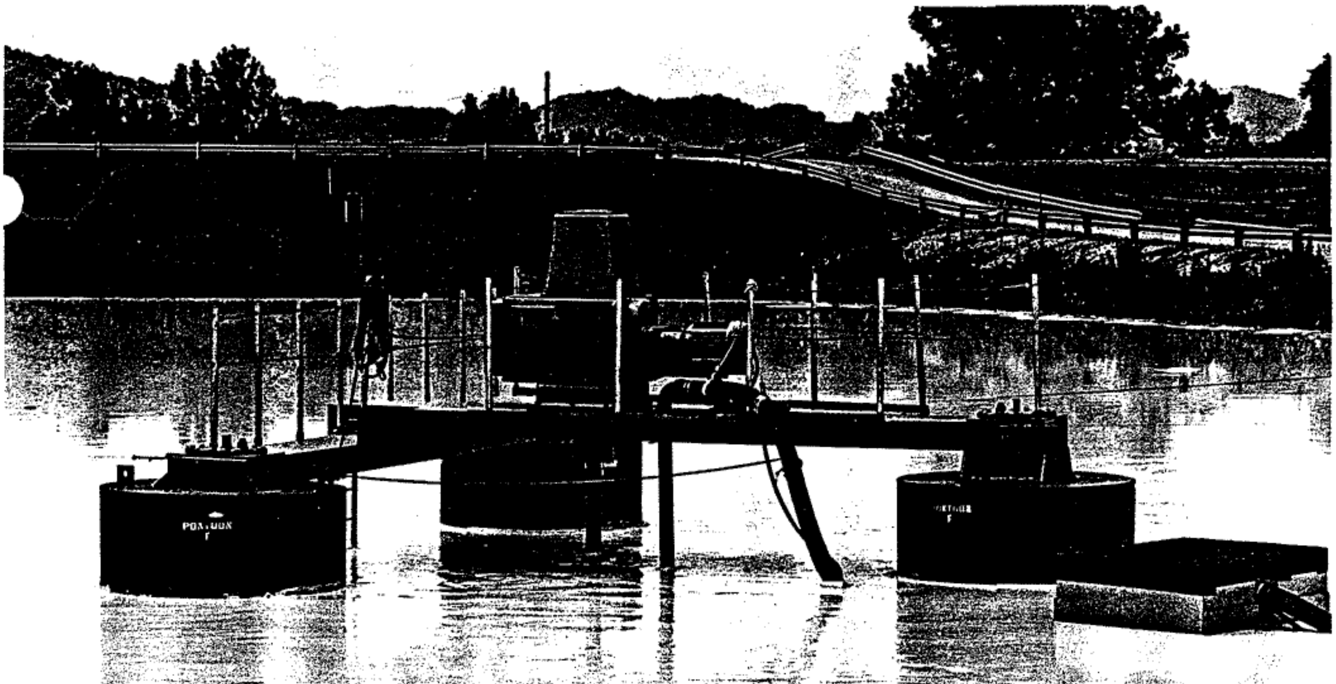

The Role of Mixing in Equalization

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Properly designed equalization facilities reduce the wide swings of waste stream characteristics, and provide a system that is less susceptible to upsets and consistently pro- des a better quality effluent than an unequalized system. Also, the operating horsepower of the equalized system can be appreciably lower than that of an unequalized system. By providing proper mixing, the volume of an equalization basin can be made much smaller than that of a poorly mixed basin while providing better results at reduced capital investment and operating costs.

An efficient equalization basin is completely and uniformly mixed so that at any instant in time the effluent concentration from the basin is equal to the concentration within the basin. By definition, the influent to the system is to be instantly and uniformly mixed throughout the basin. The degree of mixing depends upon the relationship of the residence time in the equalization basin to the cycle time of the flow and concentration variations in the influent stream. Specifically, the time to blend in the feed stream must be small relative to the total residence time.

Types of Equalization Basins

There are two basic types of equalization basins. The hydraulic, which is characterized by a varying flow into the basin and a constant flow from the basin. The liquid level, and therefore the volume, of the basin changes and may increase or decrease depending on whether the flow in the basin is greater than or less than the flow from the basin. Hydraulic equalization basins will dampen both hydraulic and concentration cycles in the influent stream. The second 'pe of equalization basin contains a constant volume. .uctuations in influent stream concentrations are dampened by the volume of the equalization basin, buth the flow from the equalization basin is equal to that of the influent to the basin. Therefore, flow from the constant volume equalization basin continuously changes as does concentration. Only the hydraulic equalization basin will dampen out any fluctuations in flow in the influent stream.

Types of Influent Stream Fluctuations

Three general types of streams will benefit from equalization. In the first the concentration remains constant, but the flow of the influent stream varies. The second is one in which the concentration varies, but the flow remains constant. The third is a stream in which both concentration and flow vary, and the frequency and amplitude of the variations differ.

Constant Concentration — Variable Flow

Although somewhat rare in waste and water treatment applications, there are instances when waste streams of varying flows have a relatively constant concentration and it is desirable to dampen the feed rate of the contained contaminant to the down stream process. To accomplish this, hydraulic equalization is used where the flow from the equalization basin is maintained at a constant rate. Since the flow into the equalization basin varies, the volume and therefore the liquid depth in the equalization basin also varies with time. Constant flow is generally maintained by pumping the wastewater from the equalization basin.

By maintaining constant flow from the equalization basin, the rate of contaminants discharged in the effluent stream remains constant since the concentration of contaminant in the influent stream is a constant. Mixing in hydraulic equalization basins is provided to maintain solids in suspension if solids are contained in the influent stream. Since the concentration of contaminants remains constant, mixing would not be required if there were no need for suspending solids.

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Constant Flow - Variable Concentration

This type of waste stream is easily handled in equalization basins with constant volumes. To illustrate, **Figure 1** depicts a flow of 2,500 gpm with an average BOD concentration of 500 mg/l and a ± 400 mg/l concentration variation from this average. The ratio of maximum BOD discharge divided by average BOD discharge from the equalization basin is shown plotted against equalization basin residence time. The example has been worked out for both one and four hour periods of the concentration variation. It can be seen that when the equalization basin residence time equals the cycle time, the concentration variation from the average value has been reduced by a factor of approximately 6. Once an equalization basin detention time equal to the cycle time of the concentration variation has been obtained, little benefit is gained by adding equalization volume unless extremely close control is required over the effluent characteristics.

Variable Flow — Variable Concentration

The most typical type of stream is one in which both flow and concentration randomly vary. Equalization of these typical streams can be accomplished by either fixed or varying volumes in the equalization basin. The following examples are based on constant equalization volumes, but varying equalization volumes can also be handled in a similar, but more complex fashion.

Where both flow and concentration vary, the decision as to the use of equalization depends upon the ratio of the period of the concentration fluctuations to the period of the flow fluctuations as well as the ratio of the amplitudes of the concentration fluctuations compared to those of the flow fluctuations. This complex interdependence has so far defied single rules-of-thumb, and individual analysis of each complex system must be made before the advisability of equalization can be determined. A further complication involves the phase of the concentration and flow variations. Whether or not the flow and concentration variations are exactly in phase, out of phase, or randomly distributed greatly affects the characteristics of an equalization system.

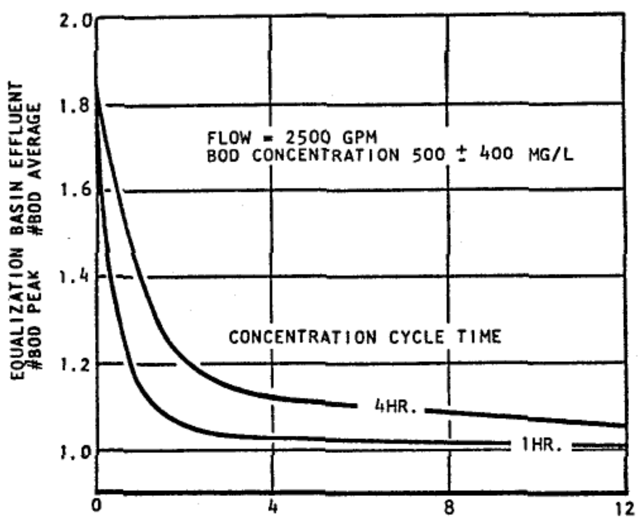

Fig. 1. Equalization basin effluent vs. basin residence time for a constant flow and varying BOD concentration.

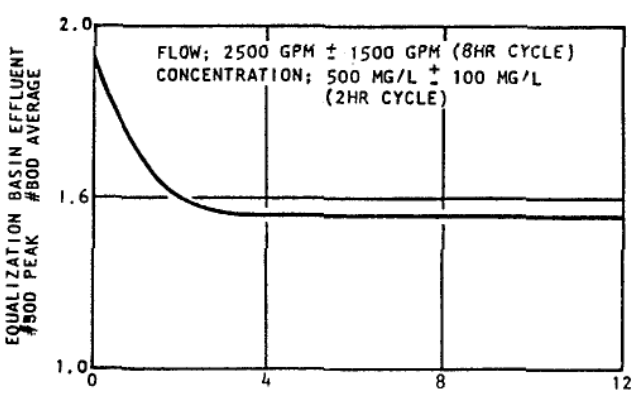

Fig. 2. Equalization basin effluent vs. equalization basin residence time for variable flow (8 hour cycle) and variable concentration (2 hour cycle).

Figure 2 depicts a flow varying from 1,000 to 4,000 gpm with an 8 hour period. The concentration variation is from 600 to 400 mg/l with a two hour period. Using BOD as the contaminant, the maximum rate of BOD discharged from a completely mixed equalization basin is ratioed to the average discharge from the equalization basin and plotted versus equalization basin residence time. It is evident that little benefit is gained by equalization since only about a 20 percent reduction in maximum feed rate of contaminant can be realized with this particular waste stream.

Table 1 summarizes the characteristics of a waste stream in which equalization may prove beneficial. The feed rate of BOD contained in the raw waste stream varies from a maximum of 1,800 lb. per hour to a minimum of 50 lb. per hour depending upon the flow and concentration.

Table I
Waste Characteristics

	Flow (gpm)	BOD (mg/l)	lb/hr
MAX	4000	900	1800
AVG	2500	500	625
MIN	1000	100	50
	8 hr period	4 hr period	

Figure 3 is a plot of computer output data used to analyze this particular problem. The ratio of the maximum divided by the average BOD discharge is plotted versus equalization basin residence time in hours, based upon an average flow of 2,500 gpm. As can be seen, the maximum rate of BOD discharged from the equalization basin decreases substantially as equalization basin volume increases.

The question is, should an equalization basin be used and if so what volume should be used? These questions cannot be answered without a complete analysis of the problem and the potential solutions. Using the information shown in **Figure 3, Table II** was prepared and the system following the equalization basin was assumed to be a completely mixed activated sludge system. The system was designed to handle the peak loadings since these loadings could last for a number of hours. The equalization capacity of the aeration basin should be taken into consideration when designing such a system but this has not been the practice in the field, so that, equalization capacities of the aeration basins were not taken into consideration in the examples cited. In arriving at the mechanical aeration horsepower requirements shown on **Table II**, a constant food/mass ratio and mixed liquor solids concentration was assumed for all designs. Dependent upon equalization basin volume, the installed horsepower required to satisfy the system design can be reduced to approximately 70 percent of that required for an unequalized system by providing four hours residence time.

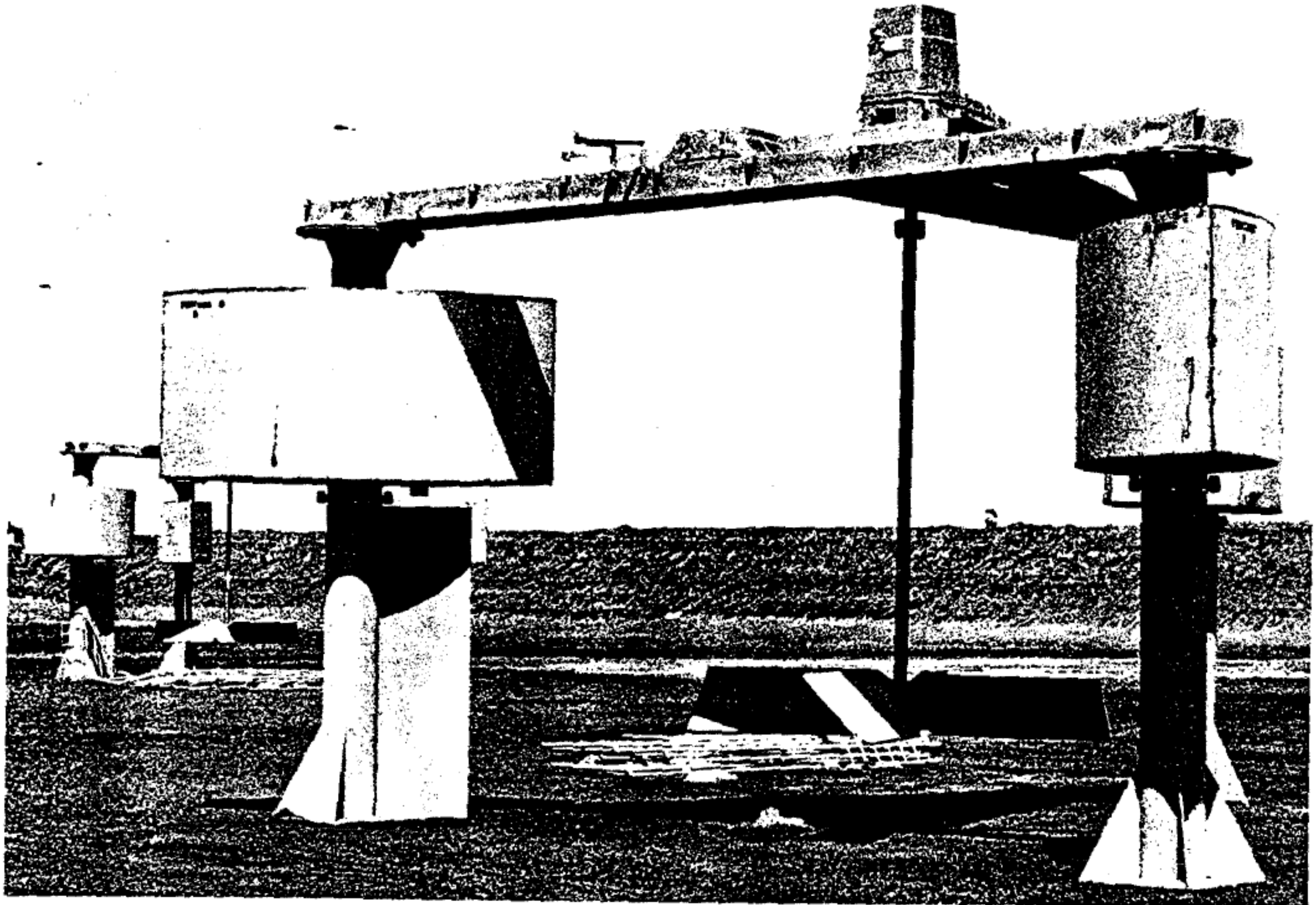

Fig. 5. Float-mounted equalization basin mixers.

sects the sloped walls. This protection is not required because of the motion produced by the equalization mixer, but because of the turbulence caused by wind action. Wind causes waves and these waves continuously lapping at the shoreline will cause erosion. Protection is generally provided by laying down a mat of stone extending 2 ft above and 2 ft below the water level on the sloping basin wall. This type protection has provided for successful equalization basin deisgn with relatively little maintenance being required.

Synthetic liners have been used to provide an absolutely leakproof basin because of the character of the materials contained in the waste stream. Precautions should be taken to ensure that the liners do not float to the surface of the basin, otherwise dewatering of the basin is required before repairs can be made. In one successful installation, a layer of soil was provided as ballast on top of the synthetic liner. The soil was then covered with crushed stone to prevent erosion.

Other types of basin liners include concrete, soilcrete, asphalt, and most other common types of construction materials. If it is necessary to provide linings, materials of construction and methods of application should be considered quite carefully since these can add substantially to the costs of the overall project.

Materials of construction for equalization basin mixers and support structures must also be carefully selected. This is especially true of an industrial waste system since equalization may be designed to reduce pH fluctuation, acid and caustic slugs, etc. For fixed mounted units, concrete platforms coated with acid and/or solvent resistant materials are commonly used for industrial waste treatment. The wetted parts of the mixer can be steel, coated steel, stainless steel, rubber covered, etc. The most common mixer materials are carbon steel and stainless steel.

Summary

Proper selection of equalization basin volumes and mixing equipment can provide substantial savings in both investment and operating costs for physical, chemical, and biological treatment systems. Each individual waste stream must be analyzed before its applicability to equalization can be ascertained. Proper equalization provides systems less susceptible to upset and therefore will provide effluent concentrations with a much narrower range of quality variation. Systems are much easier to control since shock loads are greatly reduced, and as a side benefit, less complex instrumentation, control systems, etc. can be installed.

In evaluating the use of an equalization basin, consideration must be given to the period and amplitude of both flow and concentration variations in the raw waste. In this paper, sinusoidal fluctuations have been used in all examples cited, but evaluation procedures are available for random fluctuations of both flow and concentration considering both period and amplitude of these fluctuations.

Critical to the successful operation of an equalization system is the proper installation and baffling of the fluid agitation equipment used to provide mixing in the system. Whether fixed or floating, equalization mixers must be properly baffled to provide optimum process results at reduced operating costs. ■

mixing applications. As depicted in **Figure 4**, baffles installed at the walls of the equalization basin will produce the mixing patterns to optimize the applied horsepower. In larger equalization basins, wall baffles become impractical and the baffles are fastened to the legs of the structures supporting the mixers. Where new equalization basins are being constructed, fixed mounted mixers will normally be used as these can be installed as the basin is constructed, and dewatering of existing facilities is not required.

Where existing facilities are to be upgraded, or where the soil conditions are such that fixed platforms cannot be utilized, floating mixers can be designed for use in equalization basins. Since it is desirable to place the mixing turbine close to the floor of the basin, float mounted equalization mixers must be designed to protect the turbine from accidental dewatering of the basin. Floating mixers, as shown in **Figure 5**, have been designed for the specific application of equalization in earthen basins. The extended legs provide protection in case of accidental dewatering of the basin. The equipment is designed to stand on the feet provided thereby maintaining the turbine free from the basin floor. The baffles required for mixing are attached to the legs of the floating mixer ensuring the proper top to bottom motion, uniform power draw, and maximum solids suspension.

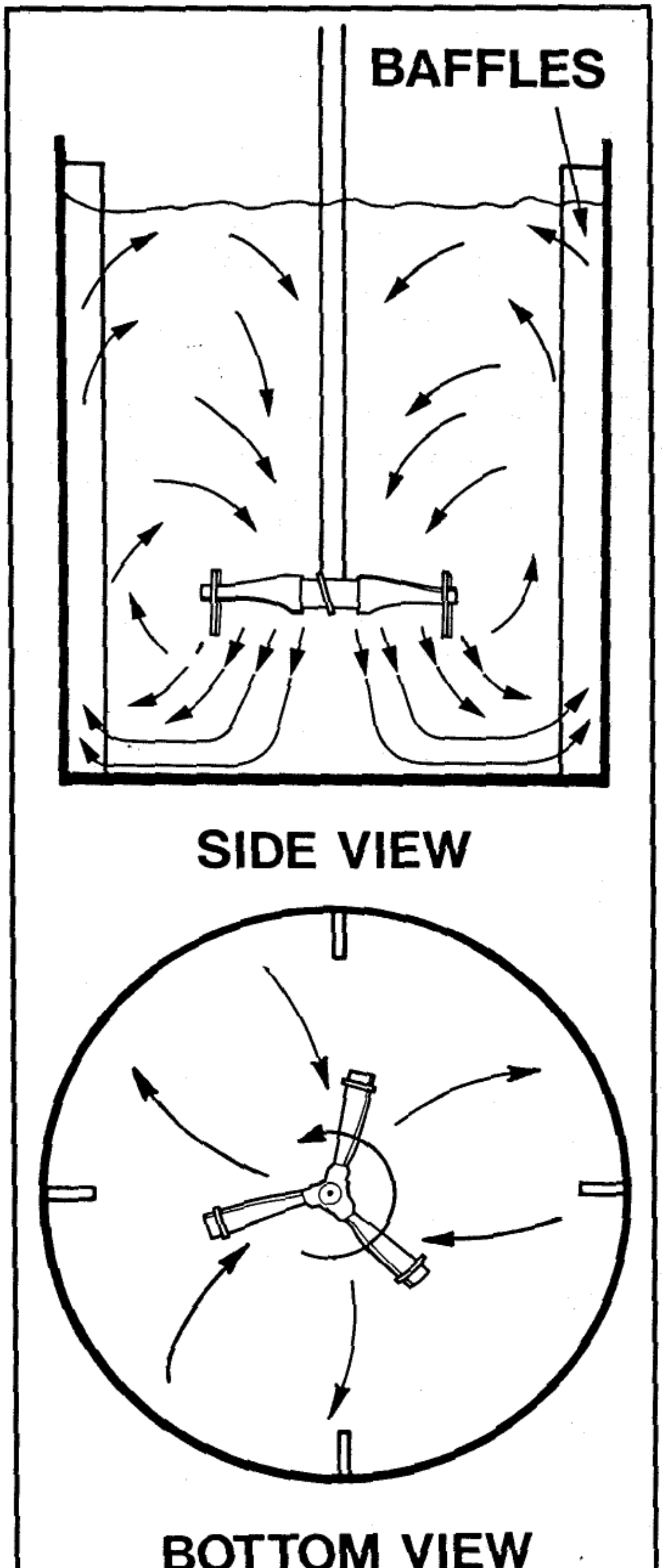

Fig. 4. Schematic of flow pattern from a properly baffled tank.

Existing Equalization Basins

Where existing unmixed equalization basins have been in operation for some time, solids accumulations may have reduced the effective volume of the system to such a point that improvement in process results is desirable. It will be necessary to remove the solids from the equalization basin in order to gain back the volume previously lost. Dewatering the basins can be expensive and time consuming and may necessitate diversion of the waste stream past the equalization basin during sludge removal.

An alternate solution is the installation of a float mounted equalization basin mixer equipped with a method of removing solids from the basin. Floating mixers can be equipped with a flexible suction line connected to a shore mounted pump. The mixer can then be used to resuspend the accumulated solids which are then removed from the basin by means of the pump.

It is not necessary to take the plant out of operation and the equalization volume can be gained back as the solids are removed. To minimize capital investment and to optimize use of the equipment, floating mixers can be towed back and forth in a basin where temporary deposition of resuspendable solids is not objectionable. In this fashion, resuspension of solids occurs and these solids are then passed from the equalization basin to the following treatment processes, when this is a desirable feature. When solids accumulations are desirable, this must be taken into consideration in the design of the mixers aid in establishing basin confirguration.

Floating mixers have been used to mix chemicals with the equalization basin contents to promote solids settling, aid in neutralization, etc. An operating floating mixer used to blend chemicals in a large industrial system is shown on the first page of this article.

Basin Design Considerations

Where earthen basin construction is to be used, the physical characteristics of the soil will determine whether or not special precautions should be taken to guard against excessive soil erosion. Many times it is advisable to install a pad of anti-erosion material directly under the equalization basin mixer. Concrete has been used quite successfully, but a less expensive installation can generally be realized by using 2 in.-4 in. sized angular crushed stone, blast furnace slag, etc. The sloped walls of the basin will require some protection at the point where the water surface inter-

Table II Biological System Design Aeration Tanks			
Equalization Time (hr)	BOD Applied Max lb/hr	Aeration Vol Million Gal	Aeration hp
0	1800	5.75	865
1	1500	4.80	720
2	1345	4.30	645
4	1200	3.84	575

Table III summarizes the equalization basin requirements, as well as the horsepower requirements of the combined *equalization aeration system. An economic evaluation of* the various alternatives available will determine whether or not equalization is practical. If an aeration system were tailored to adjust instantaneously to the fluctuating demand in the aeration basin, the total cumulative horsepower consumed to provide equal process results would be identical, with or without equalization. In the example cited, aerator flexibility would be required to handle the BOD loads ranging from 1800, down to 50 lb/hr with no equalization. This range of flexibility is generally unavailable and probably impractical. At the low loading of 50 lb of BOD/hour, mixing requirements will dictate the power requirements of the system and the total potential power savings could not be *realized. Equalization lowers the peak values, raises the* minimum values, and thereby reduces the required flexibility to practical ranges.

Table III
System Summary

Detention Time (hr)	Equalization Volume MM Gal	HP	Total System HP
0	0	0	865
1	0.15	3	723
2	0.30	6	651
4	0.60	12	587

Table IV
NPV* of Power Savings

Equalization Time (hr)	NPV (Thousand $) Year 2	Year 5	Year 10
1	16.1	37.5	65.5
2	24.4	56.5	100.0
4	31.7	73.5	130.0

*Net present value based on $60/hp/yr and 5% interest

In the field, most aeration systems are operated a majority of the time at maximum power draw and, because of this, substantial power savings can be realized by providing equalization. Based on $60/horsepower/year and a 5 percent interest rate, Table IV shows that the net present value of yearly power savings can become appreciable, dependent upon the period of evaluation selected. Based on peak loadings and no flexibility in oxygen transfer capabilities of the aeration system, a savings of $100,000 could be realized in a properly equalized system having an equalization detention time of only two hours if a ten-year evaluation is used. Substantial savings in capital investment for the aeration basin, the aeration equipment, control equipment, instrumentation, etc., make the benefits of proper equalization quite attractive.

The previous calculations all assume that the equalization basin is truly completely uniform. If the installed mixer does not provide the proper degree of agitation, then the tank will not achieve its full potential of a blending or dampening system. Blending in waste treating is a flow controlled operation which means that large diameter impellers running at slow speeds require less horsepower for the same degree of blending than do small high speed impellers. It is possible to design a number of different units all of which will give the required blending in the designated residence time. The higher horsepower units have a smaller speed reducer because they operate at higher speeds. The large, low speed impeller units require a larger speed reducer because they require more torque which is the basic desgn consideration for mixed drives. This means that a given job can be done at a low horsepower level, but at higher capital investment, and this type evaluation should be included when contemplating the use of an equalized system. Lower operating costs generally prove to be the most economical selection.

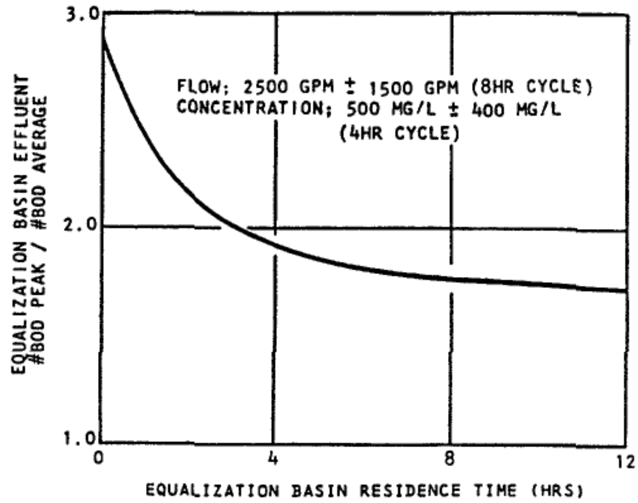

Fig. 3. Equalization basin effluent vs. equalization basin residence time for variable flow (8 hour cycle) and variable concentration (4 hour cycle).

If there are any appreciable settleable solids contained in the waste stream, these solids must either be removed prior to equalization or provisions must be made to remove these solids from the equalization basin. Normally, the lower levels in the basins are not adequate to suspend fast settling particles and therefore an accumulation of settleable solids can occur on the floor of the basin. If these particles are allowed to accumulate continuously, the effective volume of the equalization basin is decreased and less efficient equalization occurs. Solids can be allowed to accumulate in systems in which two parallel equalization basins are used. While the solids are being removed from one equalization basin for disposal, the alternate system would handle plant loads. This type system performs the dual function of primary clarification and equalization.

For a mixer to operate properly a well baffled system is required in order to make maximum use of the applied power. Improperly baffled mixers tend to swirl the basin, thereby losing the top to bottom motion desired in any solids suspension and blending application. Where swirling occurs, less efficient fluid blending results and the equalization efficiency is reduced.

The unstable hydraulic regime characterized by a swirling basin may transmit increased fluid forces to the mixing equipment resulting in a shorter lifespan. Proper baffling of each individual mixer ensures a uniform fluid regime and provides for a constant and uniform power draw. Whether fixed or floating, proper baffling is an absolute necessity in

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