United States
Environmental Protection
Agency
Region I

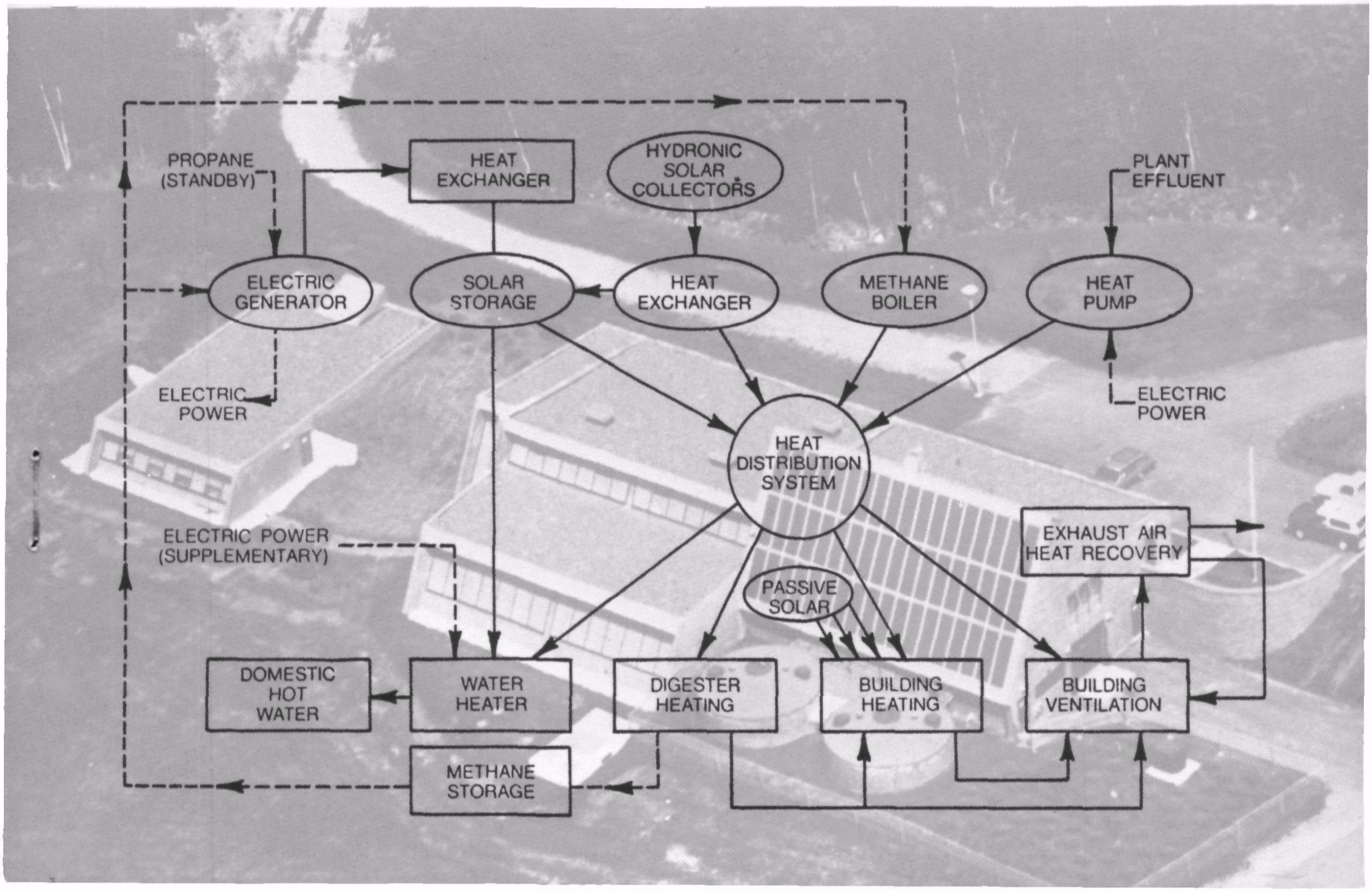
Prepared by the
Operations & Maintenance Section
Water Division
Boston, MA

June 1980

EPA

Energy Conservation In Wastewater Treatment

Considerations For Design Concepts and Operational Parameters



ENERGY CONSERVATION IN WASTEWATER TREATMENT

Considerations for
Design Concepts and Operational Parameters

Prepared by

Hibbard E. Armour, Chief
Operation & Maintenance Section
Water Division

United States Environmental Protection Agency

Region 1

William R. Adams, Jr.
Regional Administrator

June 1980

Environmental Protection Agency

Region 1

TABLE OF CONTENTS

	Page
Purpose	1
Scope	1
Source of Information	2
Introduction	2
Designed-In Features	3
In-Plant Modifications	9
Process Modifications	13
Possible Future Design Concepts	17
Recommendations	20

COVER: The Wilton, ME Wastewater Treatment Plant - *Photo and diagram courtesy of the design engineers Wright, Pierce, Barnes, Wyman Engineers of Topsham, ME.* The design makes use of passive and hydronic solar collectors, along with digester gas, to heat and otherwise fuel the facility.

Energy Conservation in Wastewater Treatment

Considerations for
Design Concepts and Operational Parameters
U.S. EPA Region 1

Purpose

This report was prepared in response to a National effort directing our immediate attention to excessive use of energy in the treatment of the Nation's wastewater streams. Subsequent chapters will be written to update the information contained herein and to present identifiable case histories of energy efficient plant designs and operations as we learn of their existence.

This report will serve to first identify energy conservation measures being employed, and secondly to recommend new measures that should be considered when planning for, and designing, future wastewater treatment plants. This report, and its future chapters, will be distributed to consulting engineers, State reviewing agencies, and to the operators of existing plants.

Scope

The scope of this report includes the following energy related considerations:

1. Those considerations that result in a direct savings on power consumption.
2. Those considerations that would reduce fuel consumption.
3. Those considerations that could lead to the use of latent energy sources which in turn would improve treatment efficiency and/or operations.

The text includes measures that were designed into existing plants; modifications that were instituted after the plants became operational; and those process control procedures that were developed by plant staffs in attempts to reduce operating costs. Material pertaining to future design concepts relates directly to innovative and alternative technology guidance and to discussions on this subject with interested parties in the field.

Source of Information

The prime source of information for this report was the experience gained through the close contact with operating wastewater treatment plants that developed under the Regions' O&M program. Many of the details, and we hope future case histories, were developed from the response to a questionnaire completed by operators of existing plants. The coordination for this effort to identify energy conservation measures was largely successful due to the excellent support from Operators Associations and the State Operations and Maintenance Offices.

Introduction

Experience shows that most of the existing wastewater treatment plants located in New England were designed with little consideration given to energy conservation either in power use or fuel consumption. At the time that many of the plants were being constructed, or were in the planning stage, the thought of an energy crisis was only a remote possibility. As the National program to construct treatment plants built up steam, the demands on the consulting engineers and the review agencies nearly overwhelmed all concerned. One of the adverse affects of this situation was that too little attention was given to inflationary trends that were developing in power costs. Much of the action now being taken to counteract the high cost of treating wastewater was developed through the diligent efforts of the plant operators.

The time is past due to recognize the energy problem and to start designing facilities that are less expensive to operate. There is a responsibility at both the Federal and State levels to produce guidance, which if followed, will yield more economical treatment of wastewater. The guidance is needed to educate the design and review engineers in planning and design techniques that will insure proper energy considerations in all future treatment works. The municipalities must in turn be encouraged to undertake energy conservation practices, and/or plant modifications, that can reasonably be accomplished using their local resources.

The following material is presented in four categories;

1. Design-In Features
2. In-Plant Modifications
3. Process Control Modifications
4. Possible Future Design Concepts

The inplant modifications are offered basically to benefit the owners of existing plants. However, this information is time-tested and as such should be given consideration by the designers of new plants. The process control modification information should be reflected in Operation and and Maintenance Manuals being prepared for new and future plants.

Designed-In Features

The survey to identify existing energy conservation measures started with an examination of the designs used to date, to determine which of their features should be considered for the future. The following designed-in features are offered for considerations:

1. Anaerobic digesters have long been used to develop a stabilized sludge and to produce a usable by-product - methane gas. Methane is commonly used as fuel to heat the digesters and sometimes is used to provide the necessary mixing in the primary digester. Plants producing excess methane often have the capability to use the gas in the plants' heating system or for heating plant water. Several plants have the capability to use methane as the fuel to incinerate grease and skimmings. A few attempts have been made to convert combustion engines to digester gas. Generators and main pumps serving the Boston MDC treatment plants are fueled by digester gas. A narrow gage train, powered by digester gas, once hauled incinerator ash from the Springfield plant to the landfill. The designs of plants making use of methane all included the capabilities to use fuel oil, natural gas, and methane. This foresight allows the plant to use commercial fuels that offer the most competitive price.

2. Many designs of anaerobic digesters incorporated features that addressed energy conservation. Older designs provided digesters that were below grade, and then later, provided earth embarkments around the tanks to give insulation from the cold. The more modern technique is to construct tanks with double walls insulated with fiber-glass. Most digester designs, involving multiple tanks, cluster the tanks in a manner that yields operational areas between units. These areas are heated by the same equipment serving the tanks and by heat that may radiate from the tank walls.

3. The more sophisticated designs make use of multiple speed controls on motors used to drive pumps and aeration equipment. The flexibility provided by this element of control allows the operator to properly pace his pumping rates and to supply only the amount of DO needed to meet the demands of the bio-mass. Such optimization yields the most economical use of electrical power. Instrumentation and automatic controls are paramount in the efficient operation of a sophisticated process train.

4. Some excellent plant designs provide a means to employ process units that will match the volume of flow being received for treatment. Such plants have compartmentalized aeration tanks, and/or multiple units, to match flow demands. All too often a plant must be operated as extended aeration, while it was designed for conventional operation only because the tanks were too large to handle the flows generated during the early life of the plant. This type of operation keeps the waste under aeration for 24 hours while in truth it only requires 6 hours. Very few existing plants are provided with flow equalization tanks. Provision of this capability would greatly reduce the power demands that result from hydraulic overloads.

5. The older treatment plants made maximum use of a hydraulic profile to reduce power needs. Much can be learned from the classical trickling filter design where full use was made of stand pipes and automatic siphons. Even the distribution arms fully utilized hydraulic principles to achieve rotation. All too often, today's designs require one or two pumpings of the entire flow. Plants

located in flood plains require effluent pumping over flood walls, a condition that could be eliminated through better siting. Everything possible must be done in the future to increase gravity flow to the plant and through the process units.

6. Many of the new treatment plant designs are making use of principles that have minimal demands on power consumption. The Oxidation Ditch makes use of a brush aerator to provide mixing and oxygen transfer. The mechanical equipment in this process has low horsepower requirements. Some of the principles employed in the trickling filter are currently being used in the Bio-Disc and the Bio-Tower. The Bio-Disc requires very low horsepower to achieve rotation while the Bio-Tower needs only pumping to provide treatment. Ideally more use should be made of lagoons and stabilization ponds, but due to space requirements such facilities are impractical in much of New England.

7. Several of the larger new plants are making use of pumping devices that are independent of power requirements or are designed to use minimal power. A very efficient unit is the screw-pump which provides completed variable flow control with only limited horsepower input. Air-lift pumps require little power to function and, with careful maintenance they perform quite well. Telescopic valves have been in use for years and they operate only on a differential hydraulic head which needs no power input.

8. More of the major plant designs are giving consideration to weather protection. It is becoming common to find enclosed headworks where the enclosure is accomplished by using fiber-glass. This material is attractive and allows the passage of light to the interior. The sun's rays provide sufficient heat to eliminate freezing of the automatic sampling equipment. A few of the new designs are providing covers for tanks such as the final clarifiers, aerobic digesters, and the chlorine contact chambers. This form of protection traps any latent heat associated with the incoming flow and reduces the risk of freezing. Plants designed in parallel often locate units in a manner that provides underground work areas, sampling stations, and pipe galleries throughout the system. Minimal heat is needed to keep such space heated and the problem of freezing is eliminated. There have been some attempts made to cover sludge drying beds. However, most of the past efforts have had only limited success due to the use of vandal- prone materials.

9. The feature of the wastewater treatment that most impacts on fuel consumption is the incineration of sludge. Much of the problem is associated with the lack of efficiency in sludge drying equipment. Equipment suppliers' claims often fall short of their mark, and in most cases, the expertise needed to run the equipment is beyond that which exists in the plant. The most promising hope we foresee in the future lies with the various presses that are appearing on the market today. When the sludge dewatering equipment fails to achieve the dryness to support burning, very expensive fuel must be added to support the incineration process. There are at least two

heat treatment units designed to improve the dewatering and burning characteristics of the sludge. The heat source available to support these units is the major factor that determines whether or not they will be used after installation. The efficiency of the more classic sludge drying systems is usually chemical dependent. The better designs provide means to use both polymers and metal salts for conditioning. In this manner the operator can optimize the drying process and improve incineration thus reducing the use of fuel.

10. Designers of small treatment facilities have provided several plants with wedge-wire units to dewater sludge. These units are energy free and are capable of matching many of the mechanical units that are in use today.

11. Existing designs frequently fail to consider haul distance to sludge disposal sites. The increase in fuel costs is having a serious impact on this non-process related activity. Similarly, many plants are burdened with sprawling layouts and extensive lawns. With the increased cost of fuel and labor the municipalities can little afford such luxuries.

12. Good plant designs provide adequate removals of gross solids, grease, and grit, prior to the process tanks. Escaping solids will result in overloading of any mechanical equipment that they come in contact with. Grit can, and often does, produce undue drag on scraper mechanisms. Excess grease results in increased demands on the aeration equipment and usually involves a complicated sub-system that is energy wasteful.

13. Older plant designs provided a pre-aeration capability which freshened raw waste and improved grease removal. This feature tended to reduce the aeration demand in the process tanks.

In-Plant Modifications

In-Plant modifications are those energy related changes that were implemented after the treatment plant was considered as operational. Some of these changes were accomplished by the consultant after the fact, but most of them resulted from the efforts of conscientious operators. These modifications are presented for consideration by owners of existing plants and by the designers of new plants.

1. Many of the plant operators have found it necessary to provide weather protection for exposed process units and equipment. Equipment containing conveyor mechanisms, such as grit systems, have been protected by wrapping with insulating material. Automatic samplers and exposed meter housings have been protected by insulating and installing incandescent lamps to provide heat. Many attempts have been made to cover process tanks and sludge drying beds. Proper support for cover material has been a problem in areas with heavy snow loads.

2. Operators have found it necessary to provide weather stripping and other insulation in their buildings to conserve heat. This has allowed them to lower heating temperatures and save fuel.

3. Lighting systems installed in treatment plants often light entire interiors. Operators have modified these systems to supply light

in work zones thus reducing the use of electricity. A few have installed automatic switches to turn exterior lights on and off with changes from daylight to darkness.

4. Operators have installed capacitor starters on major electric motors to reduce start-up surges. Most electric rates are based on peak demand loads. While the starters do not reduce power use, they do reduce the peak demand load and therefore reduce power cost. Capacitors are installed on line to tailor lagging power factors associated with alternating current. Lagging power factors impact adversely on power costs.

5. Plants that were not equipped with variable speed controls attempt to achieve desired control by installing timers on pump and blower circuits. The success of such modification often depends on the reliability of the designed-in metering system.

6. More precise control of pumping rates sometimes requires modification of the drive mechanisms themselves. This can be accomplished by varying the distance from the drive elements to the motors or by changing the sheaves or pulleys.

NOTE: Items 5 and 6 are energy related in that they serve to optimize plant operations. Optimization yields highest efficiency in both process control and power use.

7. The more progressive operators are experimenting with chemical additives to improve process efficiency. As such they are finding it necessary to improvise chemical feed systems.

The feed systems require metering control which may only entail timed discharge. Chemical feed may be by gravity, siphon, or if available, by metering pumps. Application is sometimes provided in-line on the discharge side of a pump, or may be in the form of batch dosage to a holding tank. Sludge conditioning prior to discharge to a drying bed may be accomplished directly at the splash pad or into a trough used for sludge distribution. Proper use of chemical additives and conditioners increase operational efficiency and in the case of sludge, increase solids concentration. Conditioning reduces drying times with corresponding savings in energy.

8. Many operators have installed in-line sampling points to provide better control over pumping operations. Periodic sampling during cycles of sludge pumping allows the operator to evaluate concentration of solids. Operators, who only have timed cycles to depend upon for control, may be wasting energy by pumping dilute solids or just plain water. The pumping of dilute solids will have an adverse effect on most process units receiving the flow. The pumping of excess water can result in excessive supernatant washouts that will produce serious sidestream overloads. These in turn can raise oxygen demands and otherwise cause process imbalances that can take days or weeks to correct.

9. Many operating facilites have found it necessary to install finer screens or bar racks to limit the amounts of gross solids entering the plant. This action protects downstream equipment and reduces the chances for overloads caused by foreign materials hanging up on pump impellers or aerator blades.

10. The hauling of sludge during cold weather is often complicated by the load freezing to the truck bed. At least one operator changed the truck bed and replaced it with an aluminum unit constructed with hollow sidewalls. The truck exhaust system was modified to discharge its hot gases into the sidewall cavity thus heating the unit and preventing freezing.

11. Many operators have painted dark work areas with light colors. This results in less power demand to illuminate the area and also improves its appearance.

12. Large plants equipped with incinerators are beginning to take advantage of new sludge drying technology. Where working budgets allow, conventional drying equipment is being replaced by presses. Some of the more innovative plants have received R&D funding to experiment with untried sludge drying concepts. The results of these endeavors are being closely evaluated to insure that successes are documented and made available to designers of new facilities.

13. Quite often operators of new plants find that little thought was given to ease of handling equipment or supplies being received. In at least one case, all loads had to be removed from the shippers truck and placed on a smaller vehicle so that they could be unloaded at a desired location. This procedure was not only a nuisance but it was energy expensive in both manpower and fuel consumption. Modifications of door clearance and installation of loading docks were necessary to correct the situation.

Process Modifications

Process modifications are presented to assist the existing plant staff in reducing energy usage and to provide energy related guidance for the writers of O&M manuals.

1. The most dramatic savings in fuel consumption is being achieved by plants equipped with incinerators but who are permitted to dispose of sludge after lime stabilization rather than by burning. Unfortunately this practice is not making use of expensive equipment funded largely through Federal grants. A more acceptable solution to the problem of high incinerator operating costs would result from the production of dryer sludge that would burn with little or no added fuel. Municipalities utilizing lime stabilization are exploiting landfill areas that will at best have only limited life. Their early consideration should be given to measures that will improve their sludge burning efficiency.

   Small plants in rural areas are frequently permitted to by-pass sludge drying equipment for land disposal of wet, aerobically digested, sludge. This operation has little if any energy related benefits other than the savings in manpower expended. Any savings in power costs related to non-use of mechanical dewatering equipment is offset by the gasoline used for transport.

2. Operators concerned with the conservation of energy are constantly trying to peak the efficiency of their process units. More attention is being directed to the optimization of powered equipment. Plants in Vermont are encouraged to borrow and use State owned recording

ammeters to identify surges and other phenomena that adversely affect power consumption. These plants are also required to equate power used to BOD removal in a State sponsored program to determine which modes of operation produce the highest efficiency with the least expenditure of energy. In addition to trying for peak operation of equipment, the good operator watches sludge blanket depths, measures solids concentrations, and watches DO parameters in all process stages. Sludge blankets have a direct effect on concentrations and in turn impact on pumping efficiency. High DO may indicate excessive aeration. Either of these factors will translate to higher power costs.

3. Proper maintenance of plant equipment is necessary to achieve a high degree of energy conservation. Poor maintenance results in wear and loss of efficiency. Improperly installed bearings will increase friction and cause the burn-out of equipment. Trash collecting on impellers causes an imbalance which produces vibrations, wear, and possible overload of motors. Clogged chemical feed lines reduce pump efficiency. Misaligned chains and drives produce unnecessary loads on motors. Accumulations of grit and solids can overload scrapers and collectors. Freezing conditions can and will overload any exposed mechanical equipment.

The above listing is far from complete with respect to maintenance factors that impact on energy use. However, the point is hopefully made that operators and maintenance personnel can play a major role in answering the energy crunch by performing their routine duties.

4. One of the most universal problems facing treatment plant operators is the processing of waste sludge. Gravity thickeners provide sufficient concentrations for primary sludge but are inefficient for concentrating waste activated sludge. Designs sometimes provide gravity thickeners to concentrate mixed primary and waste activated sludges. Little efficiency is achieved in combining the sludges. The solids concentration is too low for efficient dewatering and the supernatant from the thickener produces a strong sidestream. Both conditions result in loss of unit efficiency and higher power costs.

- Flotation thickeners are quite efficient in concentration waste activated sludge. Chemical additives enhance thickener operation and may well also improve the sludge dewatering. Efficient operation of flotation units will save energy throughout the entire sludge process chain.

- Thickening of sludge frequently must be accomplished in aerobic digesters prior to their dewatering. The most common practice used by operators to thicken this sludge is simply shutting off the air supply and allowing the solids to settle. The free stratum of water at the liquid surface is then pumped, siphoned, or drained off leaving the solids in a thickened state. Decanting becomes a problem in digesters equipped with fixed mechanical aerators. As soon as free liquid is removed from the tank, the surface falls below the aerator blade and mixing and aeration is lost unil more liquid is added. Diffused air on the other hand provides mixing and aeration no matter how much liquid is removed.

The efficiency of concentrating solids in digester tanks is the subject of several plants experimentation. Lab tests show that high cationic polymers will induce coagulation and will in turn produce rapid settling. Batch applications of chemicals in digester tanks may well solve the problem of concentrating sludge before it reaches the downstream process provided to accomplish dewatering. The more concentrated the sludge is, the less energy is required for the drying operation.

5. Several communities in New England are under Enforcement Orders to haul sludge from their plant for proper disposal elsewhere. This is being accomplished by using tank trucks for transport at a high cost per load. Operators faced with this problem are exploring the possibility of concentrating waste sludge through the use of chemical additives. Reductions of sludge volumes ranging up to 75% have been achieved in less than one hour in bench scale tests. Such a reduction in real operation would greatly reduce the burden of hauling sludge.

6. Activated sludge plants having empty aeration tanks often convert the inactive units into aerobic digesters. This conversion provides a capability to supplement existing digesters and to achieve volatile solids removal that could not be otherwise accomplished. This operation in itself is energy intensive. However, the net improvement to overall plant efficiency may yield positive returns.

7. Operators must exercise emergency generators on a fixed schedule. This may be accomplished either under loaded conditions or with no

equipment on line. The more prudent operators choose to run under the loaded condition and in turn receive the benefit of saving commercial power during the test periods.

8. Many operators install curtains or other splash protection devices around process units to reduce the amount of cleaning necessary after unit operations. This action saves manpower and reduces the amount of plant water that would have to be pumped for clean-up.

9. Plants using lime for pH control or sludge conditioning sometimes find that slurry can be purchased at about the same price as powdered lime. The use of slurry saves power otherwise used to mix the dry lime.

Possible Future Design Concepts

The future of wastewater treatment plant design holds a universe of yet to be discovered technology that will most effectively be tapped by the need to conserve energy. In the past we saw the evolution of facilities designed to remove settleable solids using principles requiring minimal expenditures of energy. The present brought the demand for a degree of sophistication that would yield secondary or tertiary removals, and with this demand, the construction of the energy gluttons that now treat our wastewaters.

Future design concepts must not only preserve the best that the past and present has to offer, but they must freely incorporate new principles as they evolve. These new principles often are proven through funding available from the EPA Research and Development Program. Once proven, they may well be considered for innovative or alternative incentives offered under the Federal grants program.

The Clean Water Act of 1977 clearly established the intent of Congress to encourage the use of innovative and alternative technology with emphasis on increased energy recovery and conservation, reuse, and recycling. The monetary incentive provides a grant increase of from 75% to 80% for those projects with designed-in features qualifying as examples of innovative or alternative technology.

The following list contains a few possible design concepts that may warrant consideration in future treatment plant designs. The concepts draw from past and present technology, and reflect some possible ideas from the future.

1. New designs of biological treatment systems should contain provisions to minimize demand for mechanically supplied oxygen. Plants treating strong wastes might well employ roughing units, such as bio-discs or towers, upstream of aeration tanks to reduce the oxygen demand of the raw waste. More consideration should be given to employing equalization tanks since these units would reduce the chance of solids washout. Loss of solids reduce process efficiency and therefore result in aeration without achieving effluent quality. Perhaps the most effective way to reduce aeration demands is by provision of flexibility in tank configuration. Design the tanks so that the plant can operate in their design mode with all foreseeable flows. A majority of new facilities are forced to operate in the extended aeration mode until they receive sufficient flow to be operated as designed.

2. The amount of pumping in a new plant may be reduced by providing better hydraulic profiles and thus allowing more use of gravity

ERRATA SHEET

ENERGY CONSERVATION IN WASTEWATER TREATMENT

Consideration for Design Concepts and Operational Parameters

(June 1980)

Page 18 - first paragraph - second sentence; should read:

The monetary incentive provides a grant increase of from 75% to 85% for those projects with designed-in features qualifying as examples of innovative or alternative technology.

flow between units. Use less energy dependent pumping units such as the screw pumps, air-lift pumps and telescopic valves. Provide pump flexibility that will match the demands of the flow being treated as well as that flow the plant was designed to treat. Many new plants are forced to return sludge at rates far in excess of demands simply because there is no way to further reduce the pumping rate.

3. New designs for activated sludge plants should give consideration to improving the biological activity. Thought might be given to wasting excess heat from incinerator stacks through aeration tanks so that more constant temperature can be maintained in the mixed liquor. Similarly, waste heat could be blown through hybrid trickling filters to improve winter activity.

4. A patent has recently been issued to protect a "man-made" micro-organism that will assimilate oil waste. Advances in this field may well produce the bio-mass of the future that will be used to clean our wastewaters.

5. More consideration should be given to renewing the use of anaerobic digesters. These units are still one of the most efficient means of solids reduction we have. The production of gas has the potential to provide usable heat, generate electricity, and to power vehicles. The introduction of garbage and other high organic waste into the system has some potential to increase gas production.

6. Improved weather protection is needed in most plants located in New

England. Plastics that will transmit light and solar heat should be used where possible.

7. More heat must be obtained from sources other than our fossil fuels. Solar panels and heat pumps are becoming more popular in the newer treatment plants.

8. New technology is being developed in the field of sludge reuse. One of the most reusable products today is developed through composting. The residue is used as a soil conditioner. Recently, a salvage company contracted to purchase a town's sludge so that it could reclaim precious metals that escaped from industry. More consideration should be given to this potential for reclaiming chemicals and minerals.

9. Consideration should be given to the possibility of generating hydro-electric power at the discharge end of the treatment plants.

Recommendations

The following recommendations are offered to encourage better utilization of energy saving measures in the design, modification, and operation of wastewater treatment plants.

1. The planners and designers should seek ideas and guidance from operating facilities where efforts have been made to reduce energy usage. Research of existing design concepts should be conducted to identify energy saving principles that might be modernized for future use. Application should be made for R&D grants to prove out untried design and operations concepts. Full use should be made of the incentive program associated with I/A technology.

2. The owners of operating facilites should initiate energy surveys of their facilities to learn where saving might be realized. They should strive to optimize the efficiency of each process unit in their system. The owners must encourage their operators to save energy and in turn, the operators recommendations must be supported.

3. The operator and maintenance personnel are the key to energy conservation in wastewater treatment. They must achieve the optimization that is necessary to provide the highest removal rates with minimum power or fuel expenditure. They must provide the maintenance to insure that all equipment and process units are working at peak efficiency. The plant personnel must seek ways to improve operations, or to modify equipment, so that efficiency is improved and energy demands are lessened.

It is requested that the consulting engineers, the State and Federal reviewers, and the operators of facilities, all make an effort to provide us with suggestions, case histories, or other data that can be used to promote the energy conservation cause in the treatment of wastewater. Your contribution should be sent to:

Hibbard E. Armour, Chief
Operations & Maintenance Section
Water Division
JFK Federal Building
Boston, MA 02203