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Baseline characteristics, water quality assessment and sanitary surveillance of a man-made storm water lake and environs at Abakiliki, Ebonyi State

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The challenge to meet water needs has provided impetus for the re-invention of old technologies for harvesting rainwater and storm (flood).One of such,is the development of large scale artificial storm water basin by the construction firm handling the "Ochudo" city Secretariat project in Abakiliki, Ebonyi State, Nigeria. The storm water reservoir which is an artificial water dam covers an expansive area of approximately 70,000m^2 with depths varying between 7ft and near 10ft and is fed by flood water from tributaries of riparian waterways and flood paths which drain into the excavation. Apart from flood, the reservoir is also fed by grey water from effluent receptacles from some parts of the city. As construction of the city estate nears completion with the prospects of occupation, the State Government raised serious concerns on the implications of the pond to public health. As a first step to inventing remedial strategy the State Government commissioned this study to assess the baseline characteristics and water quality of the pond and to ascertain the impact of the storm reservoir on the immediate environment.Standard routine techniques were employed in acquiring data on the baseline characteristics, water quality and sanitary condition of the pond. The land area within the project site is fallow. The dominant vegetation is characterized by grasses and tree shrubs.Within the lowland basins of the storm drain course are found subsistence rice farms irrigated by the storm flow.The soil macro-fauna consisted of the primary and secondary consumers. The primary consumers encountered included insects, millipedes, nematodes, snails and earthworms. The secondary consumers included centipedes, spiders and beetles. The soil microbes include bacteria and fungi. The vegetation within the study area has numerous toads and frogs. The invertebrate community is composed of earthworms, millipedes, snails, and insects. The water in the pond is muddy and the quality fits that of most fresh water bodies. It is rich in flocculants with high levels of Total Suspended Solids (TSS) and Total Dissolved Solids (TDS). Some quality parameters far exceed the National Standard permissible ranges for potable water. Substantial heavy metal pollutant loads were observed.The pond is rich in both phyto- and zoo-plankton. Abundant fingerlings and medium sizes of two species of common freshwater fin fishes, Catfish and Tilapia were found. The fishes were well fed and with no sign of environmental stress.The ecological impact and public health concerns on the short- and long- term effects of keeping the pond are discussed.

***Keywords**: Storm water;water quality; surveillance; microbial load; perturbations.*

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I. Introduction

Water remains a critical factor to human development. More than food it remains central to the sustainability of life on earth. Meanwhile the amount of potable water available for use continues to shrink as a result of pollution and global environmental challenges. This is most unfortunate given that the population of the earth keeps increasing, and in Africa in geometric progression, putting a greater demand on potable water.

With increased population and global trends,African traditional systems of water resource use and management which encouraged vital ecological balance is no longer sustainable.In Nigeria with an estimated population of over 160 million people, the water crisis has continued to get worse with adverse environmental issues such as disease and pestilence arising from poverty, insurgency and poor sanitation. According to the United Nations Children's Fund (UNICEF) 109 million Nigerians are without good sanitation, while 66 million of the entire 783 million people without potable water worldwide are Nigerians (The Guardian, 2013).

In a country where municipal water supply is an apparition, individuals are left to source for domestic water supply themselves. As fetching of water from rivers and streams (some of which are considerably far from living quarters) continue to exert great stress on women and children, most households are making due with shallow wells and rain water harvesting. In villages small holding catchment pits provided as storm water controls collect and hold reasonable quantities of flood water which are sometimes used in the neighbourhood for none domestic purposes. However large scale artificial storm water basins are uncommon and that is why the storm water lake created at Abakiliki, Ebonyi State, Nigeria elicits a special interest.

Abakiliki, the capital of Ebonyi State is located within 6^{o} 18′N 8^{o} 07′E. Major economic activities in Abakiliki and environs include agriculture (farming and fishing), quarrying, commerce and industry. Previously the most backward part of Southeast Nigeria, democratic governance has benefitted Ebonyi State immensely with Abakiliki its capital being one of the fastestdeveloping cities in Nigeria.The pace of infrastructural development has been tremendously fast-tracked by the state administration. One of the landmark projects in Ebonyi State is the OCHUDO City, an imposing estate designed to house the State Secretariat and which will ultimately become the hub of public service activities in the State. To facilitate this project the firm handling the construction created an artificial storm water basinwhich serves as the major source of water supply to the project.

The storm water basin covers a large area and is fed by flood water from tributaries of riparian waterways and seasonal streams which drain into the excavation.Located in a remote and isolated area there is no thoroughfare or any significant anthropogenic activity except construction works.As construction of the city estate nears completionwith the prospects of influx of occupants the State Government became worried with the danger the storm basin poses to public health raising serious concerns on the short - and long - term effects of keeping the pond.

The government as a first step to inventing remedial strategy commissioned this study to ascertain the impact of the storm reservoir on the immediate environment.

The Study Area

Ebonyi State is one of the thirty six States of Nigeria, it is located in the Southeast. (See Fig 1.). Abakiliki, the capital of Ebonyi State lies within theEbonyi (Aboine) River Basin. Its geological formation is of the Asu river group of Albian age (lower cretaceous) made up of shales, sandstones and siltstones. This sediment is folded to form the Abakiliki anticlinorium (Odunze and Obi 2013).
The google satellite image of the study site is shown in figure 2.

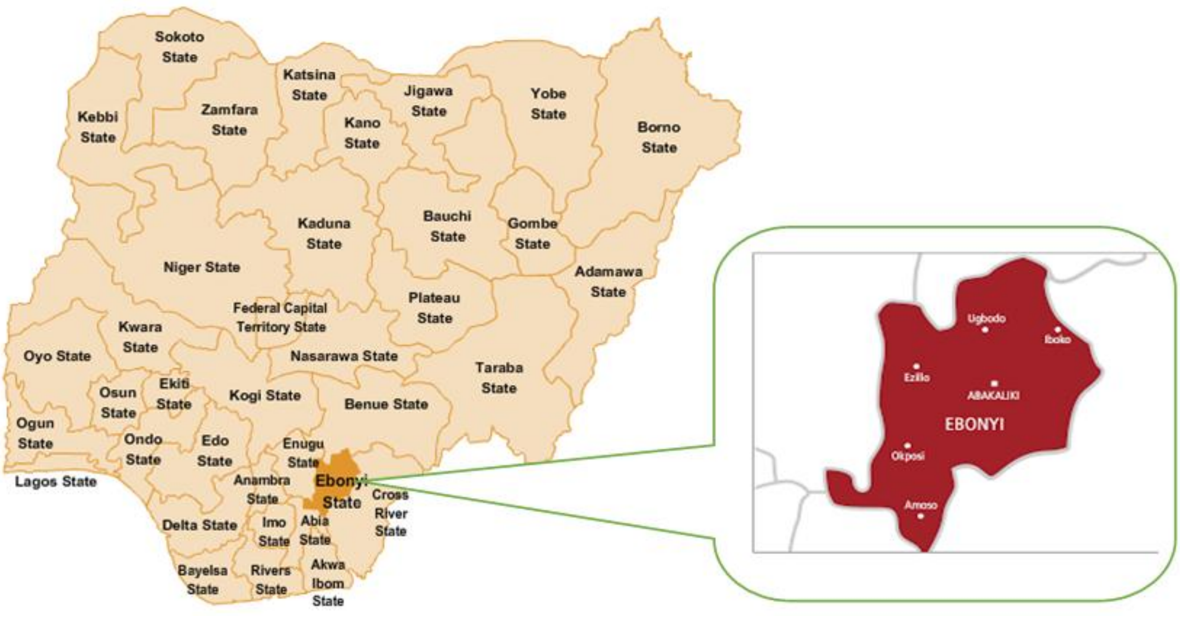

Fig. 1. Map of Nigeria showing Ebonyi State.

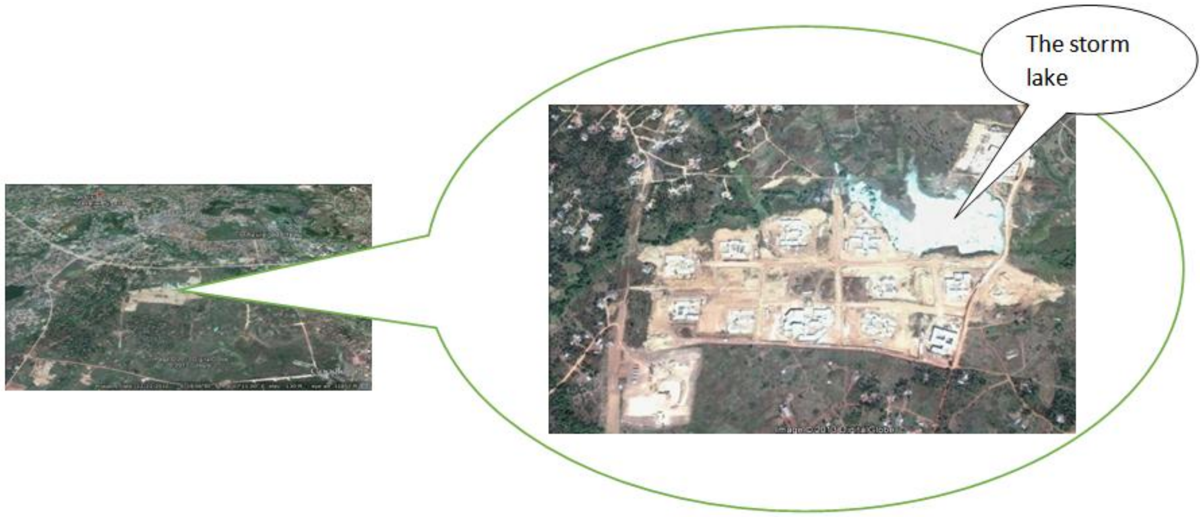

Fig. 2. Google satellite image of Abakiliki showing the project site enlarged.

Topography**:** Abakiliki has a low gently *undulating* terrain between trending rises and low hills with appreciable gradients permitting water flow. The undulating features of the land is made up of hills formed by the pyroclastic bodies(Onwe et al 2016), though no trend has been established by previous research of these conical shaped hills and other residual hills that spread sporadically within the area. The predominant shale formation largely accounts for the low erodability of the lithology (Iwuanyanwu 2014), resulting in near absence of deep cut valleys and erosion channels. The floor is usually water logged during the wet season and has gullies and ditches.

Physical properties: The area has a silty clayey hydromorphic soil with a brown loamy top horizon which overlies reddish brown silty clay subsoil(Obasi et al, 2015). It is moderately to imperfectly drained.

Temperature and precipitation**:** An analysis of existing historical records of climate obtained from archived information available in literature indicate that the maximum temperature range for the wet season (April - Sept) is 29.5 ^{0}C - 33.6 ^{0}C; while the mean minimum temperature range is 22.1 ^{0}C - 23.9 ^{0}C. For the dry season (October – March) the corresponding ranges are 31.2 ^{0}C – 34.9 ^{0}C and 20.0 ^{0}C – 23.9 ^{0}C respectively, with the hottest months being February and March.

Humidity and Rainfall**:** Temperature in the dry season results in high evapotranspiration, while the rainy season presents with generally lower evapotranspiration.The average monthly rainfall ranges from 31mm in January to 270 mm in July, with the dry season experiencing much reduced volume of rainfall unlike the rainy season, which has high volume of rainfall. Average annual rainfall varies from 1,500 mm to 1,650 mm. These climatic conditions according to Ezeh and Anike(2009) are responsible for the development of thick lateritic soils in the Abakaliki area and its environs.

II. Methodology

The underlisted systematic processes were adopted in this study:

- Literature review of the area
- Appraisal of existing environmental conditions
- Impact identification

A detailed environmental data acquisition on the ecological and socio-economic setting of the project wasobtained from literature and residual habitat of unhindered areas.The data acquisition was for effective baseline assessment and environmental interfacing. Appraisal of existing environmental conditions involved carrying out baseline survey at the project site at regular intervals of 30 days between July2014 and December 2014. The environmental baseline study focused on existing environmental status, vegetation and ecology of the coastal area.Impact identification were made onsite and by relating the pre-project baseline information from literature and residual habitat of unhindered areas to the existing environmental status.

Water quality assessment and sanitary surveillance was also undertaken at each sampling occasion. Field samples were randomly selected in triplicates from designated sampling points and analyzed in the laboratory. Physicochemical data obtained were compared with the Nigerian Standard for Drinking Water Quality, NSDWQ (2007) established by the Nigerian Industrial Standard (NIS) 5542:2007 of the Standard

Organization of Nigeria, SON and the National Environmental Surface and Groundwater Quality Control Regulations, NESGQCR (2011) enacted by the Nigerian Environmental Standards and Regulations Enforcement Agency. Standard microbial techniques were adopted in characterizing the microbial population.

III. Results And Discussion

Field studies.

Surface Water Characteristics: The storm water reservoir is an artificial water dam (see plates 1 & 2) and covers an expansive area of approximately 70,000sqmetres and depths vary between 7ft and near 10ft (see plates 3 & 4). It is fed by flood water from tributaries of riparian waterways and flood paths which drain into the excavation.Apart from flood, the reservoir is also fed by grey water from effluent receptacles from some parts of the city. The water is muddy brown in colour but becomes clearer during the dry season when there is less of storm water inflow.

Plates 1&2. Different approaches of the project site showing massive ongoing construction and some members of the team taking on-site maesurements and collecting samples.

Plate 3 & 4. Picture revealing the expanse of the storm lake during the day and at twilight

The dammed water is released through underground channelization pipesinto flood plains, helping to irrigate upland rice cultivation along its flow course and as well emptying into distant rivers. The outlet pipes releases water from the dam with sufficient force eroding the top soil (see plates 5 and 6) and exposing the geologic shale outcrops along the flood plain (see plates 7 and 8). The predominant shale formation of Abakiliki largely accounts for the low erodibility of the lithology, resulting in near absence of deep cut valleys and erosion channels along the flow path. However the sheath erosion that forms along the pathway devastates arable lands.

Plates 5&6. Underground storm channelization pipes at project site

Plates 7 & 8. The manifest nature of the geological outcrops along eroded flood plain.

***Vegetation*:**The dominant vegetation is characterized by grasses and tree shrubs as shown in plates 9 and 10. The prominent vegetation are the herb layers (E-storey)and the D-storey (less than 2m). Within the immediate neighbourhood of the project site abound grasslands and vegetation with D- storey (10-15m) with sparsely populated palm trees (plates 11 and 12) most of which have been suffocated by the persistent storm water leading to loss of foliage and death.Within the lowland basins of the storm drain course are found subsistence rice farms irrigated by the storm flow.Stunted trees and pockets of derelict woodland existwhere the lithology has undergone high degree of laterization. Elsewhere, typical characteristics of the tropical rain forest are displayed; multitude of evergreen trees, climbing plants, parasitic plants that live on the other plants, and creepers.

The storm water overflows the reservoir into the neighbouring vegetations destroying farmlands, suffocating economic trees like the palm tree (see plates 11 and 12), threatening the population of weaver birds which is preponderant in the area, and which builds their nests on the palm fronds and devastates the entire ecosystem.

Plates 9 and 10. Dominant vegetation characterized by grasses and shrubs

Plates 11 & 12. Suffocating palm trees with palm fronds bearing weaver birds' nests

Physicochemical properties:

Water is a natural resource that is essential for the sustenance of life. All natural waters have self-purification potentials and have the capacity to assimilate certain amounts of waste without apparent effect upon the environment. The summary of the physicochemical characteristics of the water samples from the study area is presented in table 1.

Table 1. Physicochemical parameters of the water

Physical parameters	**Sample ranges**	**Water Quality Limitation Criteria for surface water**	
		NESGQCR (2011)[1]	**NSDWQ (2007)[2]**
pH	6.1 – 6.3	6.5 – 8.5	6.5 – 8.5
Temperature (^{0}C)	30.6 – 33.0		Ambient
Conductivity(µS/cm)	16.15 – 23.20		1000
Turbidity (NTU)	3810 – 5310		5
Total dissolved solids, TDS (mg/l)	4000 -6000		500
Total suspended solids, TSS (mg/l)	4320 - 4540		
Hardness (mg/l)	40 – 42		150
BOD (mg/l)	80 – 96	3.0	
COD (mg/l)	320 -340	30	
DO (mg/l)	32.0 – 35.0	Minimum 6.0	
Colour (TCU)	Muddy brown		15

Odour	Objectionable	Unobjectionable	Unobjectionable
Taste	Objectionable	Unobjectionable	Unobjectionable

1. NESGQCR -National Environmental Surface Water Quality Control Regulations.
2. NSDWQ -Nigerian Standard for Drinking Water Quality

Hydrogen-ion (pH) concentration: The water is slightly acidic with an average pH of 6.2, this is within the 6.5 – 8.5 pH limit recommended by both NSDWQ and NESGQCR for potable water.

Water Temperature: The surface water temperaturewas acceptably ambient varying between 30.6^{0}C and 33.0^{0}C in all thelocations with a mean of 31.4^{0}C.

Conductivity: Electrical conductivity measures the ability of water samples to conduct electricity and is a function of the concentration of ionized substances in water. It can also be an approximate measure of the total concentration of inorganic substance in water. Conductivity values recorded in this study were from 16.15 – 23.20µs/cm.

Turbidity: Turbidity reflects the amount of suspended and dissolved solids in the water. It is a measure of the depth of illumination or the depth to which light can penetrate. The turbidity values of the water body was very high (3810 to 5310 NTU) with a mean of 4560 NTU which is far morethan the recommended limit of 5 NTU for potable water. The high turbidity is partly due to high level of humic acid and sediments from flood run-off feeding the water body.

Colour: The water in the pond is muddy brown in colour and is objectionable. Variation in water colour is primarily governed by the presence of humic substances, eroded soil debris, human and industrial wastes and sometimes the type and density of phytoplankton. The water colour correlated positively with the turbidity.

Total Dissolved Solids (TDS) and Total Suspended Solids (TSS): Rich in flocculants both the Total Suspended Solids (TSS) and the Total Dissolved Solids (TDS) were high. The TDS content is an index of the amount of dissolved substances in water. The TDS value varied from 4000 to 6000mg/l with a mean of 5000mg/l, which is above the recommended limit. The TDS correlated positively with conductivity and salinity. The TSS varied between 4320 and 4540mg/l with a mean of 4430mg/l which is far above the 30mg/l recommended limit.

Dissolved Oxygen (DO): The concentration of dissolved oxygen in water is a reliable index of organic pollution. The dissolved oxygen range is between 32 and 35mg/l with a mean value of 33.5mg/l. This is high and very high levels of DO are not recommended for domestic and industrial water supplies and boilers in order to prevent corrosion of iron and steel pipes in the distribution system.

Biochemical Oxygen Demand (BOD): Biochemical Oxygen Demand (BOD) is an empirical determination of the amount of oxygen utilized during a specific incubation (usually for 5 days) for the biochemical degradation of organic materials (termed carbonaceous biochemical. Natural waters of BOD values of above 4.0mg/l are considered to be polluted. The BOD values ranged from 80 to 96mg/l. With a mean value of 88mg/l, the BOD of the pond is far above the recommended limit.

Chemical Oxygen Demand (COD): The COD often called the reducing capacity measures the oxygen equivalent of the organic matter content of a sample that is susceptible to oxidation by a strong chemical oxidant. With the COD range of 320 -340mg/l and a mean value of 330mg/l the water is heavily polluted.

Soluble Anions:

Table 2 is the result of the anion levels in the water. Except for Sulphate ion all other anions are within the permissible ranges.

Table 2: Anion ranges of the water

Chemical parameters (Anions)	**Value ranges**	**Water Quality Limitation Criteria for surface water**	
		NESGQCR(2011)	**NSDWQ (2007)**
Phosphate (mg/l)	0.056 – 0.074	3.5	
Nitrate (mg/l)	0.169 – 0.187	9.1	50

Nitrite (mg/l)	0.18 – 0.19	0.02	0.2
Chloride (mg/l)	67 – 89	300	250
Sulphate (mg/l)	100 -225	100	100

Exchangeable cations

Sodium (Na), Potassium (K), Calcium (Ca) and Magnesium (Mg), in solutionform the exchangeable cations. Their constituents in the water are shown in Table 3. All the values are within the permissible ranges.

Table 3: Exchangeable cation profile

Chemical parameters (Cations)	Value ranges	Water Quality Limitation Criteria for surface water	
		NESGQCR(2011)	NSDWQ (2007)
Magnesium (mg/l)	2.16 – 4.24	40	0.20
Selenium (mg/l)	8.20 – 8.77		
Potassium (mg/l)	2.60 – 2.80	3.5	
Sodium (mg/l)	4.67 – 5.56	120	200
Manganese (mg/l)	0.034 – 0.043	40	0.20
Silicon (mg/l)	2.08 – 2.18		

Heavy Metals (Trace Elements)

Natural waters contain very small quantities of several essential metalsincluding iron (Fe), Zinc (Zn), Manganese (Mn), Chromium (Cr), Copper (Cu),Nickel (Ni), Cadmium (Cd), Aluminum (Al), Vanadium (V), Lead (Pb), andMercury (Hg). These metals, also called trace elements or micronutrients arenon-biodegradable but easily assimilated and bio-accumulated in the

protoplasm of aquatic organisms. While nickel (Ni), copper (Cu) and arsenic were not detected, molybdenum occurred in very minute concentration while the others appear in moderate concentrations as shown in table 4. Cadmium, lead and mercury are of public health significance as they are known to be toxic to the kidney and the central nervous system. Of greater worry is the high concentration of aluminum. Aluminum is implicated in neuro-degenerative disorder.

Table 4: Heavy metals in the storm water basin

Heavy metals*	Value ranges (ppm)	Water Quality Limitation Criteria for surface water	
		NESREA (2011)	NSDWQ (2007)
Cadmium (mg/l)	1.19 – 1.34	0.005	0.003
Silver (mg/l)	0.13 – 0.16		
Cobalt (mg/l)	0.00 – 0.10		
Iron (mg/l)	4.37 – 5.41	0.05	0.3
Lead (mg/l)	0.00 – 0.09	0.01	0.01
Mercury	0.68 – 0.80	0.001	0.001
Tin	0.36 – 0.38		
Vanadium	0.103 – 0.133		
Bismuth	0.013 – 0.018		
Molybdenum	0.00 – 0.01		
Zinc	0.016 – 0.024	0.02	3.0
Aluminum	11.21 – 16.22	0.20	0.20
Copper	n.d	0.001	1.0
Chromium	n.d	0.001	0.05
Arsenic	n.d	0.05	0.01
Nickel	n.d	0.01	0.02

***** n.d – not detected.

Aquatic ecology

Phytoplankton: Phytoplankton are of great ecological significance because they constitute themajor portion of primary producers in the aquatic ecosystems. They are autotrophic microscopic plant organisms inwater bodies, which are capable of photosynthesis. Predominant planktons found in the water include diatoms or

Bacillariophyta, green algae or *Chlorophyta*, blue green algae or *Cyanophyta*, and euglenoids or *Euglenophyta*. Diversity is a measure of ecosystem stability.

Zooplankton: Zooplankton occupy a central position in the food webs of aquatic ecosystems and many of them feed largely on algae and bacteria. They are microscopic animals.The most preponderant types of zooplanktons found were *Rotifera* and*Copepoda*.

Fisheries: Two species of fish, Catfish and Tilapia were identified in the pond. Both are common freshwater fin fishes; abundant fingerlings and medium sized fishes, well fed, and with no sign of environmental stress were found.

Aquatic organisms: The macrofauna consisted of the primary and secondary consumers. The primary consumers encountered included insects like dragonfly, millipedes, nematodes, snails and earthworms. The secondary consumers included centipedes, spiders and beetles.

Microorganisms: Storm water has enormous capacity to trap and incubate disease causing organisms as they are rich in both organic and inorganic pollutants taken along as run-offs.
The microbes include bacteria and fungi and these contribute substantially tothe re-cycling of nutrients and materials within the ecosystem.Total bacteria count was observed to fluctuate between 3.5×10^4 to 9.3×10^4. The predominant bacteria isolates identified were *Bacillus* sp., *Klebsiella* sp.,*Staphylococcus* sp., *Escherichia* sp., *Pseudomonas* sp., *Proteus* sp., and *Serretia* sp. while the fungal population was dominated by *Mucor* sp., *Aspergillus* sp., *Candida* sp., *Cladosporum* sp., and *Penicillium* sp.

An appraisal of the storm water quality using routine physicochemical assessment criteria (like taste, odour, colour, turbidity, pH, conductivity, iron and nitrates) and bacteriological quality show that the water may not be ideal for potable use. The storm water basin is a natural stabilization pond which operatesa natural process for wastewater treatment that employs a combination of macrophytic plants, substrates and microorganisms.Such water pool can safely be used in circumstances where impacts on human health and environment are well understood and all possible action is taken to eliminate risks (WHO/FAO/UNEP, 2006). Of particular application is its use in agriculture. Its safe use in irrigating rice farms as already noted can reduce the pressure exerted by human activities on existing fresh water resources and augment water supply in such a rapidly growing urban setting.

The government is apparently left with two choices; to let the storm lake remain or to fill up the basin and reclaim the site. The first option is desirable for land reclamation for further development. However it is a capital intensive venture requiring proper storm water reticulation with risk of occasional flooding posing a great danger to public health. The second option offers greater environmental stability. Apart from acting as a stabilization pond, along with the surrounding vegetation the lake will act as a carbon dioxide (CO_2) sink for the city estate as well as supply humid air.With the prospect of occupation of the Secretariat buildings, there will be increased commercial activity within and around the estate, presenting the challenge of the lake becoming a solid waste receptacle and a breeding ground for water-borne and air-borne diseases. With assured routine clean up action which guarantees environmental renewal, risk-benefit balancing no doubt confers greater desirability quotient on keeping and maintaining the lake.

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