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Municipal water supplies - technology costs

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ABSTRACT

This paper considers the cost of Treated Water Supply vis-a-vis the Technology employed in Ibadan Municipality, the largest City in Black Africa. Serving a population estimated at about 2.0 million, the City's two existing Water Schemes, Eleyele (1942) and Asejire (1972) are analysed both from the viewpoint of the technology employed vis-a-vis the cost of design, construction, maintenance and rehabilitation.

It is shown that unless ways and means of employing a less expensive/indigenous technology is looked into, developing countries will probably continue to depend on loans for the ever rising cost of foreign components, in view of spiralling inflation, in order to finance their most basic necessity of life.

Some possible types of appropriate technology that can be employed are suggested with a view to reducing the capital and operational cost thus resulting in lower unit cost of treated water and easier cost recovery.

1.0 INTRODUCTION

The need for effective planning and husbandry of man's most basic necessity of life is greater today than at anytime in history. In the past, water was not considered to be an economic good, subject to the laws of supply and demand, but rather a physical substance required by a particular community.

In contrast, today, higher living standards and urbanization have resulted in ever-increasing demands for water. Energy costs for pumping have been translated into increased water costs. Higher interest rates are now a serious consideration in planning multimillion-dollar water supply projects in developing countries.

In the particular case of Ibadan Municipal Supplies, it is shown that the conventional water supply methods developed primarily for industrialized nations, is considered uneconomical when local adaptation is not given the priority it deserves.

2.0. PROFILE ON IBADAN WATER SUPPLY SCHEMES

2.1. <u>Historical Profiles on Schemes</u>

At present, the City is supplied with water from two sources namely the Asejire and Eleyele Dams. The Asejire Waterworks was commissioned in 1972 with an installed capacity of 82,000m^3/day (18 MGD) and an ultimate capacity of 164,000m^3/day (36MGD). The Eleyele works was commissioned in 1943 with an installed capacity of 9000m^3/day (2MGD). The Eleyele works was uprated in 1959 to 18,000m^3/day (4MGD) and 17,000m^3/day (6MGD) in 1961.

A third treatment plant the Osegere was utilized to augment the city's supply by 13,500m^3/day (3MGD) from the late 60's to 1972 when it was abandoned for the Asejire works. See fig.1 for a general map on the Schemes.

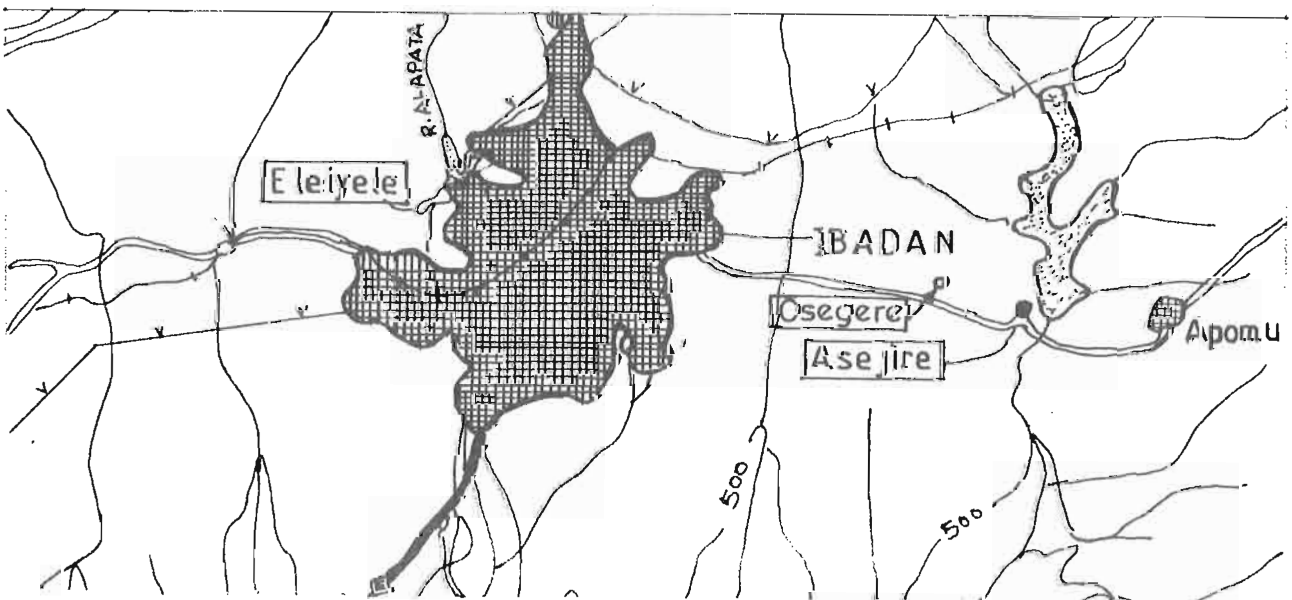

fig.1 - Location Map of Schemes

Presently, the Asejire works is delivering about 46,000m^3/day (10 MGD) instead of 82,000m^3/day while Eleyele is delivering 11,000m^3/day instead of 27,000m^3/day. Osegere is providing none as at now. Thus, out of the total of 120,000m^3/day (27 MGD) installed capacity, only 56,000m^3/day (12.4 MGD) is being obtained from the works (i.e. 47%).

2.2. Technological Profile on Facilities

The existing plant at Asejire was built under the USAID and comprises six "multicone" aerators, chemical dosing of lime, alum and chlorine, settlement in six "accelator" clarifiers, rapid gravity filtration through fine media in eight double-bed filters and collection in a clear well before pumping. The plant is arranged in two stages I & II each comprising three aerators, three clarifiers and four filters. There is provision for future extension stages III and IV to double the plant capacity. The Osegere plant consists of four steel hopper bottomed clarifiers and 3 rapid gravity sand filters (horizontal type) and associated building and appurtenaces. The Eleyele headworks which is located in the immediate vicinity of dam/impounding reservoir has the following facilities/component parts, aerator (perforated pipe type) sedimentation tanks, filter tanks, pressure filters, low lift and a high lift pumping station.

3.0. TARRIFF STUDIES OF EXISTING SYSTEM

3.1. Water Rate-Making Process

The rate-making process for a public utility that is to a large extent self financing typically begins with a determination of the revenue target. When the target is determined on a utility basis, the desired total revenue is set equal to the full opportunity cost of the operation of the utility.

3.2. Average Cost Pricing for Existing System

It can be assumed that loans in respect of both Eleyele and Asejire Schemes have by now been fully paid for and hence current costs incurred in water production is basically that of operation and maintenance. Placing a Naira value on the various costs incurred, the following calculation are typical of the present day situations on an annual basis.

The present total annual running costs is ₦24,103,313.76* (Conversion rate of $1 = ₦5.50)

With a current average annual production of 20,440,000m^3, the average cost is equal to ₦1.18/m^3 in contrast to the figure of ₦ 0.20/m^3 in 1980 according to the WHO mission (1982).

3.3. Marginal Cost+ Pricing for Investment Decision

Two major types of investment on the Ibadan Water Supply Scheme will be studied thus:

3.3.1. Rehabilitation Works. The depreciated capacity of the existing system is 56,000m^3/day. It is intended by way of refurbishment/rehabilitation of existing plant to increase the capacity to 120,000m^3/day. The basic formula for determining the unit cost of an increment of water supply is [5]:

$$x\left\{q_0 + \frac{q_1}{(1+i)} + \dots + \frac{q_t}{(1+i)^t} + \dots + \frac{q_n}{(1+i)^n}\right\} = (C_0 - Z_0) + \dots + \frac{C_n - Z_n}{(1+i)^n} \quad \dots(1)$$

where x is the unknown unit cost of water,

qt represents the water deliveries in year t,

Ct is the cost in year t,

Zt is the value of offset to costs associated with the project in year t

i is a constant rate of discount

n is the last year in which the investment has any effect (i.e. project life)

In the simple case such as ADB-financed rehabilitation works on the Ibadan Water Supply System qt and Ct are constant begining with year 1 (i.e. $C_1 = C_2 = C_n$; $q_1 = q_2 = q_n$) and capital cost C_0 will be incurred only in the initial period t = 0 Denoting $C_1 = C_2 = C_3 = C_n$ as an annual operating cost Y, we have equation (1) modified as follows:

$$x\, q \sum_{k=1}^{n} \frac{1}{(1+i)^k} = C_0 + Y \sum_{k=1}^{n} \frac{1}{(1+i)^k} \quad \dots(2)$$

Solving for x,

$$x = Y/q + C_0/q \cdot \frac{i(1+i)^n}{(1+i)^n - 1} \quad \dots(3)$$

putting i = 10.3% = 0.103 , n = 25 years
Co = ₦80,000,000
and
q = 23,360,000m^3/year
(being additional over existing)

Assuming the corresponding value of Y is that affected by operations, maintenance and chemicals on a pro-rata basis then
Y = ₦18,991,594.78/year

Thus from eqn (3)

x = 0.813 + 0.386 = ₦1.2/m^3

3.3.2. Long-term Expansion Works. If an assumed population of 3 million is to be catered for in the year 2010, then the expected delivery at a modest per capital consumption of 150 litres/day is 450,000 m^3/day. Thus the extra delivery is 450,000 - 120,000 = 330,000m^3/day.
If the extra delivery is denoted by q* and it is assumed to build up arithmetically over a load-building period starting with q*/L in year 1 and reaching full capacity q* in year L, and if the capital costs are incurred only in year 0 in the amount Co, and operating costs remain costant at Y*

throughout the project life n, then the following formulae (ref. 5) holds:

$$x = \frac{C_o + Y^*\left\{\frac{(1+i)^n - 1}{i(1+i)^n}\right\}}{q^*\left\{\frac{1+i}{Li}\left[\frac{(1+i)^L - 1}{i(1+i)^L}\right] - \frac{1}{i(1+i)^n}\right\}} \quad \text{....(4)}$$

If the present level of operation/construction costs are allowed to apply, the following can be reasonably assumed

Co = ₦350,000,000.00 (approx.)

$Y^* = \frac{1}{2}(Y_1 + Y_2)$ = ₦51,410,840.55

where Y is initial operating cost = ₦4,896,270.53 /per year and Y_2 is final operating cost = ₦97,925,410.58/year

n = 50 years , L = 20 years (from 1990)

q^* = 120,450,000 m^3/year

i = 0.103 (assuming same interest rate)

Thus x = 2.91 + 0.936 = ₦3.846/m^3

3.4. Cost Recovery Vs Government Subsidy - The last few calculations have shown that with the present cost of treatment components cost recovery is not feasible even with substantial Government subsidies. There is a price limit beyond which consumers are not willing to pay any extra amount incurred in additional supplies. If we denote this limit by D and the marginal cost by MC, then the level of Government subsidy required is (MC - D) at any investment level. Judging from the precarious economic situations consumers are currently facing in the country, it is doubtful if they could be asked to bear the high costs involved in the modern technological investments in water supplies.

4.0. APPROPRIATE/LOW-COST/EASY-MAINTENANCE TECHNOLOGY

Provision of appropriate technology is not always easy to achieve. In fact, obstacles exist which serve as detours to the development and implementation of relevant water treatment technology. The following principles are nevertheless suggested as helpful guides in applying appropriate technology.

4.1. Treatment Plant Component Parts/Process. In the case of Ibadan Water Supply Schemes, the following processes are especially recommended for necessary adaptations, among others.

4.1.1. Clarification. It may be recommended here that a flat bottomed upward flow sludge blanket clarifier will be more appropriate than the existing system. It has no moving parts and therefore easy to maintain. Furthermore, the incoming water is distributed through a manifold pipe system at low level with nozzles arranged to give an even distribution over the whole floor area. The distribution system and nozzles are designed to give sufficient gentle turbulence to allow flocculation and coagulation of microfloc particles. The sludge is bled off manually from a side hopper bottom.

4.1.2. Filtration. The present system uses a pneumatically controlled module for determining the appropriate time for backwashing. However, as pointed out by K. Voss and H. Gros a system of regulation by overflow can be adopted. In this case, the water level, after washing is just above the surface of the filter medium. This is achieved with the aid of submerged partitions which will ensure that the water is spread uniformly over the whole filter without disturbing the filter medium. The subsequent rise of water in this system gives an indication of how clogged the filter has become. When the maximum load is exceeded, part of the water flows into the backwash water channel and the noise signifies that it is time for backwashing.

4.2. Whole Treatment Systems.

4.2.1. Gravity Flows. The process and water flow arrangement should always be such that any unnecessary expenditure on energy of pumping is avoided. For instance instead of having both the low and high lift pumping stations, the treatment works could be sited on nearby hill while only low-lift pumping is done just to the treatment works and gravity flow supplies the consumers. Akinola (1984) noted that the major constraint against this is the settlement of our population on hilly terrains. However, our planners could look carefully into ways of diverting people's settlement to the valleys in future Development plans.

4.2.2. Mini/Peripheral Schemes. Akinola (1984) has pointed out the adage that "the strength of the chain is in the weakest link" is no truer in chains than in large and extensive water Schemes. A typical example in this regard is the New Ede/Osogbo/Ife/Gbongan etc. Water Supply Scheme covering so many big urban and rural areas at the same time. A disadvantage of this is that a breakdown of the scheme will lay off all towns and villages supplied simultaneously. Thus for the case of Ibadan Municipality, a study of 50km radius of the town will reveal sources that could be harnessed separately for peripheral water Schemes and which in fact will meet the City's ultimate demand if added together with the existing plant. If the points raised in Section 4.1. are applied to such schemes it can be shown the overall cost of supply will be much less and thus easier cost recovery.

5.0. RECOMMENDATIONS AND CONCLUSIONS

This paper has suggested some guidelines on the type of technology to adopt while expanding a Municipal Water Supply. The best index on the type of technology to adopt is the Marginal Cost of the proposed investment. Given a particular level of Government subsidy, the marginal cost should equate the sum of Government subsidy and Consumers maximum payable price for the given demand. If this is not feasible, then ways and means of "scaling down" the adopted technology must be looked into especially using local adaptation/substitutes for foreign components.

REFERENCES

1. African Development Bank Project appraisal for Ibadan Water Supply Schemes, 1986 (Unpublished)

2. David Holtz and Scott Sebastian: Municipal Water Systems - The Challenge for Urban Resources Management, 1978

3. Marshall, A. Principles of Economics (8th Ed.) London. Macmillan and Co. Ltd. (1920)

4. Jack Hirshleifer et al. Water Supply - Economic, Technology and Policy, University of Chicago Press (1963)

5. K. Vos and H. Gross. Optimization of Surface Water Treatment in Tropical Countries in "Developing World Water", 1981-1990"

6. World Health Organisation/World Bank Cooperation Programme - Water Supply and Sanitation Sector Planning Document, Oyo State of Nigeria, 1982.

7. Akinola J.K. Mini-Schemes for Rural Water Supply Development. Proceedings International Seminar on Water Resources Management Practices, Ilorin, Nigeria (1984).

FOOTNOTES

*The breakdown is as follows:

(i)	Salaries and Administration	= ₦6,450,851.04
(ii)	Operations and Maintenance	= ₦6,625,433.00
(iii)	Replacement and General Expenses	= ₦6,625,433.00
(iv)	Chemicals	= ₦9,992,212.44
(v)	Electricity Consumption	= ₦1,034,817.28
	Total	₦24,103,313.76

+In marginal cost pricing, the price of water is determined from the cost of supplying an additional unit of water. David Holt'z (1978) has pointed out that this definition is equivalent to viewing demands of water as the willingness of consumers to pay rather than viewing water use in terms of absolute demand by a projected population.