidi, A. A., Waziri, N. M., Maji, A. T., Yakubu, M., & Suleiman, M. T. (2019). Contaminant Transport in the Alluvial Sediments of River Gbako Flood Plains around Badegi, Central Bida Basin, Nigeria. *American Journal of Earth Sciences*, 6(1), 14-19.

[8]. Tijani, M., Crane, E., Upton, K. O., Dochartaigh, B. E. & Bellwood-Howard, J. (2018). Africa Groundwater Atlas: Hydrogeology of Nigeria. British Geological Survey Publication. http://earthwise.bgs.ac.uk/index.php/Hydrogeology_of_NigeriaAccessed [29/06/19].
[9]. Offodile, M. E. (2002).Groundwater Study and Development in Nigeria, Mecon Geology and Engineering Services Ltd. ISBN 978-30956-2-5 453pp.
[10]. Bear, J. (1972). Dynamics of Fluids in Porous Media. Elsevier, New York, USA.
[11]. Uma, K. O., Egboka, B. C. E. & Onuoha, K. M. (1989). New Statistical Grain-size Method for Evaluating the Hydraulic Conductivity of Sandy Aquifers. *Journal of Hydrology,* 108, 343-366.
[12]. Smith, M. J. (1984). Soil Mechanics. 4th edition, Longman Scientific and Technical, page 1-14.
[13]. Rawls, W. J., ACSE, M., Donald, L. B. & Norman, M. (1983). Green-Ampt Infiltration Parameters from Soil Data. *Journal of Hydraulic Engineering*, 109(1), 62-70.

Michael Chimezie Okeke. "Groundwater Flow and Contaminant Transport from Municipal Solid Waste in Bida, Central Bida Basin, Nigeria. "IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG) 7.5 (2019): 09-15.