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A COMPUTER BASED OPERATIONAL STRATEGY FOR THE JOINT TREATMENT OF MUNICIPAL AND INDUSTRIAL WASTEWATERS

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and

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A COMPUTER BASED OPERATIONAL STRATEGY FOR THE JOINT TREATMENT OF MUNICIPAL AND INDUSTRIAL WASTEWATERS

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The objective of this Conference, which is the exploration of symbiotic relationships between industries, municipalities and agriculture in the utilization of water, is an exciting one in that it represents a serious attempt to define and improve upon the mutually beneficial interactions between these three systems instead of focusing upon the detrimental interactions as has so often been the case in other Conferences devoted to water pollution control. However, it is also somewhat frightening to be asked to present a paper at such a Conference since the overall system with which it is concerned is so large in scale, has poorly defined boundaries and internal detail, and is subjected to so many economic, sociological, and political inputs and constrains. From a quantitative viewpoint, such a system can only be classified as "fuzzy" and the authors have no desire to lose whatever credibility they may have by attempting to develop a "quick" dynamic model for such a system and make predictions based on computer simulations using this model.

Nonetheless, there are some key concepts and tools of systems engineering which have considerable potential for the study and improvement of such large scale systems. The authors have decided to concentrate

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upon two of these concepts, dynamic behavior and information handling, which have seen relatively little application in environmental engineering, and show by means of a simple example how these two concepts might be implemented using a digital computer to provide a beneficial interaction between industries and municipalities in water pollution control.

DYNAMIC BEHAVIOR

Changes with respect to time are always taking place in the inputs, outputs, or environment of a system as well as in the characteristics of the system itself. It is important to identify the nature of these changes and the rates at which they occur. Some may be so slow that they need not be considered for a particular system while others may be so rapid and of such short duration that they also have no appreciable effect on the system. However, there are many changes with time which do affect the behavior of a system and these should be considered in analysis, design, and operation. These changes with time are of special importance in the development of management and control systems since the very need for these systems is caused by dynamic behavior. Some examples of important changes with time which can affect the industrial-municipal-agricultural complex are as follows:

1. Fluctuations in stream flow rates.
2. Shifts in land use patterns and especially the long-term shift from agricultural to municipal use.
3. Variations in the market for an industrial product.
4. Changes in effluent and water quality standards by regulatory agencies.
5. Fluctuations in influent wastewater flow rate and composition for a wastewater treatment plant.

Wastewater treatment plants provide an excellent example of systems in which little attention has been paid to dynamic behavior even though there are large temporal variations in the plant inputs. It is not surprising therefore, that there are also wide variations in plant efficiency as well as occasional gross failures. However, almost all design formulae are based on the assumption of steady state and use average, or at best maxima and minima, values for the inputs. Because of such formulae, it is relatively easy for a design engineer, who is not exposed to the effects of these temporal variations as is the operating engineer, to slip into the habit of "steady state thinking." This habit, like most habits, can be extremely difficult to break.

Dynamic formulae, or in modern day terminology "dynamic mathematical models", are needed for the description of time dependent phenomena such as occur in wastewater treatment plants. However, prior to the advent of computers, a computational bottleneck existed and efforts at the development of dynamic models were usually of little practical value since the equations could not be solved anyway. It might be noted that this is probably the major reason for the predominance of steady state models in the technical literature. The assumption of steady state has the effect of reducing differential equations to algebraic equations thus making them much more amenable to solution.

The ready availability of high-speed digital computers has largely eliminated the computational bottleneck and solution of the equations which comprise the dynamic mathematical model can now be easily attained by computer simulation. Moreover, it is no longer necessary to spend a great deal of time learning to use the computer. The simulation languages now available are heavily user oriented thus permitting the engineer to concentrate on model development and simulation results rather than on the details of the computations. However, as with much new technology, this can be a two-edged sword and must be handled with care. The ease and speed with which computer simulations can frequently be made can lead to a neglect of the equally important step of model validation and, in the extreme, can result in one becoming so enamoured with the techniques that the purpose for using them is almost forgotten. Large quantities of worthless results can be obtained via computer simulation if the model used is not a reasonable representation of the real system.

INFORMATION HANDLING

Environmental engineers are familiar with the theory and technology involved in the handling of materials and energy. However, they are not as accustomed to consciously thinking of information in the same terms although this is of equal or greater importance. A major reason for this is that only in recent years has an adequate aid to information handling, the digital computer, become available to assist the engineer in the task of information handling. Examples of information of importance for an industrial-municipal-agricultural complex would be that needed to describe changes with time for the items listed earlier in this paper under dynamic behavior. In examining these information needs, it should be kept in mind that they comprise a time spectrum ranging from the historical through the present and up to predictions into the future.

The technology involved in information handling is of more recent vintage than that for materials and energy; however, many of the same concepts are applicable. The handling of materials, energy, and information all involve collection, transportation, processing, storing, and distribution. Flow diagrams are used to analyze the handling of information in the same sense as they are used to analyze the handling of materials and energy. An example of an information flow diagram is given in Figure 1 where the temperature of a process is to be automatically controlled. The temperature of the process is changed from its desired or reference value by some input disturbance such as a change in environmental temperature or heat input to the process. Information regarding this change is collected by a sensor such as a thermocouple and then transported by electrical or pneumatic means to an automatic controller. The controller first processes this information by comparing the actual temperature with a desired, or set point, temperature stored in its memory. If the actual temperature is not equal to the desired temperature, the controller further processes the information by means of a control algorithm to determine the amount of control action needed. It then distributes the processed information to a final control element, the valve in this instance, to adjust the heat input to the process.

The accuracy and timeliness of information are of key importance and must be selected to accomplish the objectives of the information handling system. An example of the need to consider the timeliness of information is provided by the biochemical oxygen demand (B.O.D.) test which is the most widely used means of determining wastewater treatment plant efficiency. This test requires five days to complete and therefore can represent a significant information time delay. From the

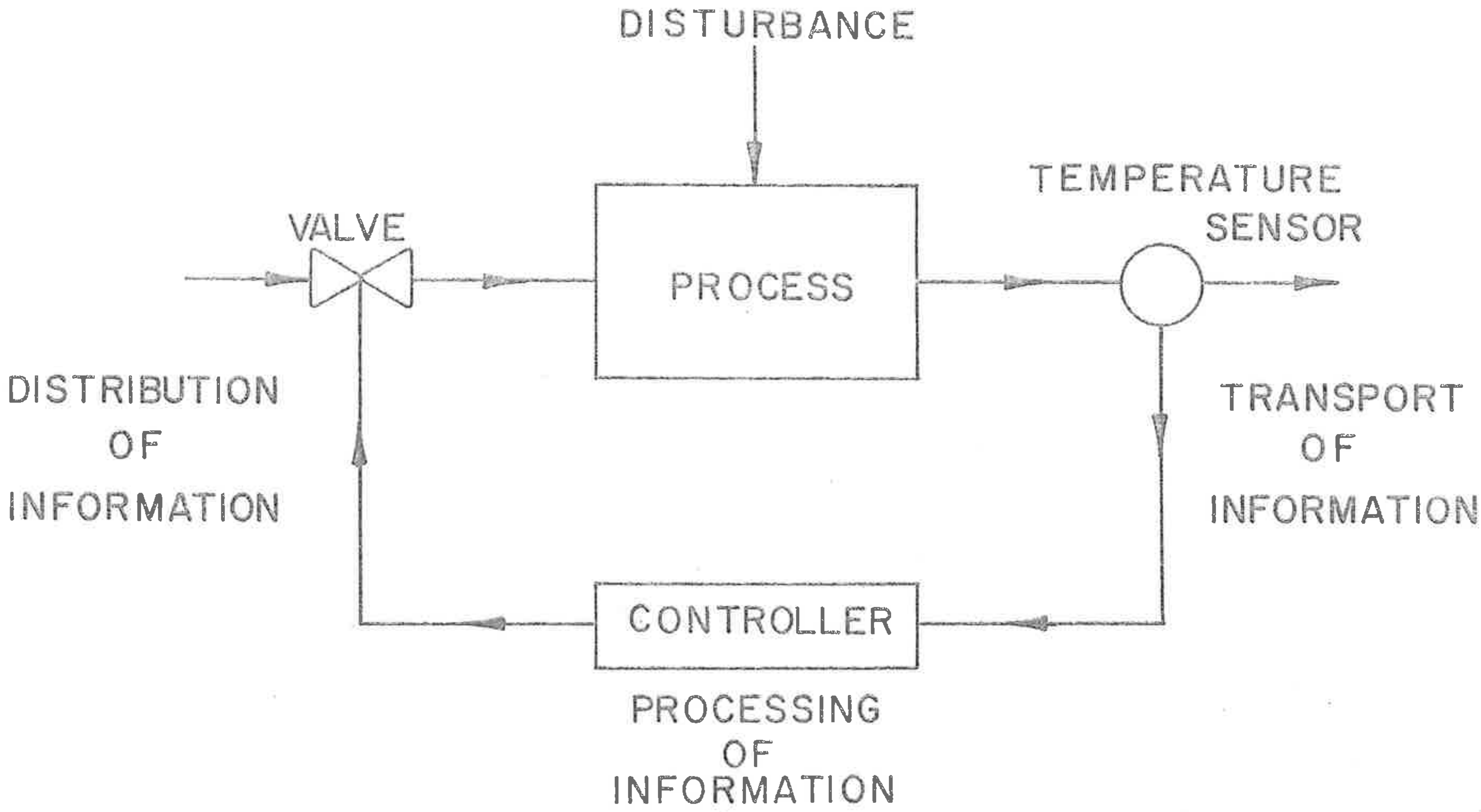

FIGURE I. INFORMATION FLOW DIAGRAM FOR AN AUTOMATIC CONTROLLER viewpoint of a regulatory agency, this time delay is not normally serious since the information is usually only transmitted to the agency at monthly intervals and an even longer time interval may be required to process the information and take legal or other action. However, from the viewpoint of the plant operating engineer, this is a serious time delay since corrective action for low process efficiency must be taken well before five days have elapsed. This example also illustrates another important point, this being that there are strong interactions between information needs and dynamic behavior. The slower response time of the regulatory agency permits the collection of information at less frequent intervals and with longer time delays than is possible for the plant operating engineer who must deal with hourly and daily fluctuations in wastewater flow rate and composition.

The handling of information costs time and money just as for the handling of materials and energy and it is usually necessary to accept some uncertainity in the information. Also, materials, energy and information are interdependent and trade off's are possible. For example, the collection of a large amount of information concerning wastewater flow rates and composition for the design of a small treatment plant is usually not justified since it would be more economical to increase the size of the plant. This increase in size would involve the expenditure of more materials and energy but would decrease the cost of information. However, this would not be the case for large treatment plants which have much higher capital costs and it can therefore be seen that the time and money spent in collecting information for plant design should be a function of size or capital cost of the plant. The same is true for plant operations.

Just as the computer has largely eliminated the bottleneck associated with the solution of dynamic mathematical models thus permitting their practical application, it has also resulted in an enormous reduction in the amount of human effort required to transport, process, store, and distribute information. In the authors' opinion, it can truly be said that we are in the midst of a new revolution, this being the information revolution which has been brought about by the ready availability of high-speed digital computers. However, all revolutions have their bad points and just as the ease of computer simulation has sometimes resulted in the generation of worthless results, the ease of transporting, processing, storing, and distribution of information by use of the digital computer has also had some detrimental effects. The collection of information still requires a very substantial amount of human effort which seems to have been forgotten by many of those using the computer for information handling. There are many examples of this, but perhaps one of the most important in the water pollution control field is the enormous amount of information which must be collected for environmental impact statements. This obviously involves the expenditure of substantial time and money.

COMBINED TREATMENT OF MUNICIPAL AND INDUSTRIAL WASTEWATERS

The treatment of combined municipal and industrial wastewaters offers many advantages such as the economics of scale for both construction and operation. However, there are problems involved in such combined treatment systems and included among these are the toxic effects of some industrial wastewaters on biological treatment processes and the possible need for physical and/or chemical processes to remove substances which are not amenable to biological treatment. Combined treatment can sometimes therefore represent an expensive solution to the removal of pollutants. The authors would like to show how some of the problems associated with combined treatment might be solved by taking advantage of the dynamic nature of the wastewater inputs through use of the appropriate information handling techniques.

The concentration of pollutants in industrial wastewaters is frequently higher than that in municipal wastewaters and many of these wastes are discharged as batches or "pulses" instead of continuously. This batch mode of discharge therefore suggests that it might be possible to time the discharge of these wastes to the municipal sewers for transport to a combined treatment plant when the municipal wastewater flow rate is at its lowest. Upon arrival at the treatment plant, the mixture of wastewaters could be diverted to a variable volume holding tank and then, depending upon the characteristics of the industrial wastewater, be bled into the biological process over the full 24 hour period or treated by physical and/or chemical processes prior to discharge into the biological process for further treatment. It should be noted that the arrangement of the processes is reversed from that normally considered for such treatment plants in that the physical and/or chemical processes would <u>preceed</u> instead of <u>following</u> biological treatment. A possible flow diagram for such an operational strategy is illustrated in Figure 2 with the potential advantages of the strategy being given below:

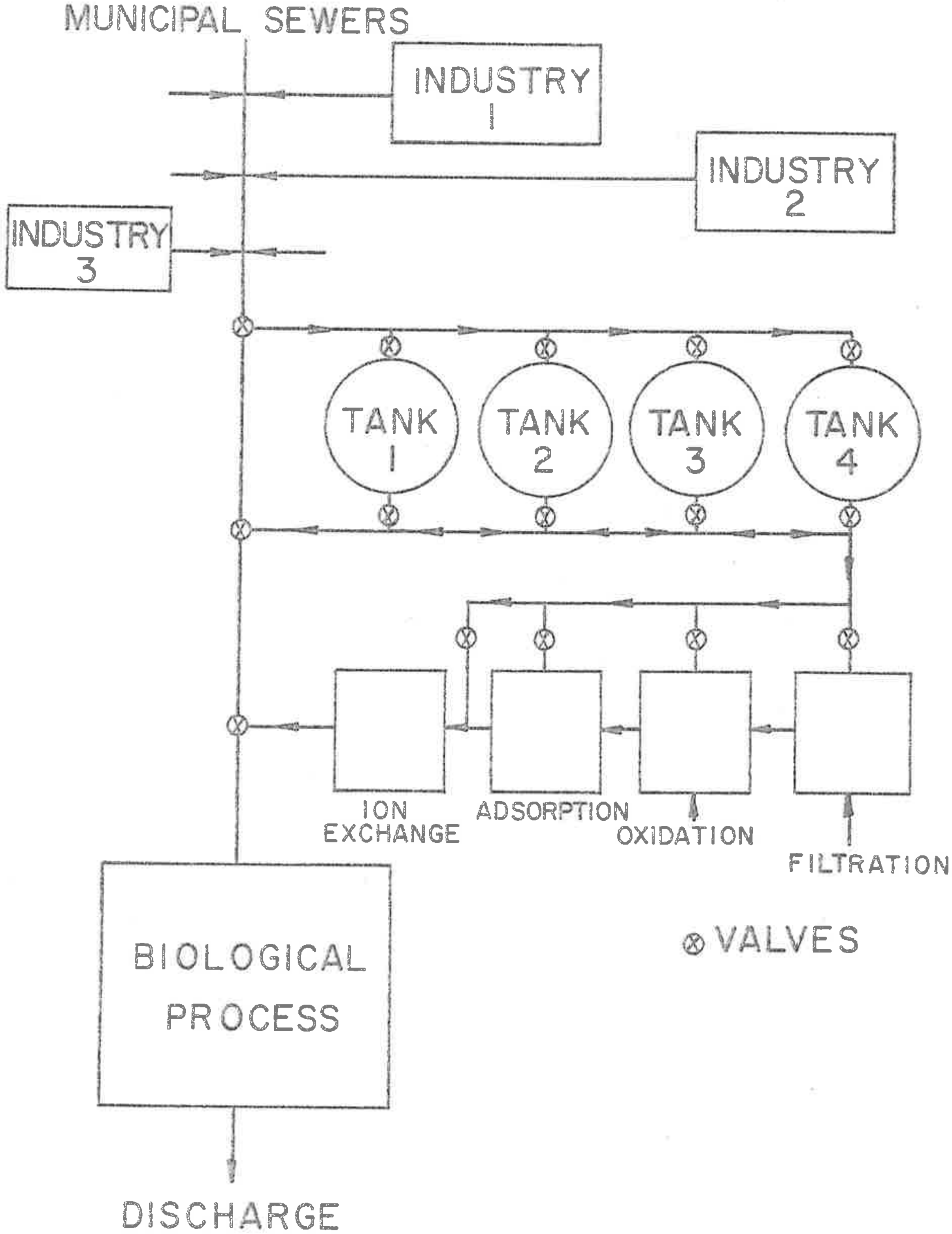

FIGURE 2. OPERATIONAL STRATEGY FOR COMBINED TREATMENT OF INDUSTRIAL & MUNICIPAL WASTEWATERS

1. Detrimental efects of toxic or inhibitory substances on the biological process could be reduced by either of two alternates, these being:

   a. If the substance can be metabolized by the biological process in low concentrations but is inhibitory in high concentrations (for example, phenol), its concentration could be kept low by bleeding it into the biological process over the full 24 hour period.

   b. If the substance cannot be metabolized by the biological process and would also be detrimental to the receiving body of water, it could be routed to the physical and/or chemical treatment processes.

2. The discharge of pulses of rapidly biodegradable organics to a biological process can also be deterimental to a biological process through either exceeding the capacity of the aeration equipment or by creating a condition known as sludge bulking. Several alternates would be available and among these are:

   a. Discharge of the material to the biological process during low flow periods when excess aeration capacity is usually available.

   b. Bleeding of the material into the biological process over a longer period of time in an attempt to minimize the effects of sludge bulking

   It should be noted that the effects of pulses of rapidly biodegradable organics on biological processes are not well defined and research would be needed to establish the proper mode of discharge of such wastes.

3. Required sizes, and therefore costs, of the physical and/or chemical processes should be reduced for the following reasons:

   a. The physical and/or chemical processes would be handling lower flows since the mixture of wastewaters is captured only over a portion of the day, and this at low flow periods, and is then processed over a 24 hour period.

   b. The higher concentrations of the industrial wastes resulting from the lower dilution would provide higher transport and reaction driving forces for the physical and/or chemical processes.

4. It would be possible to use the most appropriate physical and/or chemical process for treatment of the individual industrial wastes by provision of several variable volume holding tanks thus permitting waste classification according to treatment needs.

Since item three results directly from a decreased dilution of the industrial wastewater with the municipal wastewater, the old adage "the solution to pollution is dilution" might in this instance be more aptly stated as "the solution to pollution is concentration!"

One of the keys to the success of the proposed operational strategy would be the capability for minimizing the mixing of the wastewaters in the sewers. Preliminary evaluation of the feasibility of the strategy for a given system could be accomplished by developing a dynamic model of the sewerage system and then using computer simulation to estimate the dilution of the industrial wastewater and its time of arrival at the combined treatment plant. A suitable technique for validating the dynamic model would be to add an inert tracer along with batch dumps of the industrial wastes. If construction of a new treatment plant was being contemplated, minimization of mixing might be one of the factors to be considered in selecting the plant location.

An essential factor for the success of the proposed strategy would be to obtain the cooperation of the industries in scheduling the dumping of their wastewaters into the municipal system. The industries would have to agree to dump their wastewaters during off-peak hours for the wastewater treatment plant with the time of dumping being regulated by the municipality. Although this might require the construction of some storage capacity on the part of the industries, this could perhaps be offset by the municipality providing the industry with off-peak wastewater treatment rates. Ample precedent for the provision of off-peak rates for other services can be found in the communications and airline industries, among others.

Control of the dumping schedule could be largely automated by using a small digital computer to accomplish the following tasks:

1. The appropriate person at the industrial site would signal the plant computer that he wishes to dump a certain volume of a particular wastewater.

2. Using the dynamic mathematical model of the sewerage system, the computer would then calculate the time at which the wastewater should be dumped to minimize mixing with other wastewaters in the system. Since this is an optimization problem, judgement factors other than mixing with other wastewaters would have to be incorporated into the objective function and an example might be that of simultaneously keeping the flow rate to the physical and/or chemical processes as low as possible. Constraints would obviously also be involved and a typical constraint might be a maximum length of time that the industry can store its wastewater without dumping.

3. The computer would then inform the industry of the time (or period of time) when the wastewater can be dumped.

4. The industry would then signal the computer as to the exact time of the dump.

5. The computer would then determine the time at which the plant influent should be diverted to a holding tank and would open the appropriate valves to accomplish this diversion. It would close the valves when calculations show that the major portion of the industrial wastewater has been diverted into the holding tank. Information as to which holding tank should be used would be obtained from a classification of the wastewater according to its wastewater treatment characteristics.

The above control strategy would be classified as an open loop system in that there is no feedback to the computer as to whether or not it has operated the valves for diversion to the holding tanks at the appropriate times. It would therefore be expected that not all of the wastewater would be diverted. The alternate to this would be to provide sensors, if they are available, for detection of the different industrial wastewaters. These would provide more information thus removing some of the uncertainity from the control strategy. However, it would be obtained at the expense of purchasing and maintaining the sensors.

Although the example given is for a combined treatment plant receiving several different types of industrial wastes as well as municipal wastes, the basic concepts should also be applicable to industrial wastewater treatment plants which receive the wastewaters from several different manufacturing processes. In those industries where the manufacturing processes are under computer control, a communication link could be established between the two computers for automatic transmission of the desired information.

SUMMARY

Two key concepts of systems engineering, dynamic behavior and the handling of information, have been reviewed and discussed with emphasis on their potential application to water pollution control systems. An application of these two concepts in the development of a possible operational strategy for the combined treatment of municipal and industrial wastes is presented. The basis of the strategy is the scheduling of batch dumps of industrial wastes so that they arrive at the treatment plant relatively unmixed with other wastewaters. This would be accomplished by real time computer simulations using a dynamic model of the sewerage system. Possible advantages of the strategy include (1) Avoidance of the detrimental effects of toxic or inhibitory substances on biological processes; (2) Prevention of the discharge of high concentrations of rapidly biodegradable organics to biological processes at inappropriate times; (3) Reduction in required sizes of physical and/or chemical processes; and (4) Use of the most appropriate physical and/or chemical process for a given industrial wastewater.