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## Design of water treatment plants in Kenya

Dr Maurice Mbede Ndege

### ABSTRACT

The goal of water treatment is the production of safe and reliable water to any consumer. There are several ways available that can be applied to ensure that the laid down standards are maintained. For a developing country like Kenya, difficulties in maintaining these standards arise due to a number of reasons. Appropriate technology, with operator and end user in mind, should be carefully evaluated by the design engineers to enable sustainability of such projects.

### INTRODUCTION

The ultimate goal of any water treatment is the production of potable and reliable water without excessive cost to the consumer. In general the principal guidelines in water treatment design will include:

- a. Simplicity, reliability, durability and economic feasibility of the design.
- b. The treatment process should produce water of high quality at a minimal cost.
- c. There should be uniform distribution of plant flow in individual treatment units through hydraulically balanced designs and layouts.
- d. The processes and equipments used should be simple to operate and maintain.
- e. The availability of labour and the local conditions like soil, climate and cultural values should be evaluated.
- f. Simple process controls with some justifiable degree of automation should be provided.
- g. Avoid/minimize, as much as is practicable, the importation of equipment and materials.
- h. Provide for possible future hydraulic overloading and some excess hydraulic capacity in channels, pipes and basins.
- i. Manufacturers and chemical supplies should be readily available to provide necessary service.
- j. Safe features should be provided.
- k. Provide good access to all process units and a centralized plant operational control board.
- l. Plant wastes should be easily disposed of to reliable and good sites.
- m. Evaluation of public attitudes toward plant location and operation should be carried out.
- n. A thorough investigation of alternative sources of water and power should be carried out.

These fourteen items listed above are important considerations in water treatment plant design. As for Kenya, items a through l are particularly relevant.

Technological conditions in developed and developing countries are different. Applications of advanced technologies have often been of little value to developing countries. On numerous occasions projects have failed or been abandoned due to the inappropriateness of the technology used. In appraising new water treatment technologies, only engineers who are familiar with local conditions should modify and develop new technologies to meet the local needs. In this process, the local engineer must consider, among others, the following major considerations.

- a. Understand the local politics.
- b. Understand the national sanitation and pollution policies.
- c. Know the local codes, the drinking water standards and material specification.
- d. Understand the local traditions, customs and cultural beliefs on the construction and operation of the treatment works.
- e. Availability of both skilled and unskilled personnel.
- f. Check on the availability of local construction materials, chemicals and equipments to be used.
- g. Limitation of the available capital.

### DESIGN RECOMMENDATIONS FOR KENYA

The following water treatment units are recommended:-

- flow measurements
- prolonged storage
- infiltration
- coagulation
- flocculation
- sedimentation
- filtration
- disinfection
- aeration

Before a treatment works is designed, an investigation conducted on whether it would be feasible to use an alternative source with better raw water quality should always be conducted. The WHO guidelines have been adopted for use in Kenya. Bacteriological quality is centred on the number of faecal coliforms and coliform organisms per 100 ml of the sample. Indication as to the treatment

Table 1: Raw water guideline values

Class	Coliform organism	Type of treatment N/100 ml
1	0 - 50	Disinfection only
2	50 - 5000	Full treatment required (coagulation, flocculation sedimentation, filtration & disinfection)
3	5000 - 50 000	Highly polluted, require extensive treatment
4	above 50 000	Very, very polluted, needing special treatment. Usually unacceptable as source

required for raw water is given in Table 1 while Table 2 gives the permissible aesthetic quality in cases where it is not possible to produce water of desirable aesthetic quality for domestic purposes as per the WHO guidelines.

In case 40% of the number of coliforms are found to be of the faecal coliform group, the source needs extensive treatment.

There should be a thorough evaluation before selection between conventional treatment, direct filtration or in-line filtration.

#### Flow meters:

A V notch weir or a flume is the most suitable type of flow rate measuring device. The Thompson weir is suitable for quantities up to 50 l/s. The Parshall flume has the advantage over other flow measurements as it can be constructed from the locally available concrete and it contains a hydraulic jump which minimizes clogging and enhances chemical mixing. The flumes are located at high enough elevations such that outlet head loss does not constrict flow at peak and future flow rates.

#### Prolonged storage:

This serves a threefold purpose:

- algal activity

- ultra violet rays in sunlight
- improves reliability

The storage basin is constructed by erecting a simple earth dam up to a height of 6 m with a dead storage of about 2m and a detention period ranging from several weeks to a few months. This stage serves as a pre-treatment process.

#### Infiltration:

This is employed where the water source is either a lake or river and a need exists for artificial recharge. Bank filtration is the most commonly applied method. A distance of 50 m or more from the source to the recovery point is recommended to ascertain both the bacteriological and chemical quality of the water.

#### Coagulation:

Aluminium sulphate (alum) is the used coagulant. If pH control is necessary, lime, not caustic soda, is first considered due to its lower cost and better safety in handling. Three types of chemical mixing used are rapid, gravitational and mechanical mixing. Gravitational mixing is the most commonly used and involves feeding the chemical into a baffle chamber, an overflow weir or a hydraulic jump. It is important to have the coagulant continuously fed. Mixing time has to be within 1-10 sec with G-values between 500-1000s<sup>-1</sup>.

Table 2: Permissible Aesthetic Quality

Parameter	Unit value	Guideline
Chloride	mg/l	600
Colour	TCU	50
Copper	mg/l	1.5
Iron	mg/l	1.0
Manganese	mg/l	0.5
pH	-	6.5-9.2
Solids	mg/l	1500
Turbidity	NTU	25
Zinc	mg/l	15

**Flocculation:**

This can be accomplished through the use of gravitational and mechanical mixers. Gravitational flocculation is the more commonly used method with baffled chambers designed for channel velocity of 0.1 to 0.3 ms for the first 2/3 of the chamber and 0.3 to 0.4 ms for the last 1/3 of the chamber.

Preliminary jar tests are valuable in establishing design criteria for both flocculation and sedimentation. Baffled channels can either be the over-and-under type or the round-the-end type. The over-and-under baffled channels possess good mixing with very little short circuiting but have high head losses across the channel. The round-the-end type baffled channels have variations in mixing intensity and time due to variations in flow but have low head losses across the channel.

Other important considerations for enhancing flocculation include:

- the velocity gradient, G
- flocculation time, T
- utilization of tapered mixing.

The detention period should be 15-20 minutes, while the velocity gradient should be 30-605-1. The value of GT ranges between 104 to 105.

**Sedimentation:**

Horizontal and upflow settling tanks are the two basic types in use. Upflow settling tanks perform well under certain strict operational conditions:

- relatively constant hydraulic loadings
- relatively constant rainwater quality
- carefully operational control by qualified operators

These conditions are difficult to satisfy continuously, making upflow tanks generally not suitable for rural or urban water supplies except under very exceptional circumstances.

Horizontal flow tanks are the most commonly used for the following reasons:

- the process is cost effective for large scale water works (say over 0.5<sup>3</sup>/s flow rate)
- the process is easy to operate and maintain
- predictable performance under most operational and climatic conditions is possible
- the process can be tolerable to shock hydraulic and water quality loads

The most common basic design criteria for horizontal tanks are:

**Filtration:**

- surface loading often chemical coagulation and flocculation of 1.0 m<sup>3</sup>/m<sup>2</sup>.h
- determination time - 2 to 4 hours
- the ratio length/width between 3:1 and 6:1
- effective water depth - 3 m minimum

Filtration is a physical and chemical process for separating suspended and colloidal impurities from water by passage

through porous media. In the past 30 or 40 years there has been very little change in the basic filtration design concepts. Modifications such as multi-media filtration, deep-bed coarse single medium filtration and use of polymers as filter aids, have substantially improved particle removal.

Presently, the most commonly used types of filter in Kenya are those which depend on the type of filter rate control of which the two basic types are:

- slow sand filters 1.0-1.4 m thick with effective sand of size between 0.15-0.35 mm and the uniformity of coefficient of 2-5. Surface loading rates of 0.1-0.2 m<sup>3</sup>/m<sup>2</sup>h
- rapid sand filters 0.7-1.0 thick with effective sand size of between 0.5-1.0 mm normally 0.6-0.8 mm and the uniformity coefficient not exceeding 1.5 surface loading rates of 5 m<sup>3</sup>/m<sup>2</sup>h

Economical factors have made the slow sand filters the most commonly used types even where turbidities of waters are between 100-200 NTU as opposed to the recommended 10 NTU for best performance. Rapid sand filters tend to clog relatively fast and are used in big water works in towns generally. Backwashing of the filters needs a careful operation so as not to lose a lot of the finer grained media.

**Disinfection:**

Water disinfection is a process by which pathogenic micro organisms are destroyed, thus providing essential public health protection. Chemical disinfection using calcium hypochlorite or tropical chloride of lime is commonly used. Gas disinfection is not recommended. Feeding the chemicals is by gravity dosers or displacement dosers with recommended contact period of 30 minutes in the clear water tank. A survey in most rural water works showed that almost no disinfection is carried out as the shortage of the disinfectants is paramount.

**Aeration:**

The use of aerators of the cascade or multiple tray types and diffusers with surface loading of 30-70 m<sup>3</sup>/m<sup>2</sup>h levels of Iron and Manganese in the surface waters is very high. Ground water aeration is necessary. Usually this process proceeds sedimentation or filtration of Iron or Manganese laden high water.

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**CONCLUSION**

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Detailed design of water treatment plants requires special consideration of many factors. Paramount among these factors is the availability of capital, raw materials, equipment, chemicals and skilled labour. Proper evaluation of these factors can lead to construction of a highly efficient facility that requires little operation and maintenance. The real problem in any treatment works is particle separation. In Kenya, concentrated efforts in pre-treatment would be very economical in the long run. The design engineers should carefully evaluate the different options and advice in a more reliable and sustainable process.

