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ENERGY CONSUMPTION OF ADVANCED WASTEWATER TREATMENT AT ELY, MINNESOTA

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by

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FOREWORD

Effective regulatory and enforcement actions by the Environmental Protection Agency would be virtually impossible without sound scientific data on pollutants and their impact on environmental stability and human health. In addition, it is necessary that energy utilization be evaluated to assure that these actions are not contrary to the energy conservation efforts of our Nation. Responsibility for building this data base has been assigned to EPA's Office of Research and Development and its 15 major field installations, one of which is the Corvallis Environmental Research Laboratory (CERL).

The primary mission of the Corvallis laboratory is research on the effects of environmental pollutants on terrestrial, freshwater, and marine ecosystems; the behavior, effects, and control of pollutants in the lake systems; and the development of predictive models on the movement of pollutants in the biosphere.

This report quantifies the energy used as a result of operating an advanced wastewater treatment plant which includes phosphorus removal. Other reports are being prepared which describe the impact upon the Shagawa Lake ecosystem due to the reduction in phosphorus loading.

A. F. Bartsch
Director, CERL

ABSTRACT

This report analyzes energy use for the advanced wastewater treatment plant at Ely, Minnesota, and breaks it down into three major categories; plant operation, support services, and indirect use. It provides a detailed analysis of plant operation, process by process and shows that energy used in the operation of the treatment process is minimal when compared to support services and indirect use.

This report covers a period from April 1, 1973 to March 31, 1974 and work was completed as of March 31, 1974.

CONTENTS

ACKNOWLEDGEMENTS

The author wishes to thank R. M. Brice for his considerable help in supplying information on the operation of, and equipment located at, the treatment facility. This paper would not have been possible without his assistance. In addition, I would like to thank Mr. F. Frigiola, Ecodyne Corporation; Mr. D. T. Prew, Tolz, King, Duvall, Anderson and Associates; and Mr. M. Preiss, of Cardox Corp., for supplying information and reviewing the draft manuscript. Additionally, Dr. John Sheehy, Mr. R. Smith and Dr. G. D. Zarnett provided useful comments on the manuscript.

SECTION I

INTRODUCTION

The art of decision making in any given area has become increasingly complex as our society has become more and more interdependent and as technology has advanced. This is particularly true in the areas of pollutant generation and impact and energy development and utilization. Unfortunately most decisions in these areas have been made in the past, and still are, on the basis of "how to put out the fire" not "how to prevent the fire". It has also been found that in resolving a problem, new problems are often created, some of which are harder to deal with than the original. A classic example is air pollution. One often used solution has been to utilize wet scrubbers; this transfers the problem from the air to the water. One then proceed to treat the water, which transfers the problem from the water to the sludge. The sludge often is disposed to the land or to the sea, which again transfers the problem. This time it is in a form with which scientists are still trying to deal. An exercise like this takes time, uses resources and employs people but may never really solve the problem. True problem resolution may be (and usually is) at the point of origin where the problem may be minimized or prevented.

Energy consumption at wastewater treatment plants may, in the future, be a significant input to the decision makers when determining the extent or type of treatment. Smith (1973) studied energy consumption in primary, secondary and tertiary municipal wastewater treatment plants. His work is based upon both theoretical and actual plants. However, he did not evaluate indirect energy consumption such as that used in production of chemicals. Zarnett (1975) used the direct energy consumption data compiled by Smith and added his own calculations for indirect energy consumption. This paper deals with actual energy utilization at one specific facility, the Advanced Wastewater Treatment (AWT) plant at Ely, Minnesota, and is a follow on to the environmental impact study by Kibby and Hernandez (1976). An evaluation is made of direct and indirect operational energy consumption, but does not include energy utilized in construction. That is an area which must eventually be dealt with, but is beyond the scope of this paper.

To put this study into perspective, a brief history of the initiation of the AWT plant and a description of the plant itself is necessary. Prior to initiation of the AWT, phosphorus entering Shagawa Lake was discharged from the secondary facility operated by the City of Ely. The U. S. Environmental Protection Agency (EPA), in cooperation with the City of Ely, funded construction of an advanced wastewater treatment facility to demonstrate that a reduction in phosphorus from a point source could reduce the trophic status of Shagawa Lake (Malueg et al. 1975). The tertiary plant which began operation in the spring of 1973 was designed to limit the phosphorus content of the effluent to 0.05g/m^3

(mg/l) or less. Operating data since that time indicate that the effluent from the plant does indeed meet design criteria. Both the resultant water quality and the limnological characteristics of Shagawa Lake have been reported in the literature by Malueg *et al*. (1975) and by Larsen *et al*. (1975) and will not be discussed here.

It should be recognized that the Ely AWT was designed and constructed as a research facility with very high phosphorus removal efficiency. However, this did not significantly increase the level of energy utilization; therefore, a comparison with non-research facilities is valid.

SECTION II

WASTEWATER TREATMENT PLANT

Prior to construction of the tertiary treatment plant, the Ely, Minnesota, waste treatment facility consisted of a conventional secondary treatment operation. Wastewater entered the facility, passed through two parallel grit chambers, and then through a bar screen and comminuter. The waste proceeded through a primary clarifier, trickling filter, and secondary clarifier. After the effluent left the secondary clarifier, it was chlorinated and discharged into Shagawa Lake (Brice, 1975).

Historically, sludge from the secondary clarifier was returned to the influent line of the primary clarifier and sludge from the primary clarifier was digested and discharged to sludge drying beds. Although the plant was designed to use digester gas to heat the digester, it was also necessary to use supplemental gas (Brice, 1975).

The tertiary treatment system was constructed as a research facility with a maximum of operational flexibility. Because of this, it is possible to pump almost any part of the waste "from anywhere to anywhere." Chemicals can also be introduced at many points in the system. However, much of this capability is not used and a standard procedure, which is working quite satisfactorily, was developed. It is this normal operating procedure which will be described. A plant flow schematic is shown in Figure 1.

The effluent from the secondary treatment facility is pumped to a solids-contact clarifier at a rate of 4,164 m^3/d (1.1 mgd) (Sheehy and Evans, 1976). Flow from this clarifier goes to a second, similar clarifier and then to a flow splitter box which feeds by gravity to four dual media filters.

The filters polish the effluent by removal of suspended solids containing phosphorus. Use of dual media (anthracite and sand) permits longer filter runs while still achieving excellent solids retention capability. Backwash water is returned to the secondary plant influent line. The filter effluent is chlorinated and discharged to Shagawa Lake or pumped back to the plant for use as process water.

It should be noted that an activated carbon feed capability is available for the removal of soluble organic phosphorus, or other uses as indicated. However, due to normal plant efficiency activated carbon is seldom used; consequently, the analyses which follow do not include an assessment of the activated carbon system.

Chemical sludge is withdrawn from the tertiary system at both clarifiers and pumped to a gravity sludge thickener. Organic sludge from the primary and secondary clarifiers goes to the sludge thickener where it is mixed with the chemical sludge from the tertiary plant. From the thickener the sludge is pumped to a rotary belt vacuum filter and trucked to an approved sanitary landfill. In the event of equipment failure the sludge can bypass any given treatment facility and be discharged to a sludge holding pond. Filtrate from the vacuum filter and slurry from the vacuum are discharged to the equalization tank and returned to the head of the plant.

The tertiary treatment plant was designed to treat 5,678 m^3/d (1.5 mgd) and from April 1, 1973 - March 31, 1974 was treating 4,164 m^3/d (1.1 mgd). All data in this paper are for this time period. Overall plant performance relative to certain parameters is presented in Table 1 (Sheehy and Evans, 1976).

TABLE 1. ELY AWT PLANT PERFORMANCE

	Influent	Effluent	Removal			
	g/m^3 (mg/l)	g/m^3 (mg/l)	%	g/m^3 (mg/l)	kg/d	Mg/yr
Total P	7.1	0.05	99.4	7.02	29.2	10.7
Suspended Solids	202.0	1.30	99.4	201.0	837.0	306.0
Alkalinity (as $CaCO_3$)	181.0	41.90	76.9	139.0	579.0	211.0
BOD	90.0	12.30	86.3	78.0	325.0	119.0

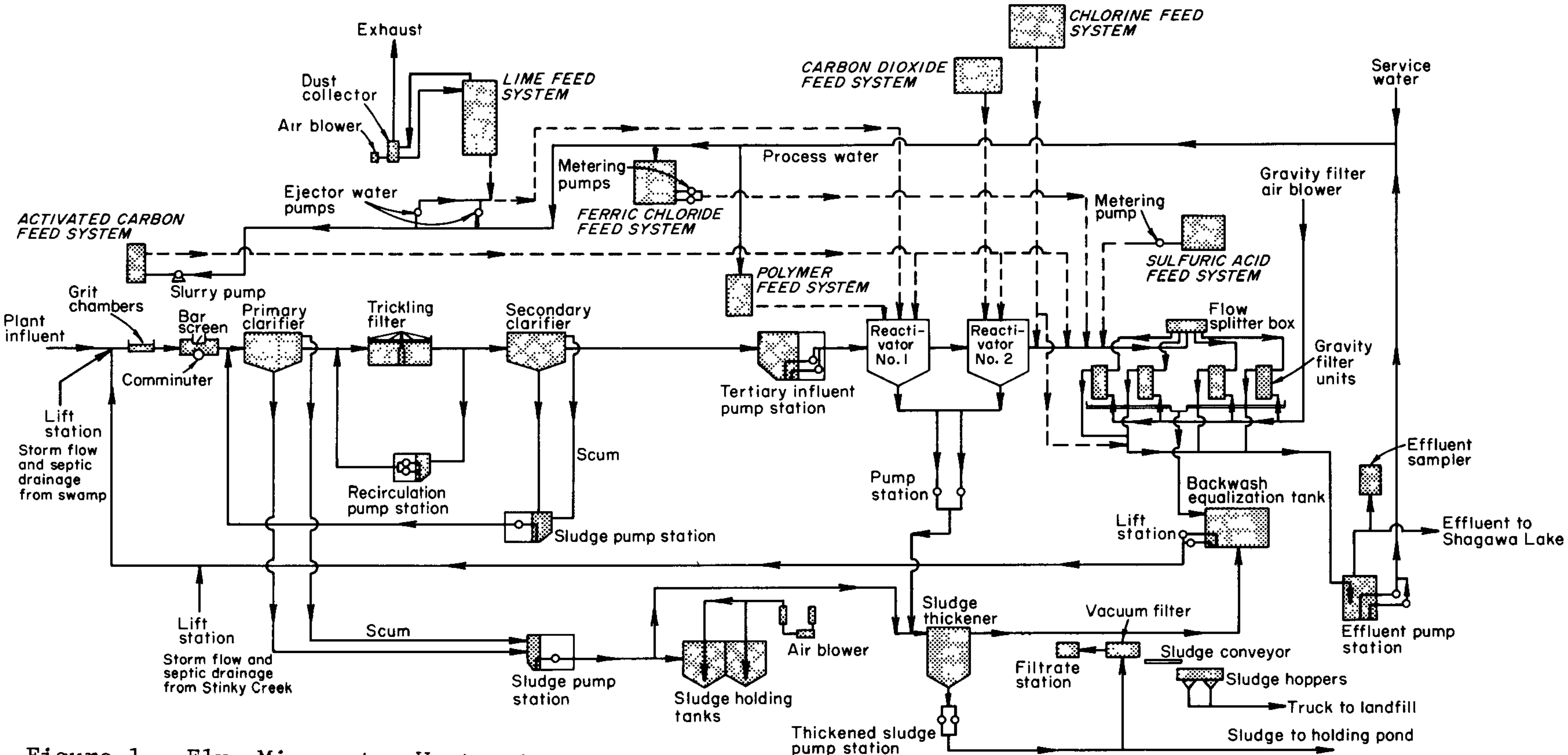

Figure 1. Ely, Minnesota, Wastewater Treatment Plant Normal Flow Schematic

——— *Process piping*

– – – *Chemical feed piping*

SECTION III

DIRECT ENERGY UTILIZATION

Direct energy utilization, for the purposes of this paper, is that energy which is utilized directly in the operation of the facility for such uses as pumps, motors, chemical feed equipment, lighting, and heating. It does not include energy utilized in the production of chemicals or other resources.

To arrive at actual (or estimated) energy utilization by various plant processes it is necessary to make certain assumptions and establish standard procedures for calculations. Since electrical meters and duty cycles are not available on most pumps, motors, etc., it is usually necessary to calculate power consumption on the basis of pump or motor characteristics, and normal operating efficiencies. These calculations were carried out in the same manner as was done by Smith (1973).

A major part of electrical consumption at a treatment plant is due to pumping the main stream or ancillary streams from one level to a higher level. The horsepower consumed in pumping water is given by the following relationship:

$$\text{Pumping Horsepower} = \frac{\text{mgd} \times 10^6 \times H}{1440 \times \quad \times e_h} \quad \frac{8.34 \text{ lb/gal}}{33{,}000 \ \frac{\text{ft}\cdot\text{lb}}{\text{min}\cdot\text{hp}}}$$

mgd = volume of water pumped, millions of gallons per day
H = total dynamic head, ft. of water
e_h = hydraulic efficiency

This can be simplified as follows:

$$\text{Pumping Horsepower} = \text{mgd} \times 0.1755 \times H/e_h$$

The hydraulic efficiency of water pumps depends on the volume of water pumped as well as the total dynamic head delivered. Since most water pumps are driven by induction motors, the speed of the pump is almost fixed. If the duty cycle for a pump is known, the hydraulic efficiency can be accurately determined. This information was not available in most instances at this plant. Therefore, rough averages for hydraulic efficiency were used as presented by Smith (1973):

up to 1000 gpm	70% hydraulic efficiency
1000 - 7000 gpm	74 % hydraulic efficiency
over 7000 gpm	83% hydraulic efficiency

When converting pumping or motor horsepower to electrical power consumption the electrical power in kilowatts is expressed as: kilowatt hours = 0.85 (eff.) x horsepower x hours operating as was done by Smith (1973). These basic formulae and assumptions are used throughout this report.

WASTEWATER TREATMENT

Primary - Secondary Plant

There are four sources of wastewater which make up the influent to this treatment facility and average 4,164 m^3/d (1.1 mgd): tertiary plant return streams from lift station number 1, 195.8 m^3/d (51,744 gpd); water from lift station number 2, which pumps water from "Stinky Ditch" creek containing some septic tank drainage and also some runoff from the sludge holding pond, 87 m^3/d (23,000 gpd); swamp water from lift station number 3, 142.8 m^3/d (37,720 gpd); and municipal wastewater from the City of Ely, 3,738 m^3/d (987,536 gpd).

Lift station number 1 has two 200 gpm pumps designed to operate against a total dynamic head of 55 feet. In pumping an average of 195.8 m^3/d (51,744 gpd) this station utilized 52.2 MJ/d (14.5 kWh/d). Lift station number 2 has two 100 gpm pumps designed to operate against a total dynamic head of 40 feet. It pumps an average of 87 m^3/d (23,000 gpd) and utilizes 16.9 MJ/d (4.7 kWh/d). Lift station number 3 has two 100 gpm pumps designed to operate against a total dynamic head of 30 feet, and pumps an average of 142.8 m^3/d (37,720 gpd) and utilizes 20.9 MJ/d (5.8 kWh/d). The municipal waste water from the City of Ely enters the plant by gravity flow so no pumping energy is utilized.

The total energy used for influent pumping is 90 MJ/d (25.0 kWh/d) for a plant treating an average of 4164 m^3/d (1.1 mgd). If all influent flows were reduced proportionately the energy consumption for influent pumping would be 81.7 MJ/d (22.7 kWh) for 3,785 m^3/d (1.0 mgd). Flow through the primary and secondary treatment plant is by gravity.

Throughout this paper, energy used for treatment of 4,164 m^3 (1.1 mgd) is converted to probable energy use for 3,785 m^3/d (1.0 mgd). This is done to provide a comparison with the work done by Smith (1973).

Preliminary treatment includes a grit chamber, bar screen and comminuter. The grit chamber and bar screen are manually cleaned, and this use no electrical power. The comminuter was designed for 5,678 m^3/d (1.5 mgd), with a peak flow of 28,387 m^3/d (7.5 mgd). It is operated 24 hours a day by a 1.5 hp motor with energy consumption of 110.2 MJ/d (30.6 kWh/d) independent of flow.

From the comminuter the sewage flows by gravity to the primary clarifier. This is a 15.2 m (50 foot) diameter circular settling basin with mechanical equipment for sludge and scum removal, operated by a 0.5

hp motor. This unit operates 24 hours a day with an energy consumption of 36.7 MJ/d (10.2 kWh/d) independent of flow.

Flow from the primary clarifier is by gravity to the trickling filter. This is an 18.3 m (60 foot) diameter, 1.8 m (6 foot) deep filter consisting of rock varying in size from 7.6 - 10.2 cm (3 - 4 inches) in diameter. Wastewater is distributed over the surface of the filter by a four-arm reaction type rotary distributor, so no additional energy is used. Recirculation of a portion of the filter effluent can be carried out, but is not.

Flow from the trickling filter is by gravity to the secondary clarifier, this is a 15.2 m (50 foot) diameter circular settling basin, similar to the primary clarifier, with mechanical equipment for sludge and scum removal operated by a 0.5 hp motor. This unit operates 24 hours a day with an energy consumption of 36.7 MJ/d (10.2 kWh/d), independent of flow.

Tertiary Plant

Flow from the secondary clarifier is by gravity to the 208.2 m^3 (55,000 gallon) wetwell which dampens flow variation and allows nearly constant hydraulic loading of the tertiary treatment units. Pumping from the wetwell is accomplished by two variable speed 1,100 gpm pumps designed to operate against a total dynamic head of 65 feet. In pumping 4,315 m^3/d (1.14 mgd) this station utilized 1291 MJ/d (358.5 kWh/d). If the primary plant influent flows were reduced to 3,785 m^3/d (1.0 mgd) the energy use would be reduced to 1132 MJ/d (314.5 kWhd).

Wastewater is pumped from the tertiary influent wetwell, and all flow through the tertiary system is by gravity. The tertiary treatment system includes first and second stage lime clarifiers in series, each with a 3 hp motor driven scraper and an 8 hp variable speed (21-84 rpm) pump. The first clarifier is 16.7 m (55 feet) in diameter with a height of 5.9 m (19.5 feet). The second clarifier is also 16.7 m (55 feet) in diameter, but is 5.0 m (16.5 feet) in height. Both units have a hydraulic capacity of twice the design flow, 11,355 m^3/d (3 mgd). Flow goes from the second clarifier to four parallel dual media gravity filters, each 3.7 m^3 (12 feet) in diameter and 4.9 m (16 feet) high. Media depth is 0.9 m (3 feet), and air scour and backwashing is automatic. All of this system is operated through a single control system. Energy consumption was calculated as 354.6 MJ (98.5 kWh) per day for each of the clarifiers, 14.0 MJ (3.9 kWh) per day for sludge pumping from the clarifiers, and 110.2 MJ (30.6 kWh) per day for the sludge thickener. Filter operation (air compressors, backwashing, etc.) uses approximately 125.6 MJ (34.9 kWh) per day. Information provided by Ecodyne Corporation indicates energy consumption for the tertiary plant (not including influent pumping) is 959.0 MJ (266.4 kWh) per day.

Service Water

The treatment plant requires large quantities of water in its operation which includes such uses as lime slurry water and other chemical feeds, plus plant cleanup, etc. Two water sources are available for this with primary reliance placed upon using plant effluent water, with Ely Municipal water for potable water uses plus backup for the use of plant effluent water. Two 300 gpm pumps designed to operate against a total dynamic head of 120 feet are used to pump 852 m^3/d (225,000 gpd) of plant effluent service water. These utilize 585 MJ (138.0 kWh) per day. If the 4,164 m^3/d (1.1 mgd) was reduced to 3,785 m^3/d (1.0 mgd) it would be approximately 531 MJ (147.7 kWh) per day. It is difficult to allocate this power use back to each process so it is left as a single item use.

SLUDGE HANDLING

Sludge Pumping and Thickening

Approximately 6.4 m^3/d (1,680 gpd) of sludge are pumped from the secondary to the primary clarifier by a 50 gpm sludge pump designed to operate against a total dynamic head of 37 feet. Energy use is approximately 1.4 MJ (0.37 kWh) per day. This would reduce to 1.2 MJ (0.34 kWh) per day at 3,785 m^3/d (1.0 mgd). A total of 12.7 m^3 (3,360 gal.) of sludge per day is pumped from the primary clarifier to the sludge thickener by a 85 gpm sludge pump designed to operate against a total dynamic head of 23 feet. Energy use is approximately 1.7 MJ (0.47 kWh) per day which would reduce to 1.6 MJ (0.43 kWh) at 3,785 m^3/d (1.0 mgd).

Sludge from the two lime clarifiers goes to a single pumping station containing two variable speed (84-420 rpm) sludge pumps designed to operate against a total dynamic head of 30 feet (estimated). 67.7 m^3 (17,900 gal.) and 28.4 m^3 (7,500 gal.) per day are pumped, from the first and second stage clarifiers respectively, to the sludge thickener. Energy use is 16.5 MJ (4.6 kWh) per day which would reduce to 15.0 MJ (4.2 kWh) at 3,785 m^3/d (1.0 mgd).

The sludge thickener is 7.9 m (26 feet) in diameter and is provided with a 1.5 hp motor which drives the scraper. Energy consumption is 110.2 MJ (30.6 kWh) per day. Sludge pumping from the sludge thickener is accomplished by two variable speed (84-420 rpm) sludge pumps designed to operate against a total dynamic head of 30 feet (estimated). The energy utilized is 16.6 MJ (4.6 kWh) per day.

Vacuum Filter

The vacuum filter operation has a number of energy consumers. It is operated six days a week and averages 3.6 hours per day over the year. The filter is a continuous fabric type having a 1.8 m (6 foot) diameter drum 2.4 m (8 feet) wide. The drum is driven by a 1 hp motor using 11.0 MJ (3.1 kWh) per day. Two other motors are also used in filter operation, a 1 hp agitator motor and a 3/4 hp motor for driving the discharge roll. These use 11.2 MJ (3.1 kWh) and 8.3 MJ (2.3 kWh) per day, respectively. The vacuum pump is powered by a 30 hp motor and utilizes 330.5 MJ (91.8 kWh) per day. The filtrate pump is a 120 gpm pump designed to operate against a total dynamic head of 38 feet, has a 3hp motor, and utilizes 21.3 MJ (5.9 kWh) per day. Total energy use in the vacuum filter operation is 382.4 MJ (106.2 kWh) per day.

Sludge Cake Handling

After filtration the sludge cake drops onto a conveyor belt operated by a 2 hp motor which uses 22.0 MJ (6.1 kWh) per day. The belt discharges to two sludge hoppers where it is stored for trucking to a sanitary land fill. The trucks which haul the sludge use an average of 0.0254 m^3 (6.7 gallons) per day, or a direct energy consumption of 900 MJ (857.5 x 10^3 BTU) per day. This would reduce to 828 MJ (779.5 x 10^3 BTU) per day for a 3,785 m^3/d (1.0 mgd) flow rate.

CHEMICAL FEED

The lime feed system consists of two storage hoppers with vibrators, a dust collection system, two gravimetric feeder slaker units, two centrifugal pumps, and two hydraulic ejectors. The slaker feeder (1/4 hp), mixer (1/2 hp), and conveyor (1/4 hp) utilize 73.4 MJ (20.4 kWh) per day. The 5 hp motor that drives the 60 gpm pumps utilizes 367.2 MJ (102 kWh) per day.

Ferric chloride is stored in a 23 m^3 (6,000 gallon) tank which supplies two 0.11 m^3 (30 gallon) day tanks. Two flow proportional diaphragm pumps feed from the day tanks. Pumping energy is minimal, but the 1.5 hp motor which drives the mixer uses 110.2 MJ (30.6 kWh) per day.

Activated carbon and polymer are seldom used and consume essentially no energy.

Sulphuric acid (for pH control) is fed by pumps similar to the ferric chloride pumps, with minimal energy consumption.

Liquid carbon dioxide, used for pH control, is stored in a 22 metric ton (24 ton) refrigeration unit and fed by dissolving in recycled plant effluent. Based upon information obtained from Cardox (Chemetron Corp.), approximately 110.5 MJ (30.7 kWh) per day are required for vaporization. A 6,000 lb. per day 75 watt feeder uses 6.5 MJ (1.8 kWh) per day. Total carbon dioxide energy use is 117 MJ (32.5 kWh) per day.

Chlorine is fed by a unit similar to the carbon dioxide feeder and uses 6.5 MJ (1.8 kWh) per day.

SUPPORT SERVICES

Energy consumption for direct operation of a waste treatment facility may be comparable at various locations in the country. Support services, however, could have significantly different energy consumption levels. Direct electrical energy consumption for the treatment process at Ely was 4,388 MJ (1,219 kWh) per day, and direct electrical energy consumption for support services was 3,348 MJ (930 kWh) per day. This includes indoor and outdoor lighting; operation of tools, office and laboratory equipment; blowers for heating units; and miscellaneous other equipment and uses.

Calculations were made using the same procedure as used by Smith (1973) for outdoor lights and indoor square footage. He cites planning figures of 2-4 watts per square foot of floor space. Primarily because of extreme weather conditions almost all of this plant is covered (indoors). There are approximately 2,060 m^2 (22,170 square feet) of indoor space at this plant. Based upon 3 watts per square foot and a 10 hour day, electrical consumption would be 2,394 MJ (665 kWh) per day. With outdoor lighting this would increase to 2,448 MJ (680 kWh) per day. Actual electrical use, as stated before, was approximately 3,348 MJ (930 kWh) per day. Calculations based upon 4 watts per square foot would give an approximate electrical use of 3,240 MJ (900 kWh) per day which is very near actual. Although a 10 hour day was used, it must be recognized that an operator was present at the tertiary plant 24 hours a day, and many items such as lights, blowers, etc. often operate on a 24 hour basis.

Heating was the other large energy user in support services. Over the year an average of 0.652 m^3 (172.6 gal) per day of fuel oil was used. This amounted to 27,677 MJ (26.235 x 10^6 BTU) per day.

This plant was designed to treat 5,678 m^3 (1.5 mg) per day and treated 4,164 m^3 (1.1 mg) per day. Regardless of quantity treated (more or less), energy consumption for the support services would remain essentially the same at this plant.

SECTION IV

INDIRECT ENERGY UTILIZATION

Indirect energy is that energy which is consumed in the manufacturing or processing of a material or direct energy, which is used in the treatment plant at Ely. This includes the energy needed to produce lime, CO_2, $FeCl_3$, polymer, H_2SO_4, Cl_2, gasoline, electricity and fuel oil. The quantities of various energy sources used per year are shown in Table 2. Data was obtained from Kibby and Hernandez (1976). These quantities have been put into common energy units and are shown in Table 5.

TABLE 2. ENERGY SOURCES REQUIRED TO PRODUCE RESOURCES USED ANNUALLY FOR AWT FOR ELY, MINNESOTA.

RESOURCES		ENERGY SOURCES											
	Use Per Year	Fuel Oil		Coal		Natural Gas		Propane & Butane		Crude Oil		Electricity	
		m^3	(gal)	Mg	(ton)	m^3	(Cu Ft)	m^3	(gal)	m^3	(gal)	GJ	(kWh)
Lime Mg (tons)	488(538)	37.6	(9935)			73 x 10^3	(2.58 x 10^6)					96.84	(26,900)
CO_2 Mg (tons)	152(168)											96.48	(26,800)
$FeCl_3$ Mg (tons)	39.9(44)	nil											
Polymer kg (lbs)	304(670)	not known											
Sulfuric Acid Mg (tons)	74.4(82)	nil											
Chlorine Mg (tons)	4.7(5.2)	0.03	(7.7)	0.14	(0.15)	447	(15.8 x 10^3)					23.22	(6,450)
Gasoline m^3 (gal)	9.27(2450)					42.5	(1502)	0.06	(16.6)	--	(0.94)		
Electricity kWh	780,000	15.4	(4070)	326	(359)								
Fuel Oil m^3 (gal)	238(63,000)					1093	(38.6 x 10^3)	1.62	(427.8)	0.09	(24.3)		
TOTAL		53.0	(14,013)	326	(359.2)	73.6 x 10^3	(2,636 x 10^3)	1.68	(444.4)	0.09	(25.2)	216.54	(60,150)

Energy	Elect	3,413 BTU/kWh
	Fuel Oil	19,000 BTU/# 8#/gal
	Gasoline	20,750 BTU/# 6.152 #/gal
	Nat gas	1,050 BTU/cu ft
	Prop & But	95,500 BTU/gal
	Crude oil	138,100 BTU/gal
	Coal	8,500 BTU/#

SECTION V

DISCUSSION AND SUMMARY

This paper reports energy utilization required for the operation of the AWT plant at Ely, Minnesota, and has dealt with three major areas of energy utilization: plant operation, support services, and indirect uses. A detailed breakdown has been make of plant operation, unit by unit (Table 3) and of support services (Table 4). Indirect energy utilization is shown in Table 5, and a summary of total energy utilization is shown in Table 6.

In addition to showing operational energy use at Ely, Table 3 compares this to the data obtained by Smith (1973). There appears to be little consistency in comparing these data, but one must recognize that each treatment plant did use some different unit processes. It should also be remembered that at the 3,785 m^3/d (1.0 mgd) level Smith was dealing with a "standard" plant, whereas this paper deals with a specific operational plant and uses actual energy consumption. Another factor to consider is that the Ely plant was designed to treat 5,678 m^3/d (1.5 mgd), was being operated at 4,164 m^3/d (1.1 mgd), and data have been converted to 3,785 m^3/d (1.0 mgd). If the plant were operating at design flow, the energy utilized per 3,785 m^3 (1.0 mg) would be nearer to that calculated by Smith.

The energy utilized by support services at Ely far surpasses energy utilization in the treatment process. This is partially due to the geographical location. Nights are long and the weather is cold. Almost the entire facility is enclosed and heated, so fuel is the largest single energy use. This is of particular significance in view of rising fuel costs and potential shortages. It should be noted that regardless of the daily flow or level of treatment used (phosphorus removal) this energy use would not be reduced. Smith (1973) reports an estimate of 205 MJ (57 kWh) per day for primary-secondary plant support services. This is very close to the probable use at the Ely primary-secondary plant. He did not show similar calculations for tertiary treatment.

TABLE 3. DAILY DIRECT ENERGY UTILIZATION FOR AWT PLANT OPERATION AT ELY, MINNESOTA, COMPARED TO SMITH (1973) DATA.

	ELY, MINNESOTA, AWT PLANT				SMITH (1973)	
	Actual		Converted to			
PLANT SIZE	4,164 m^3 (1.1 mg)		3,785 m^3 (1.0 mg)		3,785 m^3 (1.0 mg)	
	MJ	kWh	MJ	kWh	MJ	kWh
PRIMARY-SECONDARY PLANT						
Influent Pumping	90	25.0	81.7	22.7	551	153
Preliminary Treatment						
Bar Screens	--	--	--	--	5.5	1.5
Comminuter	110.2	30.6	110.2	30.6	55.1	15.3
Grit Removal	--	--		--	6.1	1.7
Primary Sedimentation	36.7	10.2	36.7	10.2	110.2	30.1
Trickling Filter						
Recirculation Pumping	--	--	--	--	659	183.
Secondary Sedimentation	36.7	10.2	36.7	10.2	110.2	30.6
TERTIARY PLANT						
Influent Pumping	1,291	358.5	1,132	314.5	--	--
Lime Clarification						
Clarifiers (2)	709	197.0	686	190.5	187.2	52.
Lime Feed	440.6	122.4	400.6	111.3	--	--
Recarbonation	117	32.5	106.9	29.7	338.4	94.
Multi Media Filtration	125.6	34.9	114.1	31.7	360	100.
Ferric Chloride Feed	110.2	30.6	110.2	30.6	--	--
Chlorine Feed	6.5	1.8	6.5	1.8	2.6	0.7
Service Water Pumping	585	162.4	531	147.7	--	--
SLUDGE HANDLING						
Sludge Pumping	33.5	9.3	30.6	8.5	9.6	2.6
Gravity Thickener	110.2	30.6	110.2	30.6	36.7	10.2
Anaerobic Digesters	--	--	--	--	445	123.6
Lime Sludge Dewatering	--	--	--	--	230.4	64.0
Vacuum Filtration	404.3	112.3	367.5	102.9	205.2	57.
[1]Sludge Hauling (857.5 x 10^3 BTU)	900	250	818.2	227.3	--	--
Multiple Hearth Incineration	--	--	--	--	194.4	54.0
Misc. Pumps, Motors, etc estimated as 5% of total	256	71	232	65	--	--
TOTAL	5,360	1,489	4,873	1,353	3,503	973

[1]Gasoline use, not electrical

TABLE 4. DAILY DIRECT ENERGY UTILIZATION FOR AWT PLANT SUPPORT SERVICES AT ELY, MINNESOTA (INDEPENDENT OF FLOW)

	Actual 4,164 m^3 (1.1 mg)
[1]Miscellaneous-- lights, tools, blowers, etc.	3.35 GJ (930 kWh)
[2]Fuel Oil (Heat) 0.62 m^3 (172.6 gal)	27.68 GJ (26.235×10^6 BTU)
TOTAL	31.03 GJ

[1]Smith (1973) only showed primary-secondary support services.
[2]Smith (1973) showed no data since he did not use a specific plant at a specific geographical location.

After fuel the next largest use of energy is indirect use for the production of resources used. This use also far exceeds the energy used in the treatment process. The energy use for support services may vary greatly by geographical location of an AWT plant, but the indirect energy use will not. Regardless of where a plant of this type is located, this utilization will remain relatively high. It can readily be seen that the greatest energy use is in the production of lime and electricity. Details of energy use in production of resources are discussed in detail by Kibby and Hernandez (1976).

A summary of total energy consumption at Ely is shown in Table 6. This very dramatically shows the relative energy consumption of the three major areas of energy use. As stated before, support services energy use is disproportionately high due to the geographical location. However, it would be high at almost any location in the United States. Of the total 62.37 GJ used per day at Ely, 27.68 GJ are attributable to heating the plant, 12.46 GJ are used in producing the lime, and 12.96 GJ are used in producing the electricity used at the plant. These three items constitute 85% of the plant energy use. Energy consumption should be a consideration in the design of any treatment plant. This analysis shows that maximum energy benefit can be obtained by concentrating on conservation of electricity, heat, and lime. It should be noted that these high energy items are, to a large degree, a reflection of the advanced waste treatment portion of the Ely plant. This large energy consumption, and environmental tradeoffs discussed by Kibby and Hernandez (1976), further emphasize the necessity for thorough evaluations prior to instituting advanced waste treatment as we know it today. An additional factor which has not been studied is energy utilized in construction. Energy use is a direct measurement of cost, in both dollars and natural resources. A complete and thorough evaluation should be carried out when an advanced wastewater treatment facility is considered, and no such facility should be built unless the study indicates a true need with minimum adverse effects.

TABLE 6. A SUMMARY OF DAILY ENERGY UTILIZATION FOR AWT PLANT OPERATION AT ELY, MINNESOTA

	Actual 4,14 m^3/d (1.1 mgd)	Converted to 3,785 m^3/d (1.0 mgd)	Percent of Total
	GJ	GJ	
Plant Operation	5.36	4.87	8.6
Support Services	31.03	31.03	49.7
Indirect	26.05	23.68	41.7
TOTAL	62.44	59.58	100.0

TABLE 5. INDIRECT ENERGY UTILIZATION FOR AWT FOR ELY, MINNESOTA

RESOURCES USED		Energy Used to Produce Resources					
		Per Year		Per Day 4,164 m^3 (1.1 mg)		Converted to 3,785 m^3 (1.0 mg)	
	Per Year	GJ	BTU	GJ	BTU	GJ	BTU
Lime Mg (tons)	488(538)	4,548	($4{,}311 \times 10^6$)	12.46	(11.81×10^6)	11.33	(10.74×10^6)
CO_2 Mg (tons)	152(168)	96.5	(91.47×10^6)	0.26	(250.6×10^3)	0.24	(227.8×10^3)
[1]$FeCl_3$ Mg (tons)	39.9(44)	--		--		--	
[2]Polymer kg (lbs)	304(670)	--		--		--	
[1]H_2SO_4 Mg (tons)	74.4(82)	--		--		--	
Chlorine Mg (tons)	4.7(5.2)	43.6	(41.32×10^6)	0.12	(113.2×10^3)	0.11	(10.9×10^3)
Gasoline m^3 (gal)	9.27(2450)	3.5	(3.29×10^6)	0.01	(9.02×10^3)	0.01	(8.2×10^3)
[3]Electricity kWh	780×10^3	4,727	(4481×10^6)	12.96	(12.28×10^6)	11.77	(11.16×10^6)
[4]Fuel Oil m^3 (gal)	238(63×10^3)	88.6	(83.99×10^6)	0.24	(0.230×10^6)	0.24	(0.230×10^6)
		9.508	($9{,}012 \times 10^9$)	26.05	(24.69×10^6)	23.70	(22.47×10^6)

[1]Negligible energy used

[2]Energy used not known, but probably negligible

[3]This is net energy, based upon 33% thermal efficiency

[4]No reduction from 4,164 m^3 (1.1 mg) to 3,785 m^3 (1.0 mg) since fuel oil is used to heat the building.

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SI UNITS AND CONVERSION FACTORS USED

UNITS

length	metre (m)	energy	joule (J)
mass	kilogram (kg)	volume	cubic metre (m^3)
area	square metre (m^2)		

SI PREFIXES

Multiplication Factors	Prefix	SI Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

CONVERSIONS

To Convert From	to	Multiply by
BTU	joules (J)	1.055×10^{3}
feet	metre (m)	0.3048
$foot^2$	$metre^2$ (m^2)	9.290×10^{-2}
$foot^3$	$metre^3$ (m^3)	2.832×10^{-2}
gallon (U.S. liquid)	metre (m^3)	3.785×10^{-3}
inches	centimeters (cm)	2.540
kilowatt-hour (kWh)	joules (J)	3.600×10^{6}
pounds (lb avoirdupois)	kilogram (kg)	4.536×10^{-1}
ton (short-2000 lbs)	megagrams (Mg)	0.907

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(Please read Instructions on the reverse before completing)

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16. ABSTRACT

This report analyzes energy use for the advanced wastewater treatment plant at Ely, Minnesota, and breaks it down into three major categories: plant operation, support services, and indirect use. It provides a detailed analysis of plant operation, process by process, and shows that energy used in the operation of the treatment process is minimal when compared to support services and indirect use.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Energy Consumption	Advanced Wastewater Treatement	

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