# INDUSTRIAL POLLUTION CONTROL OF ROSETTA BRANCH, NILE RIVER, EGYPT

**N. Donia*, I. El-Azizy** and A. Khalifa*****

* Lecturer, Eng. Dep., Institute of Environmental Studies and Researches, Egypt
** Associate Professor, Faculty of Engineering, Egypt
*** Professor of Hydraulics, Faculty of Engineering,
Ain Shams University, Egypt

## ABSTRACT

In Egypt, Rosetta branch, one of the two main branches of the Nile River, is impacted by several industrial companies at Kafr El-Zayat City which potentially affect and deteriorate its quality of water. The main objective of this paper is to develop a water quality control software in order to define the quantity and quality of waste loads, the degree of treatment to the wastes needed before discharging them into the water, to select the optimum treatment alternative and to predict the effect of a proposed waste effluents on the downstream quality especially at the drinking water plants abstraction points.

**Key Words:** Water Quality Modeling, Pollution Control, Water Quality Control, Optimum Treatment.

## 1. PROBLEM DEFINITION

The main River Nile when reaches to the Delta is divided into two branches Rosetta and Damiata branches. The Rosetta branch flows downstream Delta Barrage to the North-West where it ends with Idfina Barrage which releases excess water to the Mediterranean Sea, see Figure (1).

The Rosetta branch water serves for a wide range of functions including agricultural, industrial and domestic water supply, fisheries and recreation. But unfortunately the Rosetta Branch is impacted by several industrial companies at Kafr El-Zayat City. These industrial outfalls are El-Mobidat, El-Malyia and Salt and Soda companies which are discharging directly at the east bank of the branch. Therefore the water quality deterioration is pronounced, the high values of water turbidity were recorded at Kafr El-Zayat, also high values of BOD, Phosphates and TDS, (EEAA [2]).

## 2. THEORETICAL APPROACH

A water quality control software for Rosetta Branch has been developed using the visual basic programming language. The purpose of the software is to allow decision makers to evaluate the implications of policy related water quality control measures to performance standards and economic instruments. Rosetta Water Quality Control software integrates the water quality modeling and the water quality control policy using:

- A database in which the key elements of the problem are defined; The Water Quality Control Software use five different databases: The watershed database, the pollution sources database, the treatment alternative database and the scenario database.
- A control model which is capable of simulating various flow, load and policy conditions and generating optimal solutions for user specified problems;
- An interface which is rich, functional and flexible to provide operations in water quality control.

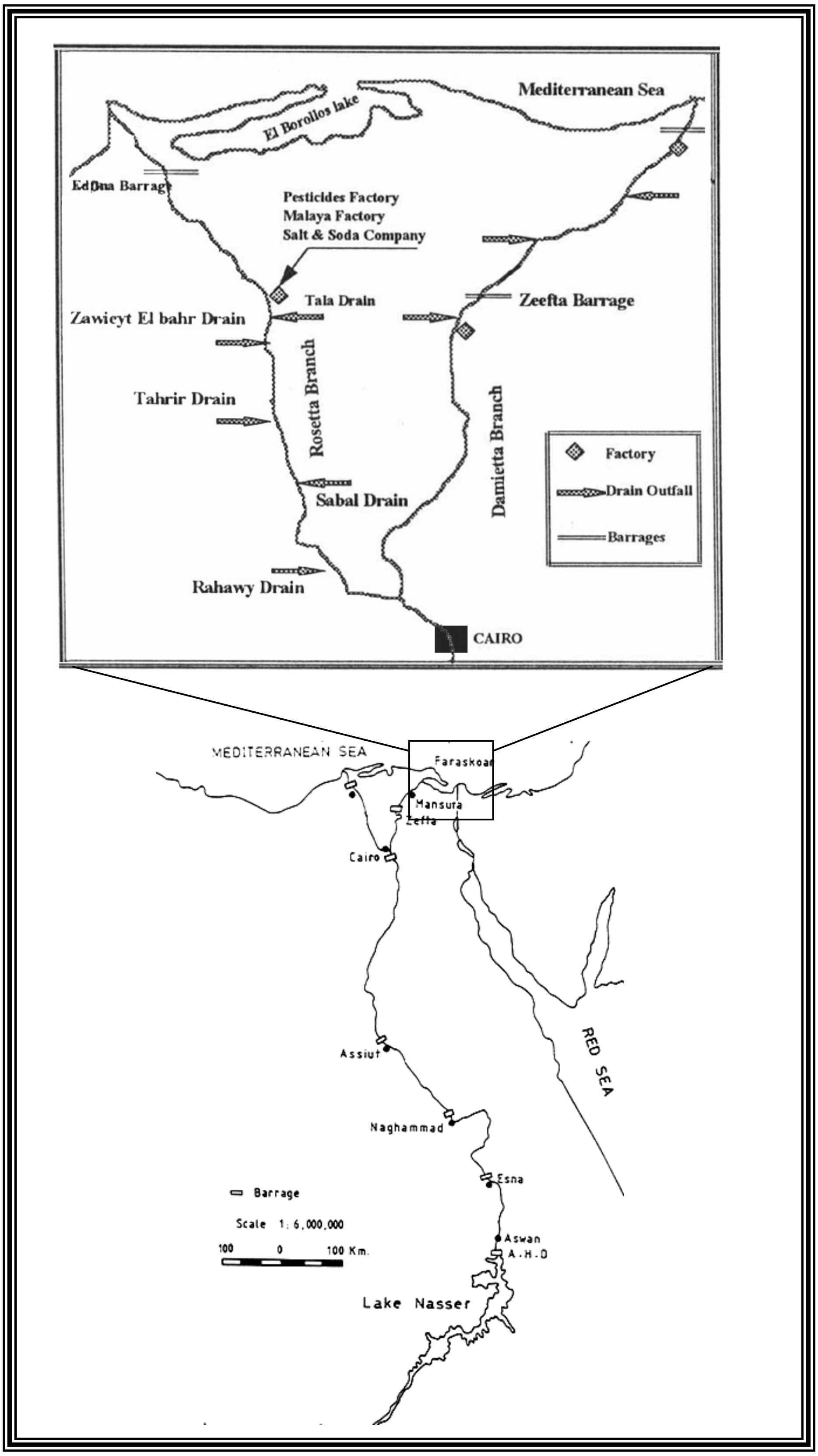



**Figure 1** Location Map of Rosetta Branch of the Nile River

## 2.1 Model Databases

The Water Quality Control Software uses five different databases:

- **The Stream Database**
  In this software, the basic unit for water quality management is a stream. A stream is modeled as a network and a set of point sources along it. Rosetta Branch was divided into 15 sections as shown in figure (2). The river network consists of river sections which can be considered as administrative units for water quality management.

- **The Pollution Sources Database**
  Three different source types can be handled with the water quality control model; the municipal, industrial and agricultural sources. The data includes the pollution source name, type and location.

- **The Treatment Alternatives Database**
  The data includes effluent discharge, treatment technology and plant capacity for alternatives. These parameters have implications on capital cost (IC), operation, maintenance and replacement (OMR) cost and treatment efficiency (which indicates effluent water quality), (USEPA [5]).

- **The Scenario Database**
  Water Quality Control Software is a tool for analyzing different scenarios. For example, scenarios are created by changing the treatment levels of point Sources. The scenario database consists of data related to treatment alternatives at the treatment plants.

- **The Standard Database**
  The standards database includes data about the local and global and ambient standards of rivers water quality. Egyptian guidelines were taken as reference for the ambient water quality of the Rosetta Branch and the European standard was taken as reference for the use of the river water for drinking abstraction or and fishing.

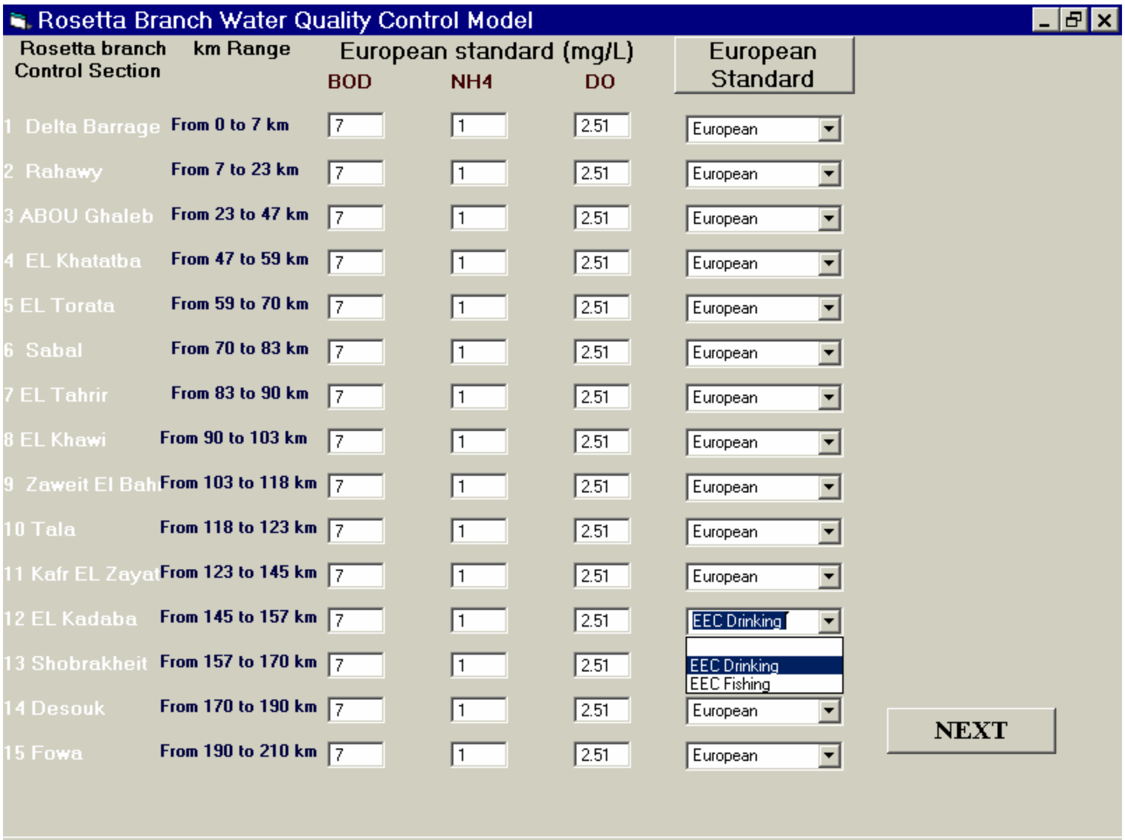



**Figure 2** The Rosetta Branch Control Sections represented in the water quality software

## 2.2 The Water Quality Control Model

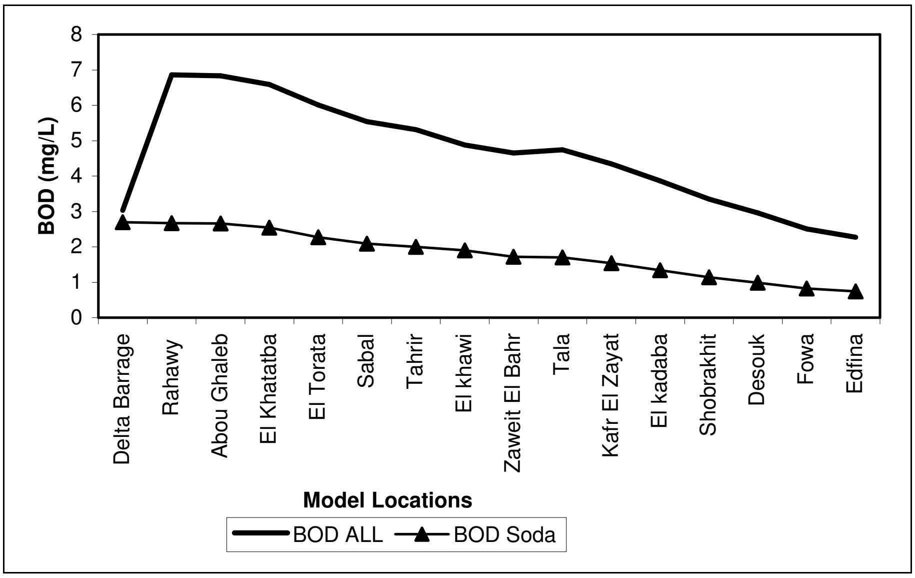
The developed control model consists of three major models:

### 2.2.1 The Simulation Model

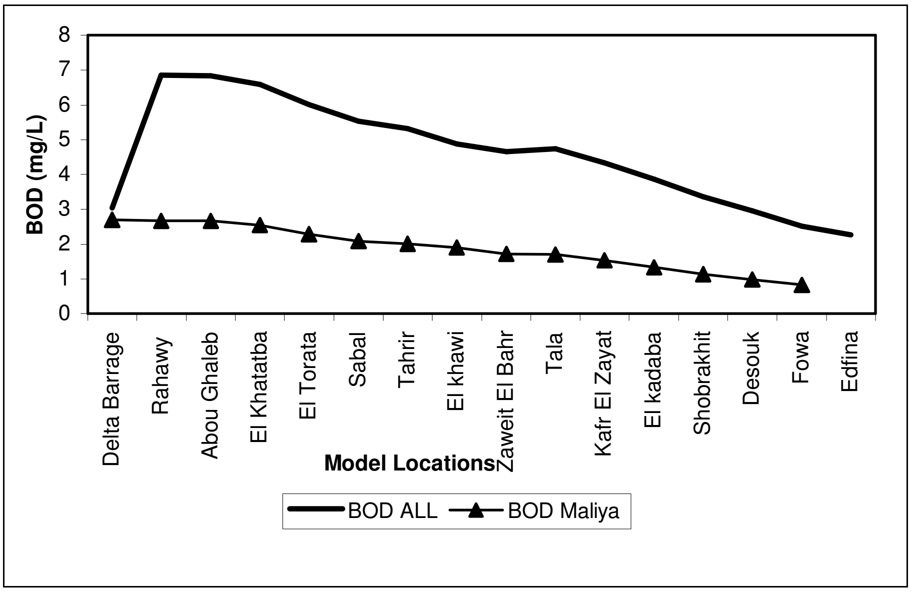
(The DUFLOW package, Version 2.05) was used for the simulation model (ICIM [3]). It simulates the one-dimensional unsteady flow in open channel. A dissolved oxygen module was built within the DUFLOW package to simulate the water quality parameters (Dissolved oxygen (DO), biochemical Oxygen demand (BOD) and Ammonia ($NH_4$)).

The model was evaluated and was calibrated based on field and historical data. Once the model has been successfully calibrated and verified, its predictive ability should be further considered by sensitivity analysis. This involves a study of the extent to which the models accuracy in prediction is affected by changes in the inputs to the model.

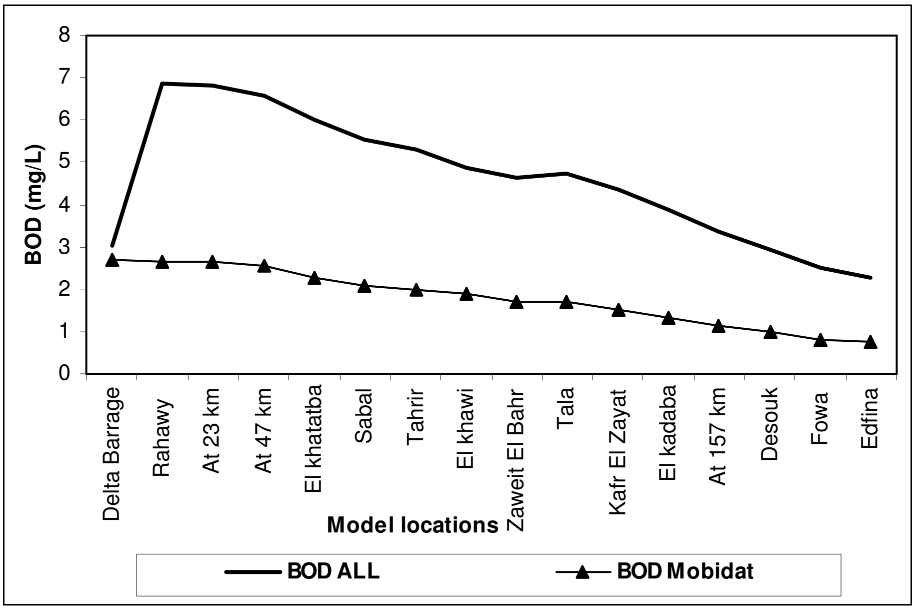
The effect of each pollution source separately is analyzed. This was done by calculating the change in the BOD concentration in Rosetta Branch due to each pollution source and comparing this effect with the present status. The fluctuation of BOD for the two factories (Salt and Soda factory and Maliya factory), is low than in case of Mobidat factory as shown in graphs (1, 2 and 3).




**Graph 1** Effect of Salt and Soda Factory on BOD Profile along Rosetta Branch




**Graph 2** Effect of Maliya Factory on BOD Profile along Rosetta Branch




**Graph 3** Effect of Mobidat Factory on BOD Profile along Rosetta Branch

### 2.2.2 The Economic Model

The economic model includes the function that calculates the cost of each treatment alternative. It is the sum of the capital cost and the operation and maintenance (OMR) costs. A present value analysis was conducted on the calculated costs. The costs were updated to current values using construction and labor cost indexes.

Unit cost information was obtained from (Vernick and Walker [6]) and from (Arceivala [1]) describing the cost of each wastewater treatment method. It is obtained also from (Nemerow and Dasgupta [4]) describing industrial waste treatment practices and costs for specific industries. These cost data are generalized rather than site specific and are intended primarily for comparative analysis. The user of the model should be cautioned against considering the estimates as absolute. Rather, they should be used for comparative estimating purposes and as a general guide for determining cost values.

With respects to the factory treatment processes cost, the costs of the flotation, clarification, lagooning and activated carbon processes were obtained from the fact sheets described in (Vernick and Walker [6]). These cost curves constitute the input to the model; each type of cost is obtained by entering the value of the effluent discharge of each pollution source and getting the corresponding cost value from the cost curves. The total cost of coagulation process was found to be 982,000 dollars for capital cost and 328,000 dollars for OMR cost, (Arceivala [1]).

### 2.2.3 The Optimization Model

The optimization model was developed to decide the optimum degree of treatment to the wastes needed before discharging them into the water. This optimum treatment alternative must satisfy with the objective function of cost minimization and must comply with the input water quality objectives or standards.

In the optimization model, the user must specify the objective functions and the possible constraints. The objective function is formulated as cost minimization subject to one or more constraints. The constraints specified by the user are the water quality standards at the control sections. They can be the ambient water quality standards or the standards corresponding to the required use in this control section (drinking, fishing,…).

In the objective function, cost can be specified by the sum of the total annual cost for all the treatment plants. The total annual cost of each plant is given by the sum of operation, maintenance and replacement costs and the capital cost which is transferred to an annual base.
The objective function was expresses by the following equation (1):

$$\text{Objective function} = \min \sum_{i,a} C_{Capital}[i, a] + C_{OMR}[i, a] \qquad (1)$$

Where,
$C_{Capital}$ : The capital cost associated with the design alternative
$C_{OMR}$ : The OMR cost associated with the design alternative.
i : Index denoting a point source.
a : Index denoting a design alternative for a point source.

Subject to the following constraint:

*Ambient Water Quality Standards*

Constraints an ambient water quality of each constituent for all sections in terms of concentrations: The concentration maximum or minimum can be expressed by equation (2) and equation (3) as follows:

$$Z[i, j] \le Z_{Max}[i, j] \qquad \forall\, i, j \in \{\text{harmful constituent}\} \qquad (2)$$

$$Z[i, j] \ge Z_{Min}[i, j] \qquad \forall\, i, j \in \{\text{useful constituent}\} \qquad (3)$$

Where,
$Z_{Max}$ : The maximum allowed concentration for a harmful constituent
$Z_{Min}$ : The minimum required concentration for an useful constituent
i : An index denoting a point source
j : An index denoting a design alternative for a point source

The user can choose single or multiple source optimizations. Using the optimization model, the optimum control policy is selected. This selection requires data about the alternative treatment technologies for various pollution sources. The type of treatment processes associated with each pollution source and the corresponding removal efficiency. The water quality model determines if this alternative is compatible with the given constraints. The compatible alternative with the minimum cost is the optimum treatment alternative for this pollution source.

For each design alternative, the water quality is estimated at the river sections using the simulation model. The design alternative is discarded if it does not meet with water quality requirements. When the optimization procedure reaches the end section, the set of feasible solutions (the solutions satisfying the water quality requirements) is completed. Among these solutions, the one produced by the set of wastewater treatment alternatives with the smallest values of the objective function is the optimum solution.

Following the selection of alternative processes applicable for the treatment of a particular waste, the cost of each process constitutes the most significant criterion for the selection of a final process design. The technique used by the water quality model to optimally allocating waste water treatment alternatives is illustrated in figure (3).

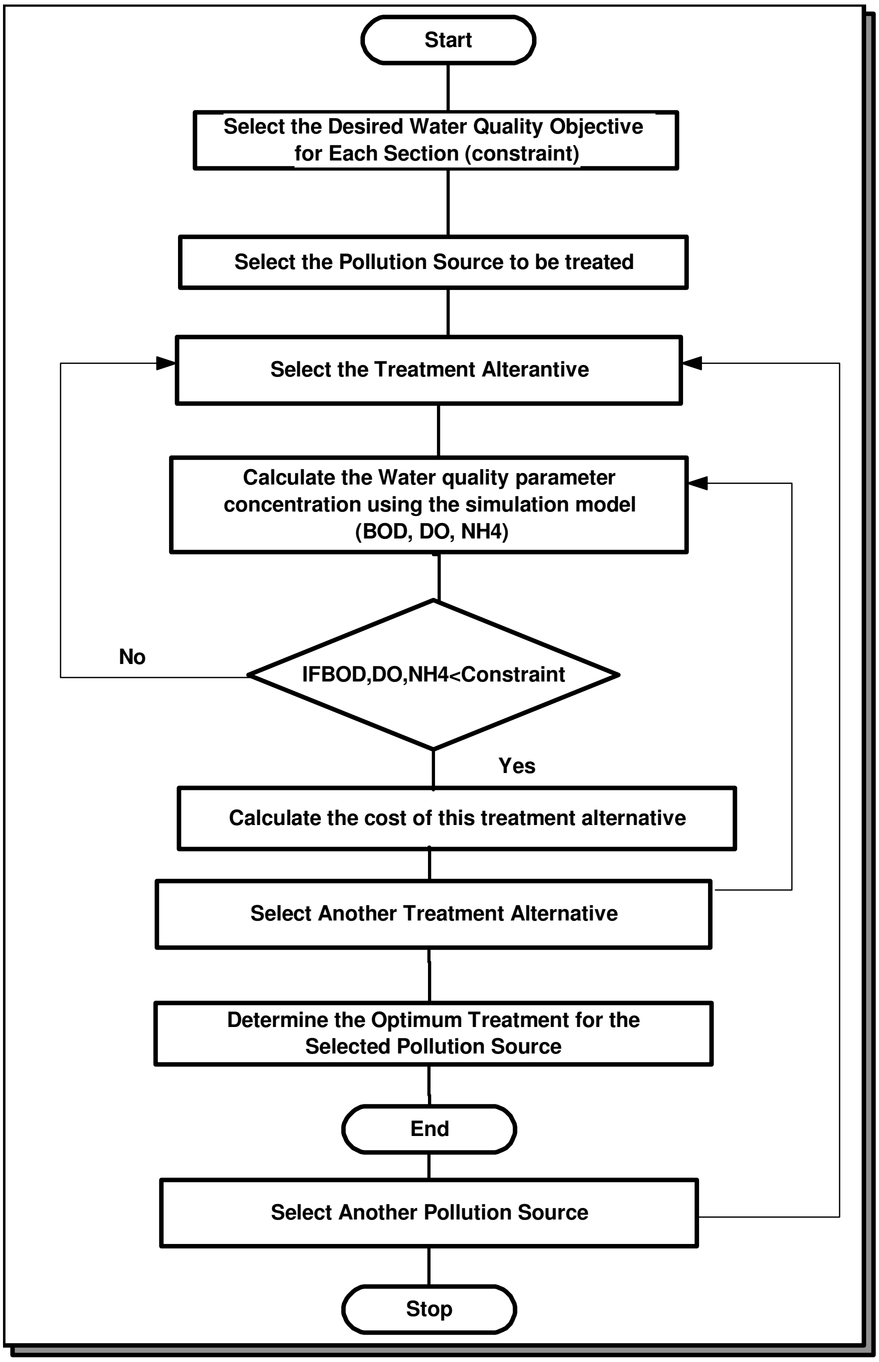



**Figure 3** Flowchart for optimization model

## 3. INDUSTRIAL POLLUTION CONTROL SCENARIOS

The first control scenario uses the single point source optimization option of the water quality control model. The first control scenario was designed to select the optimum treatment alternative of each factory. The water quality objective is to satisfy the Egyptian water quality standards at the discharge section. The treatment cost for each treatment alternative was calculated for each factory. Figure (4) shows the result of cost calculation of the Salt and

Soda Factory as example. The simulation results indicate that the for the Salt & Soda factory, the coagulation is the optimum treatment alternative. The mechanical clarification option is the optimum treatment alternative in case of Mobidat factory whereas for the Maliya Factory, the precipitation with $CaCl_2$ is the optimum treatment alternative.

Whereas the second control scenario uses the multiple point source optimization option of the water quality control model. The second control scenario was designed to select the optimum treatment alternative of each factory along the branch to satisfy with the required water quality objectives. The water quality objective is to comply with the drinking water quality standards at the discharge section. The simulation results as shown in figure (5) indicate the optimum treatment required for each pollution source to satisfy with the water quality objectives. They show also that the total cost of treatment of the three factories in order to satisfy with the required water quality objective.

## 4. CONCLUSION

Finally, the water quality control software was successfully developed to allow decision makers to evaluate the implications of policy related water quality control measures to performance standards and economic instruments. Applications demonstrate that the developed Rosetta Water Quality Control software was designed to assist in the evaluation of alternative strategies for water quality control of Rosetta Branch. Therefore, it can be used by decision makers as a tool to quality management and resource allocation, in order to achieve designated water quality objectives.

## 5. RECOMMENDATIONS

Based on the results of this study, further studies are recommended. These include the specification of stream water quality objectives as an essential part of the Egyptian Water Quality guidelines program, the estimation of base flow and seepage into the simulation model and the construction of data information centre to provide required information of decision makers and promoting awareness and a sense of participation in the study area community. This study is expected to help the decision maker to take the suitable actions to improve the water quality of Rosetta Branch.

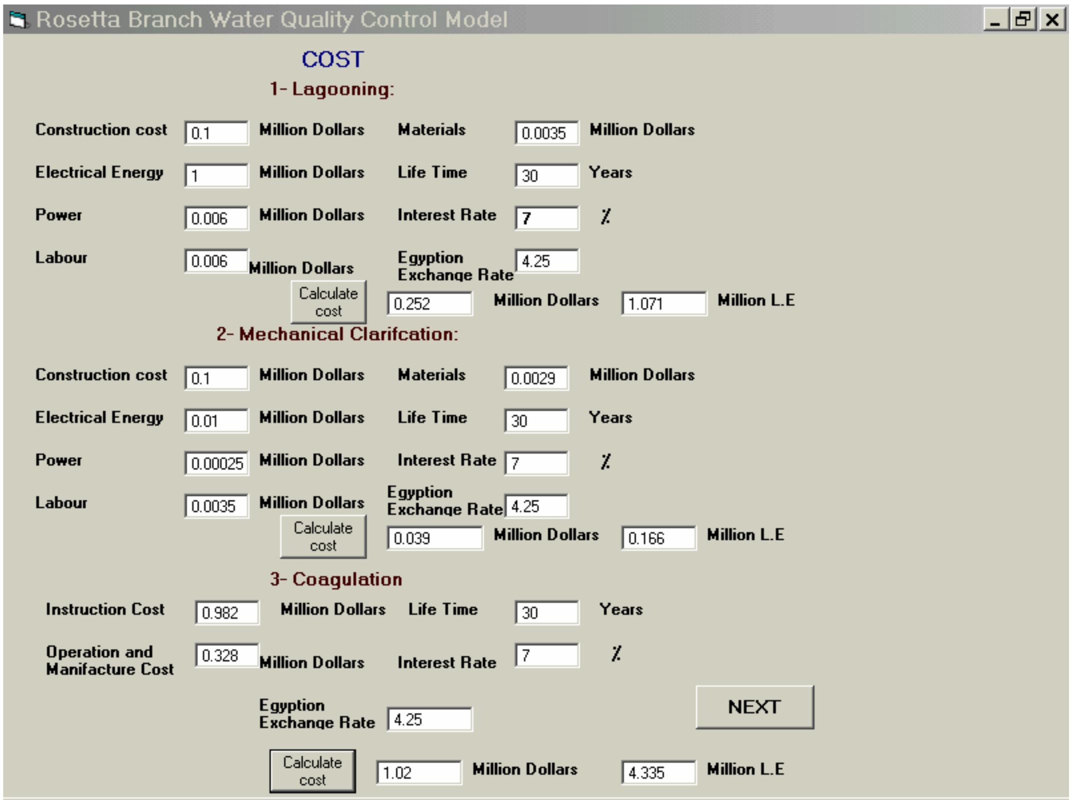



**Figure 4** Result of Cost Calculation for Salt and Soda Factory

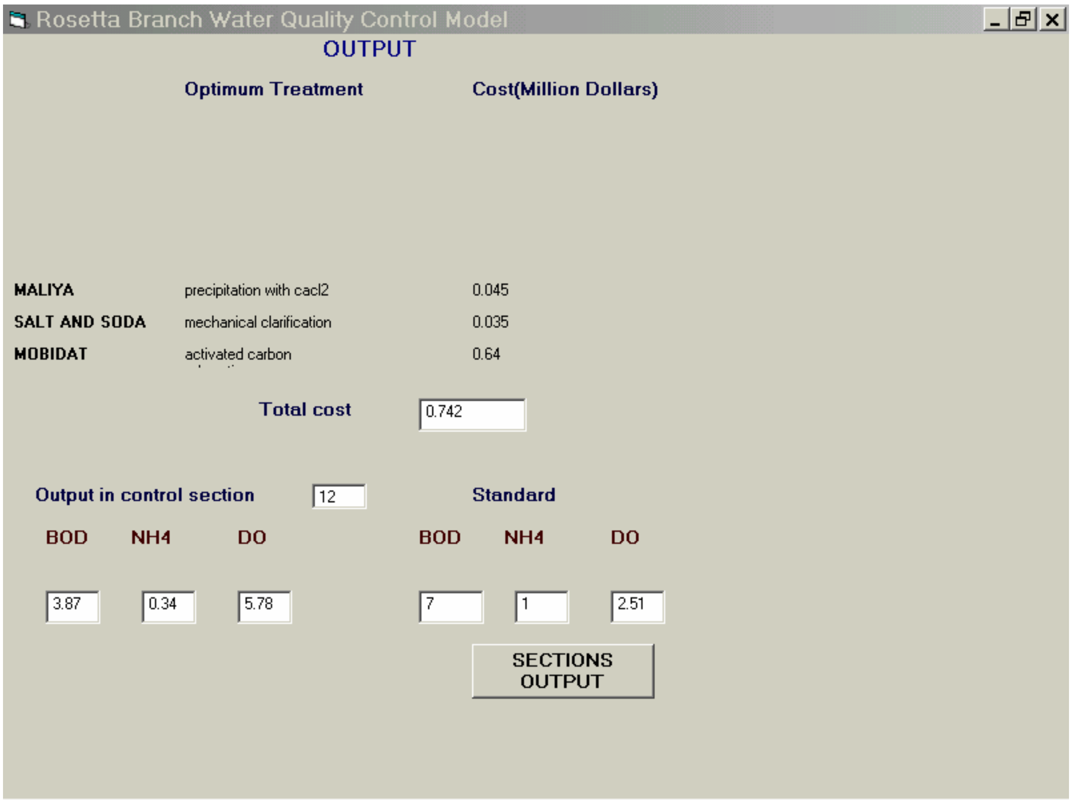



**Figure 5** The Optimum Treatment Alternatives of Factories along Rosetta Branch

## REFERENCES


1. Arceivala, Wastewater Treatment for Pollution Control, Tata McGraw-Hill Publishing Company Limited, New Delhi, 1996.

2. EEAA, Industrial Wastewater Pollution Abatement in Kafr El-Zayat, Pre-Feasibility Study, Technical Cooperation Office for the Environment, 1994.

3. ICIM, DUFLOW - a Micro Computer Package for the Simulation of One Dimensional Unsteady Flow and Water Quality in Open Channel Systems, Bureau ICIM, Rijswijk, The Netherlands, 1995.

4. Nemerow and Dasgupta, Industrial and Hazardous Waste Treatment, Environmental Engineering Series, Van Nostrand Reinhold, New York, 1991.

5. USEPA, Memorandum: Revisions to OMB Circular A-94 on Guidelines and Discount Rates for Benefit-Cost Analysis, OSWER Directive No. 9355.3-20. United States Environmental Protection Agency, Washington D.C, 1993.

6. Vernick, A. S. and Walker, E. C., Handbook of Wastewater Treatment Processes, Burns and Roe Industrial Services Corporation, Paramus, New Jersey, 1981.