

IMPACT OF URBANIZATION ON SUB-SURFACE WATER QUALITY IN CALABAR MUNICIPALITY, NIGERIA

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ABSTRACT

The study seeks to evaluate problems caused by urbanization on sub-surface water in Calabar Municipality. Water samples were collected from (20) twenty locations within the study area. Aerial photographs of 1972, 1991 and orthophotomap of 2005 were used to calculate the extent of urban growth. The study reveal that there is an appreciable increase in urban growth within the study area due to population increase and the struggle to satisfy man's basic needs such as food and shelter. The built up area calculated show that 2005 has a higher value of 650m² at satellite town. The presence of faecal coliform is an indicator of the degree of contamination by sewage. pH at some locations were high because some boreholes were located very close to pit latrines, cemeteries and defunct sewages. It was observed that, the deeper the depth the better the water quality. The result from multiple regressions shows that faecal coliform, pH, Nitrate and Chlorine had a positive relationship with urbanization while sulphate ions had negative relationship. R² of 0.0501 was obtained which means that 50.1 percent of urban growth influenced water quality. It was recommended that awareness and sensitization campaigns be carried out for improved household and urban sanitation in urban areas. Finally, landfill base should be made of concrete and paved surfaces to prevent leaching of poisonous substances into the groundwater.

Keywords: Sewage, Urban growth, Pollution and sub-surface water.

INTRODUCTION

Groundwater plays a fundamental but often unappreciated role in the economic and social, well being of urban areas. Although there are no comprehensive statistics on the proportion of urban water supply derived from subsurface water, it has been estimated by (Foster et al, 1998), that more than one billion urban dwellers in Asia and 150 million in latin America probably depend directly on subsurface water. The increasing size and population of cities and towns by natural growth and by migration from rural areas is a major driver of environmental change as typified in the study area Calabar. During the twentieth century, the worlds rural population doubled but the urban population increased more than tenfold (WWAP, 2006). In the second half of the twentieth century, most of the world's urban population growth was in low and middle income countries. This urbanization trend of course has important overall implications for freshwater use and waste water management, and specifically for the development, protection and management of sub-surface water in urban environments. Data from the joint monitoring programme (WHO/UNICEF, 2004) suggest that to meet the Millennium Development Goals, some 950 million urban dweller must gain access to improved sanitation by 2015. If even a significant proportion of their figures are achieved, then the provision and protection of water resources will be an increasing challenge for the relevant municipal authorities.

Urbanization affects the quality and quantity of underlying sub-surface water by radically changing patterns and rates of recharge, initiating new abstraction regimes and adversely affecting groundwater quality (Forster et al, 1998). An assessment of the risk to groundwater from urban processes needs to take account of the interaction between the recharge and discharge pressures and the pollutant loading on the one hand, and the nature of the subsurface environment on the other (Schmoll et al, 2006). The potential for urbanization processes to have an impact on the underlying groundwater is a function both of the aquifers vulnerability to pollution and its susceptibility to the consequences of excessive abstraction. Estimating the potential urban pollution loading, it requires knowledge of population densities in the various types of centred and sub-urban housing districts and of which of them are served by sewered and unsewered sanitation. Both planned and managed disposal of solid municipal waste in landfills and unplanned, informal disposal in brick pits, dry canals and river beds, in old wells and drains, into the street and onto disused land can contribute to the pollution load.

Vulnerability to pollution is a function of the ease with which water and pollutants can move to the underlying sub-surface water, the attenuation capacity of the intervening material (Schmoll et al., 2006). These are both determined by the characteristics and properties of soil and aquifer, as described by Zaporozec, (1994) and Forster et al, (2002), and vary with hydrogeological settings. It should be remembered that many urban pollution source such as sewers and storm drainage, solid waste disposal and fuel storage tanks are likely to discharge below the ground surface, by passing any protective cover provided by the soil layer (Forster et al., 2002). Urban growth, road pavement and other developments often reduce groundwater recharge and prevent replenishment of important aquifers. Boreholes are now located near dumpsites, cemeteries and defunct sewage due to urban expansion, such as boreholes located at Akim and Big Qua Town in the study area.

The inhabitants of the study area do not acknowledge the fact that decomposers such as bacteria and fungi break down nitrogen containing molecules into ammonia gas and water-soluble salts in waste dumps, sewage and in dead organisms. These harmful chemicals percolate into groundwater through the soil and contaminate it, thereby rendering it unfit for consumption. The indiscriminate location of pit toilets in Calabar Municipality and the use of fertilizers in urban agriculture are all potential sources of sub-surface water pollution in this area coupled with heavy rains and recharge, cum the topography makes the study area vulnerable to contamination. This study seeks to evaluate the impact of urbanization on sub-surface water in Calabar Municipality based on the above trend of events.

METHOD OF DATA COLLECTION

Water samples were collected in 100cm³ polyethylene bottles without preservation the samples were collected from both private and public boreholes in the study area.. This was done mainly in the morning hours when the water table was still stable. Temperature was measured with a thermometer, pH with a pH kit, electrical conductivity with a WTW multiline p4 universal meter and these measurements were done Insitu. Aerial photographs of 1972, 1990 and orthophotomap of 2005 was used to determined the extent of urban growth in the study area. Water samples were collected from twenty boreholes and analyzed in the laboratory to determine the concentration of some physico-chemical parameters. Depth to water table was measured using the seismic refraction method. The seismic refraction method is based on the fact that elastic waves passes through different earth material at different velocities. The denser the material, the higher the wave velocity.

RESULTS AND DISCUSSION OF FINDINGS

From table 1 above it can be deduced that Satellite Town had a larger built up area of 650m² while Ikot Ansa had the smallest built up area of 345m² as at 2005. These values were calculated from aerial photograph. It was observed that the built up areas for year 2005 was the greatest which means that as at this time urbanization has really covered a large section of the study area due to increase in population which has accelerated the need for basic needs of life such as food and shelter, to keep pace with the alarming growth in population. Table 2 shows that the net impact of the modified recharge on underlying subsurface water quality is usually adverse; most of the source of additional recharge are of poor quality. Of these, unsewered sanitation is likely to be a particularly important source where dense urban populations living on shallow, vulnerable aquifer use septic tanks, soak-away, cesspits and pit latrine are used by dense urban populations living on shallow, vulnerable aquifer. Surveys have shown that nitrate in sub surface water originates from sanitation problem and this fact is buttressed by high incidence of microbial contamination in the study area.

Nitrate pollution, in subsurface water have also been reported in Kenya, Niger, and Senegal. Xu and Usher, (2006) are of the opinion that cross contamination between unsewered and sewered sanitation and poorly maintained or illegally tapped water into distribution system can also be expected. This has caused the near surface groundwater beneath many large town and cities such as Calabar in developing countries to be grossly polluted and can no longer be used for potable supply. This often drives both the municipal water supply operator and private users to work deeper for unpolluted subsurface water. The presences of faecal coliform may be a better indicator of the degree of contamination by sewage (Dallas & Day, 2003 and Emoabino & Alayande, 2006). This statement agrees with the work of miller, (2007), who opined that decomposers such as bacteria, fungi, soil insect and worms breakdown nitrogen containing ammonium ion (NH₄⁺) in waste sewage and in dead organisms. These return to the soil as water for plant use, but if in excess can percolate into sub-surface water reserves. The research reveals that presently in the study area the potential source of sub-surface water pollution is human feces from soak-away.

Table 3 shows that pH ranges from 5.0-7.1 Ikot Ansa had the lowest value of 5.0 while Etta Agbor had a value of 7.1. This implies that the water at Ikot Ansa was more acidic due to the fact that boreholes were located on cemeteries and defunct sewage disposal points. Nitrate, faecal coliform and sulphate ions ranged from 0.9-3.3mg/l, 0.75-4,32 cfu/100ml and 0.77-3.1mg/l respectively.

The research revealed that samples collected from greater depth had better quality compared to those obtained at shallower depth. The high concentration of nitrate and faecal coliform in locations such as Ikot Ansa and Nasarawa village was caused by the use of ammonia and manure as fertilizers in farming activities. The high coliform pollutions in some water samples are an indication of poor sanitary conditions in Calabar. Inadequate and unhygienic handling of solid waste could have generated high concentration of microbial organisms. High coliform counts appear to be characteristics of some urban ground water quality in Nigeria. Consistent with the work of other investigators such as Alagbe (2005) who worked on bacteriological and chemical characteristics of water supplies in Anambra and Lagos. Figure 1, shows sample points where water samples were obtained for laboratory analysis.

TESTING OF HYPOTHESIS

H₀: Urban growth has no effect in sub surface water quality in Calabar Municipality.

Table 4a reveals that R is 0.634, R² is 0.501 and the adjusted R² is 0.498. Also, table 4b shows that pH, FC and Cl were significant at 0.001 level of significance. The regression model for the relationship between urban growth and quality parameters of water is given as:

$$Y = 1215.1 + 33.3\text{pH} + 14.6\text{N} + 15.3\text{FC} - 4.2\text{so}_4 + 6.3\text{cl}$$

The model shows that there is a negative relationship between urban growth and sulphate ions, while pH, Nitrate, faecal coliform and chlorine shared positive relationship with urban growth in the study area. This means that given a unit increase in urban growth, while holding water quality constant, sulphate will decrease by a magnitude of -4.2, pH will increase by a magnitude 33.3, Nitrogen will increase by a magnitude 15.2, while chlorine will decrease by a magnitude of 6.32 respectively. With R² = 0.501, it means that 50.1 percent of urban growth influenced water quality.

CONCLUSION

The research reveals that human activities, such as farming, urbanization and sewage disposal, within the study area have great impact on the quality of sub-surface water. Urban growth calculated from Aerial photographs of 1972, 1992 and orthophotomap of 2005 showed that there was a remarkable increase in urban growth caused by population explosion. Faecal coliform population in all the water samples were higher than what is recommended by the WHO standard of zero, and this was an indication of poor sanitary conditions in the area of study. Inadequate and unhygienic handling of solid wastes could have generated high concentration of microbial organisms. The hypothesis stated was tested with multiple regression and it shows that it was significant at 0.05 level, hence the null hypothesis was rejected which states that urban growth has no effect on borehole water quality in the area under investigation. It is recommended that urban development programmes should be properly planned to avoid areas that are prone to contamination. Adequate solid waste disposal method should be adopted, phasing out open dumpsites to safe-guard public health. Finally, awareness and sensitization campaigns should be carried out for improved household and urban sanitation in urban areas.

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Table 1: Rate of urban growth obtained from Aerial photographs of 1972, 1991 and orthophotomap of 2005

S/No	Sample Location	Built up Area (m ²)			Total Built up Area m ²
		1992	1991	2005	
1.	Ikot Omin	101	202	405	708
2.	Ikot Effanga	80	170	395	645
3.	Army Continment	95	250	450	795
4.	Nasarawa Village	113	270	370	753
5.	Ikot Ansa	76	198	345	619
6.	Esuk Utan	85	185	356	626
7.	Parliamentary Village	96	177	377	650
8.	Ediba Road	109	225	395	729
9.	MCC	100	270	310	680
10.	Ikot Ishie	120	265	407	792
11.	Essien Town	102	240	465	807
12.	Ekorinim	117	280	580	977
13.	Housing Estate	108	278	490	876
14.	Big Qua Town	92	265	480	837
15.	Otop-Otop	200	320	500	1020
16.	Marian Road	100	410	650	1160
17.	Mary Slessor	170	350	450	970
18.	Etta Agbor	210	380	570	1160
19.	Edim Otop	115	240	380	735
20.	Satellite Town	170	410	650	1230

Table 2: Sources of Urban Recharge on groundwater quality

S/N	Recharge source	Water quality	Pollution Indicators
1.	On-site sanitation system	Very poor	N, CC, FC, DOC
2.	On- site disposal of industrial waste water	Very poor	HC, Industrial Chemicals N, Cl, FC, DOC
3.	Leaving sewers	Poor	N, B, Cl, FC, SO ₄
4.	Drainage from surface of soak-aways	Very poor	N, Cl, FC, HC, DOC Industrial Chemicals
5.	Seepage from canals and rivers	Poor	N, Cl, FC, SO ₄ DOC Industrial Chemicals

Where: B: Boron, Cl: Chloride, DOC: dissolve organ carbon, FC: faecal coliform, Hc: Hydrocarbon, N: Nitrogen compound, SO₄ sulphate

Table 3: Physico-chemical properties of borehole water

S/ No	Borehole Sample Location	GPS Reading		pH	Depth (m)	Turbidity (NTU)	Temp (°C)	BOD (Mg/l)	DOC (Mg/l)	(Mg/l) N	(Mg/l) Cl	(Mg/l) FC	(Mg/l) B	(Mg/l) SO ₄
		Latitude	Longitude											
1.	Ikot Omin	4.960044	8.320134	6.9	40	4	27.5	1.00	0.60	2.1	0.25	0.75	0.01	1.70
2.	Ikot Effanga	4.961843	8.317712	6.4	30	8	28.6	1.20	1.01	2.6	0.36	0.95	0.02	2.10
3.	Army Catonment	4.962794	8.318939	5.9	45	12	29.0	2.90	2.02	3.2	0.45	1.65	0.01	2.60
4.	Nassarawa Village	4.962169	8.315577	5.7	30	11	28.0	3.00	1.80	3.0	0.40	1.60	0.03	2.80
5.	Ikot Ansa	4.960766	8.313445	5.0	50	13	30.1	4.09	2.20	3.5	0.68	4.32	0.01	3.10
6.	Esuk Utan	4.963174	8.316582	5.5	10	14	29.2	1.05	1.45	2.9	0.48	3.50	0.05	2.30
7.	Parliamentary Village	4.960109	8.317936	6.8	15	10	28.3	2.95	0.07	2.4	0.20	1.05	0.05	1.50
8.	Ediba Road	4.958456	8.316444	6.7	45	6	28.6	1.02	1.02	1.9	0.29	1.15	0.04	1.30
9.	MCC Road	4.956401	8.318793	6.8	25	5	27.05	1.95	2.10	2.4	0.36	0.95	0.03	1.90
10.	Ikot Ishie	4.958830	8.313081	6.0	35	4	26.6	0.06	0.45	0.9	0.10	0.88	0.02	0.70
11.	Essien Town	4.953307	8.314489	6.5	20	3	29.9	2.06	0.60	2.1	0.33	1.25	0.01	1.60
12.	Ekorinim	4.956896	8.316669	6.1	25	15	28.4	1.85	1.10	2.5	0.34	1.50	0.01	2.40
13.	Housing Estate	4.952867	8.312438	5.5	30	11	29.6	1.09	2.30	2.7	0.63	2.30	0.05	2.60
14.	Big Qua Town	4.949014	8.323282	6.4	40	17	27.4	1.75	1.60	2.3	0.35	2.60	0.04	1.44
15.	Oto Otop	4.947927	8.329321	6.1	45	14	26.3	1.60	1.05	1.4	0.60	3.01	0.04	1.56
16.	Marian Road	4.946591	8.321659	6.9	30	9	26.4	1.10	0.90	1.4	0.80	2.20	0.03	1.23
17.	Mary Slessor	4.945404	8.324392	6.3	40	16	25.2	0.61	1.30	2.6	1.00	2.47	0.02	1.65
18.	Etta Agbor	4.944402	8.319856	7.1	45	12	27.8	1.40	1.25	1.7	0.70	1.78	0.01	1.78
19.	Edim Otop	4.934504	8.313654	6.2	30	7	29.6	2.05	1.01	2.3	0.43	1.85	0.06	1.20
20.	Satellite Town	4.924502	8.310421	5.8	25	3	30.5	1.79	0.75	1.9	0.35	2.44	0.03	1.18

Model summary

Table 4a

Model	R	R-square	Adjusted R square	Std Error of the Estimate
1	.634	.501	.498	211.43222

Predictors (Constant): pH, N, FC, So₄, cl,
 Dependent variable: Urban Growth

Coefficient

Table 4b

Model	Unstandardized coefficients		Standard coefficient	t	Sig
	B	Standard Error	Beta		
Constant	215.150	124.516	.498	1.678	
pH	33.345	2.345	.0421	.175	0.01
N	15.341	92.810	.115	.301	.005
FC	15.341	92.810	.115	.301	.001
SO ₄	-4.211	41.014	.032	.204	.002
Cl	6.321	53.231	.008	.049	.001

Predictors (Constant): pH, N, FC, So₄, cl,
 Dependent variable: Urban Growth

Fig. 1: Map of Calabar Municipality showing sampling Points

