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Water quality monitoring in Kenya

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ABSTRACT

The water quality control situation has been reviewed briefly and a discussion on the applicability of water quality modelling has then been presented. It is the view of the authors that water quality models could be of use in ensuring good quality of Kenya's water bodies both in the short and the long term.

KEYWORDS

Water quality modelling, water pollution, water quality standards, integrated long term planning, the systems approach.

INTRODUCTION

Models are idealisations of real life situations that are applied to predict the effects of alternative plans of action thereby indicating the suitability of each in solving the given problem/s. Models thus help in proper decision making. The degree of idealisation depends among other factors on the problem/s at hand, the data available or that could be availed in good time and also the availability of funds. The simplest model that gives the required information is usually the most preferable. As models are idealisations of real life it is required that they be verified using field data before their application.

For water quality control, various parameters that indicate the level of pollution exist. These include dissolved oxygen (DO), suspended solids, chemicals toxic to aquatic and terrestrial life (cyanide, heavy metals, sulphides, pesticides and their residues), phosphorus, nitrates and P^H. Among these, DO is generally the most important and critical in Kenya where most pollutants are agro-based industries with highly organic effluents.

Many water quality models have been developed. They vary from relatively simple ones(eg. the Streeter-Phelps BOD-DO model) to complex multidimensional multiconstituent models (ref.1). The more complex the model, the greater the data and computational effort required. Solution of some models may simply require the use of a calculator while others may need a powerful computer. For a specific problem, more complex models generally give more comprehensive information.

The scope of application of water quality models varies widely. A model may be used to predict the impact of an industry on a nearby stream while a more complex one could be applied to predict the effects of alternative locations and types of landuses(agriculture, urbanisation, industrialisation) and water treatment facilities on the long term water quality of a river basin. If other impacts of the alternatives (for example economic and conservation) are incorporated into the problem with the aim of optimisation, this gives rise to the systems approach. This approach is applied in the U.S.A. (ref.2) and has been proposed for future use in Ghana (ref.3).
Water quality models could also be be designed to estimate the effluent standards of discharges that will be necessary so that some set recieving water standards are not violated.

WATER QUALITY CONTROL IN KENYA

Pollution sources

As reported by Omwenga (ref.4) water pollution in Kenya is mainly caused by industries, farming activities and urbanisation. The major pollutants are;
- liquid and solid wastes from industries.

-fertilisers, pesticides and their
residues as leachetes and in runoff
from agricultural lands.
-liquid and solid wastes from urban
areas
-accidental chemical spills
Nyaga (ref.5) indicated that the ma-
jor sources of industrial wastewate-
ers are agro-based industries locat-
ed in the rural areas. The main po-
lluting industries are wet processi-
ing of coffee, sugar cane milling,
leather tanning, sisal factories,
paper mills, caneries, textile mill-
s and breweries. Nyaga further ind-
icated that the quality and quantity
of the effluents from these industr-
ies and those based in urban centre-
s is not well known. The total est-
imate of the daily volume of efflue-
nts was put at 8.3 million cubic
metres.

Water quality monitoring

The Ministry of Water Development
(MOWD) operates a water quality mo-
nitoring network covering all the
major rivers,lakes and aquifers.
The criteria used in locating the
sampling stations includes;
-the location of hydrological monit-
oring stations
-the acquisition of reference basel-
ine data at the upper reaches of
river systems
-the monitoring of effluents from
wastewater treatment works and
industries
-the immediate use of the water
-accessibility
Samples from the monitoring stations
and also from water supply works are
submitted to MOWD for analysis on a
regular basis.

Water quality standards

The generalised effluent standards
for discharge into water sources
is as follows;
Biochemical oxygen demand(BOD) < 20 mg/l
Chemical oxygen demand (COD)   < 50 "
Suspended solids (SS)   < 30 "
Nitrates   < 30 "
Sulphides   < 2 "
Heavy metals (combined)   < 1.0 "
pH   6.5-8.5

Alterations to these standards are
made for specific industries depend-
ing on processes involved, the expe-
cted volume of effluents, the dilut-
ion capacity of the stream and the
downstream use of the water. No re-
cieving water quality standards exist.
Enforcement of effluent standards

Pollution control is undertaken by
the MOWD pollution control unit.
The unit undertakes analysis of sam-
ples from the effluents of industries
and institutes legal action against
violators.

DISCUSSION

Water quality standards

Although MOWD does not apply reciev-
ing water standards, the fact that
the dilution capacity of the stream
and the volume of effluent discharg-
ed are considered in setting specif-
ic effluent standards implies the
existence of recieving water standa-
rds. The formulation and setting of
explicit recieving water standards
would however be more effective in
ensuring good water quality than the
effluent standards alone. If model-
ling is incorporated in water quali-
ty control, recieving water standar-
ds would be necessary.

Applicability of modelling for water quality control in the short term

The MOWD's procedure of setting eff-
luent standards considers the dilut-
ion capacity of the river as the on-
ly relevant characteristic. This
implicitly assumes that the polluta-
nts are conservative. This could be
considered the case over only short
river stretches with most pollutants.
To illustrate the applicability of
modelling, DO is taken as an example.
The DO concentration is affected by
sources and sinks.
The sources include;

Atmospheric rearation which could be
described by equation(eqn.) 1.

$$\left(\frac{\partial c}{\partial t}\right)_a = K_a(C_s - c) \quad --- (1)$$

where C_s and C are the saturation and
actual concentration respectively
and K_a is a value depending on the
degree of turbulence and hence the
slope and roughness of the channel.

Photosynthesis by algae which could
modelled by eqn.2.

$$\left(\frac{\partial c}{\partial t}\right)_p = P_m \left[\frac{1}{\pi} + \frac{1}{2}\sin\frac{\pi t}{12} - \frac{2}{3\pi}\cos\frac{2\pi t}{12}\right] \quad --- (2)$$

where P_m is a value reflecting the
maximum rate of photosynthesis and t

is the time in hours after the commencement of photosynthesis.

The sinks include;

Carbonaceous and nitrogenous BOD (CBOD and NBOD) as described in eqn. 3 and 4 respectively where K_d and K_n are coefficients and L and N are the ultimate CBOD and NBOD respectively.

$$\left(\frac{\partial c}{\partial t}\right)_B = -K_d L \quad --- (3) \qquad \left(\frac{\partial c}{\partial t}\right)_N = -K_n N \quad --- (4)$$

Respiration by algae expressed as

$$\left(\frac{\partial c}{\partial t}\right)_R = -R \quad --- (5)$$

where R is a constant depending on the characteristics of the algae.

Benthic deposits at the bottom of the channel which could be expressed by eqn.6.

$$\left(\frac{\partial c}{\partial t}\right)_B = -B \quad --- (6)$$

If advection is considered as a sink and be expressed as

$$\left(\frac{\partial c}{\partial t}\right)_u = -u \frac{\partial c}{\partial x} \quad --- (7)$$

then the DO balance for a stream may be expressed by eqn.8.

$$\frac{\partial c}{\partial t} = -u\frac{\partial c}{\partial x} + K_a(c_s-c) + P_m\left[\frac{1}{\pi} + \frac{1}{2}\sin\frac{\pi t}{12} - \frac{2}{3\pi}\cos\frac{2\pi t}{12}\right]$$
$$- K_d L - K_n N - R - B \quad --- (8)$$

Solution of eqn.8 may be sought analytically or may require numerical procedures depending on the boundary conditions and the dependence of the parameters of the eqn. on distance (x) and time (t). The solution would give values of the DO concentration c as a function of x and t. These concentrations could then be compared with the set standards. A model may be designed to include an interactive procedure for determining the limiting effluent standards so that the set stream standards are not violated.

The adequacy of the MOWD method needs to be checked. This could be done by determining whether once the industries are established, the water quality downstream is as the procedure had predicted. If significant discrepancies arise, then more comprehensive methods incorporating the other relevant characteristics apart from dilution capacity may be better to use. Such exercises could be considered as part of the studies for the design and establishment of the industry. The costs involved could thus be met by the developer.

In the modelling, other features like wetlands that have been found to improve water quality significantly (ref.6) could be included.

Applicability of modelling for long term water quality management

As indicated by Pavoni (ref.2), the main usefulness of water quality models is their ability to project some future condition based on measurements of the past and the speed and efficiency with which a range of alternatives may be evaluated. In Kenya, the population is still growing at a high rate and the demand for fresh water continues to rise as a consequence. Development activities such as industrialisation and irrigation continue to stiffen competition for the country's water resources and also increase the potential of pollution.

In the light of these facts, the need for long term planning for the management of water quality is obvious. For such planning to be effective, an integrated approach to land and water use is necessary. Such planning has to be multiobjective, multipurpose and multidisciplinary (ref.7). It has to use the systems approach and thereby incorporate water quality modelling.

The planning should be dynamic utilising new more appropriate techniques and data as they become available. For instance;
-cheaper and more effective treatment methods of water and certain industrial wastes may be developed.
-research may give rise to better methods of modelling components of the system.
-new data may neccesitate recalibration of some of the models used.
-there may be decline in fertiliser and pesticide use in preference of more environment friendly methods of such as organic farming.
-trends in population may vary considerably from forecasts previously used.

In water masterplans, water quality should be taken seriously. In the stage 1 Kenya National Master Plan study (ref.8) no quantitative analysis of water quality was undertaken as opposed to other aspects such as hydro-electric power and irrigation. To undertake such studies, water qu-

ality models would be of use.

CONCLUSIONS AND RECOMMENDATIONS

1) To aid in effective water quality control, there is a need to formulate recieving water standards.
2) The adequacy of the method currently used by MOWD to set effluent standards should be checked. If proved inadequate, more comprehesive procedures that incorporate other relevant stream characteristics apart from dilution capacity may be better to use.
3) There is a need for long term integrated planning for the use of land and water resources in Kenya. This would help in ensuring the long term maintenance of water quality and the optimal use of the land and water resources. It calls for the use of the systems approach and hence water quality modelling.
4) Water quality, like the quantitative aspects of Kenya's water resources should be given adequate attention in the current and future master water plan studies.

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