

OPERATIONAL WASTEWATER TREATMENT CONTROL IN THE CONTEXT OF FLEXIBLE STANDARDS

S. Marsili-Libelli

Dept. of Systems and Computers, University Florence, Via S. Marta, 3 - 50139 Florence, Italy

Abstract

The operation of a wastewater treatment plant can be significantly improved if its management is coordinated with the water quality of the receiving waterbody. This paper describes a complex modelling exercise, which couples the IAQPRC activated sludge model with a river water quality model. Based on this, an optimization scheme is set up so that the plant operation is capable of damping down sewage load peaks in order to keep the water quality within the required standards.

1 - Introduction

Over the last two decades massive investments have been made in all EEC countries to build wastewater treatment works and yet little has been done for their reliable and economic operation, with detrimental effect for the environmental quality. The reason is that vis à vis the substantial capital investments, comparatively little effort has been made to provide the treatment works with adequate control strategies which guarantee a reliable and economical plant operation. This is a serious drawback considering that each plant failure may result in a major pollution spillage, involving reclamation costs well beyond the value of the control equipment required to prevent the accident.

The idea developed in this paper is to integrate a computer-controlled wastewater treatment process into a reach-wise flexible standard policy scheme, which takes into account the water quality resulting from plant management and the upstream river quality. In fact flexible standards have not yet been implemented in Europe, though it is now recognized that they represent the intrinsic element of any advanced water quality management scheme. The reason for the delay in their implementation is the lack of adequate modelling and monitoring tools to implement plant-water body coordination. However, these constraints have recently been overcome by advanced monitoring devices, paving the way towards coordinated control.

The development of the flexible standard controller is based on the following ingredients:

- 1) The wastewater treatment works being considered is approximated by a modified IAQPRC (Henze et al., 1987; Dold et al., 1991) model with enhanced secondary settler dynamics (Marsili-Libelli, 1993).
- 2) The control action consists of either dilution with treated effluent or partial storage of incoming sewage into a buffer tank. The problem arises of the emptying policy once the peak load has passed, since a quick discharge may create a secondary load peak, and conflicts with the need to empty the tank as soon as possible to handle further overloads.
- 3) The constraint to the optimization of the filling/emptying policy is the river quality, modelled by a dynamic quality model including the most relevant parameters: BOD₅ (in dissolved, particulate and sediment forms), nutrients, dissolved oxygen, coliforms, organics and heavy metals. This model was developed by the author, based on the principles illustrated by Thomann and Müller (1987) and Ambrose (1986) with the addition of oxygen production by algae (Marsili-Libelli, 1990) and volatile organics/heavy metal kinetics.

The whole model and optimization algorithm are coded in MATLAB 4, partly as SIMULINK blocks (IAQPRC and river models) and partly as MATLAB functions (user interfaces and control algorithm).

2 - Operational control

It is supposed that the wastewater treatment works are equipped with a front-end buffer tank and adequate devices to monitor influent and upstream river water quality, as shown in Figure 1. The aim of the control policy is to design a filling/emptying strategy for this storage section, where it is assumed that no biochemical reaction occurs.

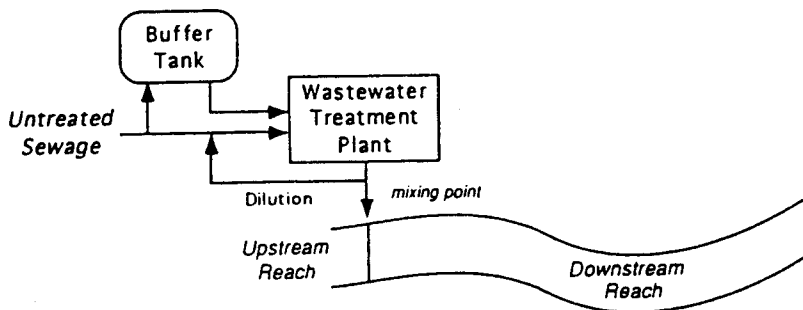


Fig. 1 - Operational control scheme.

The operational control algorithm is based on the statistical characterisation of the following process variables: upstream river quality, extent of the peak overloading (either organic or hydraulic) and an estimate of the peak repetition time, acting as a further constraint during the emptying phase. As a result the optimal filling/emptying policy prevents the downstream river quality standards from being violated.

The algorithm is oriented toward the damping of isolated peaks, either in flow or excess organic load, for example caused by a storm event or accidental spillage. From Figure 1 it is evident that the two possible control actions consist of either dilution with the treated effluent or storage into the buffer tank. By-pass is used only as a last resort when the capacity of the buffer tank is exceeded. Let us now consider these control options:

Dilution

In case that the influent organic load goes up without a corresponding flow increase, this is diluted with a fraction of the treated effluent. The required percentage of dilution is computed through simulations, so that the combined effluent meets the quality standards.

Storage

This action is taken when either or both flow and organic load increase. In this case a part of the raw influent is stored in the buffer tank, to be released later, when the peak has ended. The policy consists of two steps: filling and emptying the tank.

a) *Tank filling*: As a first step a "peak attenuation" function is defined as percentage difference of input and out peak through the plant

$$A = \frac{C_{in}^{peak} - C_{out}^{peak}}{C_{in}^{peak}} \cdot 100$$

Using the IAWPRC model, this function was approximated as a function of (p), the ratio between the entering flow (Q_{in}) and its fraction diverted into the buffer tank (Q_{bt})

$$A(p) = \gamma \frac{\alpha_1 - p^{\beta_1}}{\alpha_2 - p^{\beta_2}} \quad p = \frac{Q_{bt}}{Q_{in}}$$

where the numeric values of the constants $\alpha_1, \alpha_2, \beta_1, \beta_2, \gamma$ were determined by least-squares fitting of the model responses. In this way the required flow can be related to the desired peak attenuation. Of course it is assumed that the input load can be measured on-line. In fact there are now a number of reliable instruments for this purpose.

b) *Tank emptying*: the problem now arises of how to empty the storage tank once the peak has passed. In doing this there are two conflicting objectives to be satisfied: a fast emptying phase makes the tank quickly available for absorbing a new peak, but on the other hand this produces a secondary peak which may violate the standards. To reconcile these requirements a statistical analysis of peak repetition is set up, using a lognormal distribution to yield the minimum flow

Q_{min}^e , whereas the maximum empty flow Q_{max}^e was determined through simulation to establish a link between the output BOD peak and the emptying flow. The following diagram of Figure 2 left shows the admissible flow range (hatched area) for the emptying flow and related times bracket. Extending the statistical analysis a plant percentage Load Factor (F_c) is defined to express the linear dependence between the catchment characteristics and the excess flow caused by a storm event. This is related to the flow ratio (p) already defined. This line, together with the attenuation function can be used to determine the required storage ratio (p). This is shown in Figure 2 right.

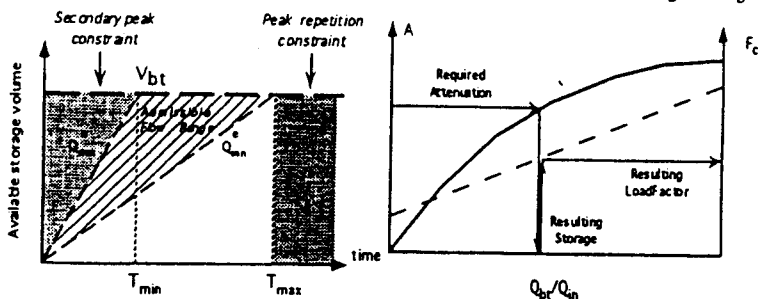


Fig. 2 - Relations between emptying flow and available storage volume (left). Resulting storage fraction (right)

3 - An example of plant management

To show the algorithm at work, some synthetic time-series of untreated sewage and upstream river quality were prepared. The former involved an abnormal peak besides the usual daily fluctuations. The algorithm should compute the best flow control action to cope with this emergency. Three kind of emergencies are considered:

- 1) *Organic overload with constant flow*: in this case the action to be taken is *effluent dilution*, the extent of which is determined on the basis of plant output constraints
- 2) *Flow overload with constant organic load*: in this case *storage* is the answer and the fraction (p) is determined with the rational behind Figure 2 right.
- 3) *Flow and organic overload*: again, *storage* is the action to be taken, with the added constraint on the emptying flow Q^e not to exceed plant or river ratings.

In the sequel some simulation results are presented where the plant output represents the constraints, in fact presently no clear river limits exist. However the validity of the exercise remains, as it can be readily extended to include river quality as the control target.

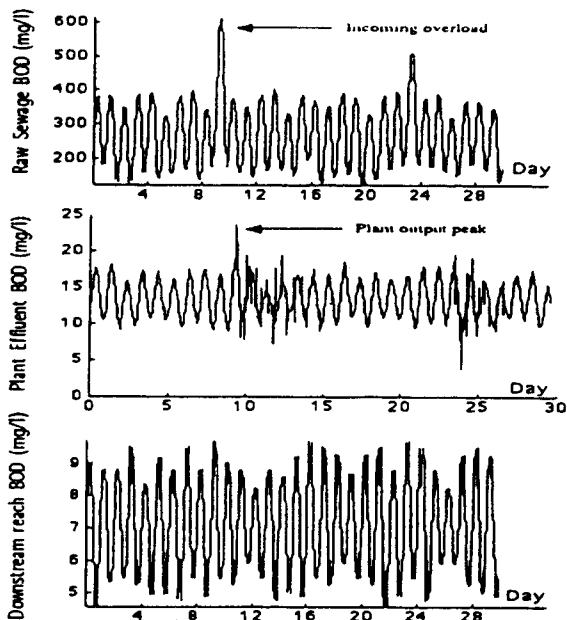


Fig. 3 - An example of plant management through storage of excess load.

From Figure 3 it can be seen that the incoming peak is smoothed out through the plant, being partly stored in the buffer tank and later released at a slower rate. The combined effect on the downstream water quality is completely negligible.

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