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Evaluation of Water Intake Structures for Municipal Water Supply Scheme in Lagos, Nigeria

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Abstract

The aim of this study was to evaluate some of the grass root problems that tend to frustrate municipal water supply efforts of the Lagos State Water Corporation. This was achieved by understudying three water withdrawal points, namely Iju, Isashi and Adiyan water intake facilities through physical observation, administration of questionnaires and Pearson's correlation coefficient analysis of data obtained through questionnaire. The correlation coefficient analysis of the location of intake against water source gave value ranges of 0.530, 0.545 and 0.586 for Iju, Adiyan and Isashi Intakes respectively. The correlation analysis of the hydraulic properties of the intake structure against water quality also revealed value ranges of 0.260, 0.236 and -0.453 respectively while the correlation analysis of intake location and water quality gave value ranges of -0.246, -0.602 and -0.827 respectively. Although, physical observations revealed that good planning, designs and constructions were achieved in all the three facilities, but unwholesome practices as demonstrated by lack of maintenance culture, archaic operational practices and inadequate funding undermined the entire water supply scheme.

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Introduction

Intakes are hydraulic structures used to extract water from the surface sources such as rivers, man-made reservoirs or lakes (Masschelein, 1992). Intake structures on channels are intended to divert a certain amount of water from the channel for diverse purposes of use such as irrigation, industrial plant cooling, potable water supply and hydroelectric power. It must be possible for both the diverted water and the remaining supply to be evacuated without damage being caused to the environment or the Intake system (Al-Layla *et al*, 1998). Generally an intake structure, if meant for the purposes of municipal water supply, is a masonry or concrete structure with the aim of providing relatively clean water, free from pollution, sand and objectionable floating materials. The basic functions of the intake structure are to help in safely extracting water from a surface source, ensure smooth, easy and turbulence-free entry of water into the conveyance passages and to stop coarse river-borne trash matter such as boulders, ice and logs of wood from entering into the conveyance passage (Vischer and Hager, 1998). To achieve this, special measures must be taken during the design and construction stages to determine the necessary amount of water to be withdrawn.

In order to put in place an efficient intake system, factors such as the environmental impact of intake structure on the ecosystem, the quality and quantity of the water to be conveyed, hydraulic factors, funding of the project, salt water intrusion, seasonal changes, maintenance of the intake system, availability of the spare parts, availability of the required trained manpower, constant and cheap energy source must be of high priority (Vermeyen, 1999). An intake (Fig. 1) should essentially have the following components: Bell mouth/cylindrical strainer, Strainer structure with arrangements for its protection, Raw water gravity pipe or channel, Gate or sluice-valve, Suction well (intake well), Foot valve, Suction pipe for the low lift pipe. Parameters that need to be considered in the design of Intakes are the availability of water, sediment transport, environmental regulation, climatic conditions, dredging, operations and maintenance (O & M). The associated Electromechanical works require a pump hall, an High Voltage and Low Voltage (step down) room, a control room, a storage room to store a complete standby pump set, the spare parts and an assortment tools, travelling crane – an electrically driven overhead crane (Al-Layla *et al*, 1977).

The authors undertook a study of the water intake operations of the Lagos State Water Corporation, the main governmental organ that has the responsibility to provide potable water for residents. Emphasis was put on the state of some selected sources of raw water and the withdrawal intake structures used to exploit the surface water resources, in order to actually see if the efforts could be sustained in meeting the global target of the provision of potable water for the masses. It was found that the three intakes have a combined maximum water production capacity of 648 million litres per day. The Iju intake which has a capacity of 192 million litres per day was constructed in 1972 and refurbished in 1986. It is the oldest. The Isashi intake was commissioned in 1976 with a capacity of 168 million litres per day. Adiyan intake is the most recently built intake. It was commissioned in 1991 with a maximum capacity of 288 million litres per day. All these intakes draw their raw water supply from the same source – Ogun River, which is the primary source of fresh water supply for the two states.

The seventh cardinal millennium development goal (MDG) addresses environmental sustainability. Within this context, the United Nation aims at reducing by half the proportion of people without sustainable access to safe drinking water and basic sanitation by the year 2015 (UN, 2007). These goals basically target developing countries of which Nigeria is strategic, being the most populous country in Africa with an estimated population of 140 million people and an annual growth rate of 3.2% (FGN, 2007). The percentage of Nigerians with access to improved sanitation facilities was put at 44% as at

2004 (UN, 2006). Lagos state, Nigeria is widely accepted as the economic and Industrial headquarters of Nigeria.

The Federal Government's official population figure of Lagos state alone (which has attracted much controversy) stands at 9.013 million people. Conversely, the Lagos State Government and United Nations say that 17 million people reside in Lagos state (Lagos State Government, 2006; Microsoft Encarta, 2005) making it one of the most populous cities in the world. Taking daily per capita water requirement for domestic use as 100 litres (Falkenmark and Widstrand, 1992), the current water requirement of Lagos residents for domestic use alone is 901.3million litres per day (using FGN data) and 1.7 billion litres per day (using Lagos State Government and UN data). By projection, water demand for domestic use alone for half of Lagos state residents by 2015 will be 580 million litres per day (using FGN data, 3.2% growth rate and projecting from 2007) and 1.13 billion litres per day (using Lagos State and UN data, 3.2% growth rate and projecting from 2006). This does not take into cognisance the fact that water withdrawal in Africa goes into Agricultural, Industrial and domestic uses in the proportion 88%, 5% and 7% respectively (Hinrichsen *et al*, 2007). Moreover, millions of people who earn their living in Lagos actually reside in Ogun state, because of the proximity and cheaper cost of living. Industrialists also have of late been locating their industries in Ogun state whereas their primary market target is the Lagos population. With this ever increasing demand for water in perspective, it is estimated that only 35% of Lagos residents are served by the Lagos State Water Corporation (FGN, 2000). It is also on record that more than 60% of water produced to serve this low percentage of people is unaccounted for and lost through leakages, illegal connections and excess consumptions through flat rate tariff (FGN, 2000). These facts paint a grim picture indeed of Nigeria and possibly of other developing countries since similar conditions are obtainable.

Materials and methods

Study area

The Lagos state government agency (Lagos State Water Corporation) utilizes the raw water from the Ogun River as the major source to increase the capacity of the treated water distribution system in Lagos metropolis and environs. River Ogun, which has its source several kilometres from the intake, has an average water level of 3.5m in the rainy season and 1.0m in the dry season. All the three intakes in this study draw their raw water from River Ogun. While the Adiyan and Iju intakes are located in Akute village, within the Ogun State boundary, the Isashi intake is located within Lagos state boundary. The Adiyan and Iju intakes are known as Akute Intakes. The Akute intakes are responsible for the raw water extraction for Adiyan and Iju Waterworks. The formation also houses and maintains the anti-salinity weir. The Adiyan raw water intake was constructed in 1991 and has been in operation since then. The average water supply from the intake is about 288 mld which is obtained from the use of three pumps of about 96 mld each. But presently only 2 of the pumps are working producing only about 192 mld. The intake is located at the upstream of the river also at a depth where it can draw water during dry seasons. The Adiyan intake does not get flooded because it was designed for the worst water in flow conditions; the highest water level recorded was in September 2003 having 4.36m and in September 2005 having 4.28m at the intake which was the peak period of the raining season. At the Adiyan intake there was a history of salt water intrusion in 1993 which affected the water supplied to Lagos state consumers but the problem of the intrusion was solved by the construction of a weir in 1995 on the Ogun River and before the intake structure. Due to the effect of this weir the salty water from the lagoon was halted which allowed the use of normal materials for pipes, fitting and pumps. The raw water passes through a coarse screen, fine screen, inlet gate and pumping chamber. The coarse screen is made up of vertical iron bars with 160mm spacing and fine screen of

20mm spacing, which prevent foreign objects from entering the raw water pumping chamber.

Data gathering and processing

Data was gathered in the year 2006 through field observation, the administration of questionnaires and interviews with the authorities of the intake facilities. The physical properties (colour and turbidity) of the source river were assessed by physical observation. A total of 21 questionnaires were administered at the 3 intake locations to Project Managers, Operations & Maintenance Managers, and Site Engineers as respondents. The questionnaire addressed issues such as the source of raw water, intake location, hydraulic properties and the quality-cum-quantity of water of the water withdrawal system. The result rankings were concluded using the Likert scale. Responses ranged from a score of 4, representing 'strongly agree' to a score of 1 representing 'strongly disagree'. Eighteen were returned giving rise to a response of 86% approximately. For the purpose of correlation coefficient analysis, the independent variables, *x* and the dependent variables, *y* were taken respectively as the river source and intake location; hydraulic properties of the intake structure and the quality of raw water; Location of intake structure and quality of raw water. Analysis of data was done by applying Pearson's correlation coefficient as stated in equations 1 to 4 (Montgomerry and Runger, 2003; Sprinthal, 2002):

$$r = \frac{S_{xy}}{\sqrt{S_{xx}S_{yy}}} \quad (1)$$

Where,

$$S_{xx} = \sum_{i=1}^{n}(x_i - \bar{x})^2 = \sum_{i=1}^{n} x_i^2 - \frac{(\sum_{i=1}^{n} x_i)^2}{n} \quad (2)$$

$$S_{yy} = \sum_{i=1}^{n}(y_i - \bar{y})^2 = \sum_{i=1}^{n} y_i^2 - \frac{(\sum_{i=1}^{n} y_i)^2}{n} \quad (3)$$

$$S_{xy} = \sum_{i=1}^{n} y_i(x_i - \bar{x})^2 = \sum_{i=1}^{n} x_i y_i - \frac{(\sum_{i=1}^{n} x_i)(\sum_{i=1}^{n} y_i)}{n} \quad (4)$$

Results and discussion

River Ogun, where the raw water is being sourced was observed to be replete with a lot of unrestricted anthropogenic activities such fishing, subsistence farming and firewood processing which contributed to increased pollution of the source water. Substances such as broken fishing nets and cleared weeds were observed to be clinging to the surface of the screens, thereby hindering the process by reducing the rate of raw water extraction. The colour of the water was observed to be greenish at the three intake sites. This discolouration was caused by the growing vegetation on the water surface. Also, manual dredging activities was observed to be carried out at both Iju and Adiyan intakes. The dredge spoils were put in canoes and disposed off at the adjacent land to the intake. This is washed back gradually into the river during raining season, thereby increasing the turbidity of the raw water while the sediment movement also clog the screens. Sediment transport is highest during the wet season thereby causing the turbidity of the water get as high as 40 N.T.U. or as low as 26 N.T.U. Due , also, to the sediment and waste disposal in the river, the colour ranged between 140 and 500 during the dry and wet seasons respectively.

Centrifugal pumps were being used at the three intake locations that were studied. The intake pipes are made of ductile iron. The sources of power come from the public power supply agency, NEPA and generators. While the public power supply is very erratic, the fuelling of the generators with diesel is an expensive, howbeit, the only alternative. These twin problems therefore ensure that even when all the pumps are functional, full daily production capacity cannot be achieved. For example, only two out of the five centrifugal pumps at Adiyan intake were working. This has reduced the water pumping efficiency. The condition of the generators at three sites is bad. This is due to lack of spare parts to replace damaged ones and the scarcity of diesel to run the machine regularly.

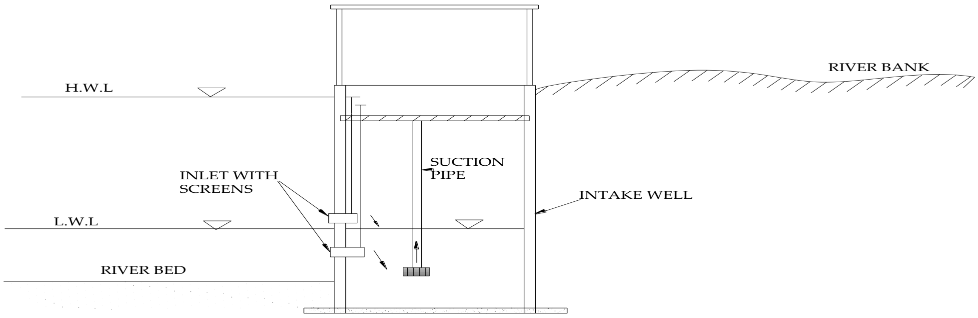

Fig. 1. A typical river intake structure schematic diagram.

The maintenance culture of the water works can only be described as very poor. It was observed that the screens were corroded, thereby putting public health at risk as a result of dissolved metal in the water which may not be provided for at the treatment plant. It was also observed at the three intake locations that the few pumps and generators that are still functioning are not being serviced. This negligence was attributed to lack of funds from the government.

Survey analysis

Results of the questionnaires that were administered were analyzed using the models stated in equation 1 to 4. The correlation coefficient for the following parameters was derived for each intake location (results are presented in Table 1).

Location of intake facility and source of raw water

The correlation coefficient values ranged between 0.530 to 0.586, with Isashi recording the highest value of 0.586, and Iju recording the lowest value of 0.530. All the three values were positive and high, indicating that there are positive correlations between the location and river source for the three (3) intake sites.

Hydraulic properties of the intake structure and quality of raw water

For Iju and Adiyan, their correlation coefficients are 0.260 and 0.236 respectively. This shows a positive but low correlation between the hydraulic properties and the raw water quality. Isashi had a correlation coefficient value of -0.453. This indicates a higher, though negative correlation between the hydraulic properties and the quality of raw water.

Table 1. Values of r = Pearson's Correlation coefficient.

Parameters	IJU	ADIYAN	ISASHI
Source& Location	0.530	0.545	0.586
Hydraulic& Quality	0.260	0.236	-0.453
Location& Quality	-0.246	-0.602	-0.827

Location of intake facility and quality of raw water

The correlation coefficients for Iju, Adiyan, and Isashi are -0.246, -0.602, -0.827 respectively. These all show a negative correlation between location and the quality of raw water for the three intakes.

Conclusion

It can be deduced from this study that significant effort has been made to meet the water requirement of the residents of Lagos and its environs. However, the expansion, maintenance and sustenance of this laudable effort are presently the greatest bane of these three water intake systems. The lack of maintenance and allocation of appropriate funding has handicapped these water withdrawal systems from delivering maximally. An intake system must have sufficient capacity to meet the maximum anticipated demand for water under all conditions. It should be supplying water of the best quality economically from the source. Analysis and field observation indicates that the design and operation of various water supply intakes have different design concept which is not suitable for all location therefore, any intake design must be based on site specific information, hydrologic, environmental and economic factors. Hydraulic analysis must be performed as an integral part of the intake design to provide flow free from objectionable conditions at the pumps.

Sequel to the conducted field investigation, questionnaire administration and survey analysis, the following are recommended for an efficient intake system:

The use of an intake well should be adopted because it serves as a reservoir for the pumps by allowing a constant inflow into the sump well. It also houses silt and sediment accumulation. The present design at Akute and Isashi lack this component.

- The use of fine and coarse screens is recommended to reduce abrasion of the pumps for the three intakes investigated.
- The pipes should be made of reinforced cement concrete (R.C.C) and distribution mains already used with cast iron can be retained.
- The regular servicing and general overhaul of the equipment such as pumps, generators etc should be done for continuous flow of water.
- The federal government should provide more funds for efficient operation and maintenance of all the intakes.
- Power supply should be accorded top priority.

The following should be considered for an appropriate location:

- The intake areas should be free of vegetation and human activities that can cause coloration and pollution of the river water.
- Dredging should be done regularly and the disposal of dredged spoils should be properly done in order to keep turbidity as low as possible.
- The intake should be located in a place where there is no fast current which may damage the intake thereby causing interruption in the water supply.
- The three intakes site should remain easily accessible during floods. Moreover, flood water should be channelled away from the vicinity of the intake.

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