

CEER-PC-020

MAGNETIC FILTRATION MOBILE TESTING LABORATORY

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MAGNETIC PIUTRATION MOBILE TESTING LABORATORY

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MAGNETIC SEPARATION PROTECT

(CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

university of Puerto Rico

May, 1979

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Research

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MAGNETIC FILTRATION MOBILE TESTING LABORATORY

(CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

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WOGNETIC PILTRATION MOBILE TESTING LABORATORY,

Roche Products Inc.

MAGNETIC SEPARATION PROJECT

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

university of Puerto Rico

May, 1979

ENDORSEMENTS:

fabasi, ?fead, Solar Divas

Anrbun 10. Bled

Des Arthur MES. Block, Scientist, Magnetic Separations Project

Dev Juan W Bonnet, Je.

center for Energy and Environment

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MAGNETIC PIMIRATION MOBILE TESTING LABORATORY

+ Magnetic Separations Project

Center for Energy and Environment Research

Caparra Heights Station

San Juan, Puerto Rico 00935

Project site + Center for Energy and Environnent Research

Caparra Height Station

San Juan, Puerto Rico 00935

?Telephone + (809) 767-0338

otal Funding

Requested + \$25,000

?his project is an experimental evaluation project ained at determining the applicability of magnetic separation to waste effluents generated in Puerto Rico and having unusually high levels of BOD and total suspended solids.

?the Center for Energy and Environnent Research is a part of the University of Puerto Rico, a non-profit institution for higher learning.

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I. Project overview

1.1 Introduction

Research and development projects ained at relevant public health and welfare problens confronting Puerto Rico have lead the scientific staff of the Center for Energy and Environment Research (CEER) to consider new technical options for treatment of waste effluents regarded as problematic ue to large daily volumes, high BOD and elevated levels of 155. Water re-use after tertiary treatment is already projected as an alternative for the Amminent problen of water x:

an effective, energy-conservative treatment method with very modest land area requirements called high gradient magnetic filtration (NGM). CEER hae established an dnplenentation, program for island-wide use of HGNP.

1.2 Objectives of the CEER's HOM Program

The objectives of the program are to:

1. provide a comprehensive compendium of waste effluent treatment applications with emphasis on most urgent needs of Puerto Rico?

2. to help design and install effluent-specific How ayatens for demonstration applications:

3, to test and monitor the operation of desonstration plants;

4. evaluate the cost-benefit in demonstration plant. applications and

5. make recomendations concerning specific large scale applications to industry and government.

ource development. This proposal deals with

1.3. CHER's Proposed Program

current research and development efforts have centered upon attempts

to flocculate and filter run slops (nosto), pharmaceutical production wastes and

also sowaye following seeding with fine magnetic powder (magnetite). Actual

#Altration of samples supplied by CEER have already been carried out in laboratorie

at Sala Magnetics, Inc., Canbridge, MA and at Salford University, Salford, U. K.

In order to develop the program more rapidly and more completely, an island based

laboratory is necessary. Consequently, CEER has contracted with Sala Magnetics,

Inc. for the refurbishing and shipment of a mobile HGMP laboratory which will be

operated at 10 different Locations on the island where effluent, streams are Likely

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?to impact the enviroment. Effluents of this type are conventionally point

sources, but non-point contributions çuch as combined storm overflow will also

be included.

4.3.1 Description of the Mobile Laboratory Facility

The Sala - HGMP AWT Magnetic Filtration Mobile Pilot Plant

is a fully automated self-contained magnetic seeding/filtration unit. Constructed on a truck-trailer chassis:

storage space. The laboratory can be equipped to measure a variety of parameters.

The plant unit is designed for automatic continuous operation without attention

for periods of up to 24 hours. A stripchart recording turbidimeter provides

continuous readout of effluent quality. With two operational magnetic filters,

simulation of the operation of a full-scale variable flow capacity unit is

The mobile plant includes laboratory, office and

possible.

Minimal magnetic filtration specifications of the mobile unit

are as follows. Flow capacity is 10 gallons per minute (0.6 Liter/s) Typical

sludge generation is 1/2 kg/hr. while the trailer may be fully self contained

and require no external utility services, if utilities are available, the re-

levant requirements are @.8 - 22kM, 120/220 V single phase electric power tap

water flow of 5-25 gpm (exclusive of feed); and compressed air 1-3 cfm at 40-60 psi. Under typical operating conditions magnetite seeding is not expected to exceed 0.25 kg/hr while alum and polyelectrolyte (or neutral) polymer flocculant dosing rates are typically 0.1 and 0.001 kg/hr, respectively. The interior of the pilot plant is shown in Figure T.

1.4 Expected benefits

1.4.1 Reseal Efficiency Criteria

The mobile laboratory will engage in on-site filtration treatment of directly obtained process waste streams, and then analytical facilities at CEER, Caparra Heights Station, will determine the efficiency of the treatment using as criteria the removal of total Nitrogen (Kjeldahl N), BOD, Suspended Solids, pH, optical absorption and heavy metals.

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1.4.2 Engineering Utilization of Results

Results of on-site testing at about 10 gallons per minute

(sum) throughput will be used to define engineering parameters and special chemical requirements as base data for design considerations of a pilot plant.

For those wastes adjudged to give a low cost-to-benefit ratio for application of this technique, recommendations for the pilot plant scaleup will be made.

IE. Project Scope

2.1 Sources of Pollut

A recently held workshop (Appendix A) dedicated to the consideration of possible applications of magnetic separations to effluents associated with Puerto Rican industrial and domestic waste streams identified point Sources, PRASA treatment plant sources (including effluent polishing), and diffuse (non-point) sources as worthy of attention.

2.1.1 Point sources

Point sources of pollution are usually identified with in-

dustrial processing or manufacturing. The following listing and comments apply to those point sources considered to be actual or potential problem effluents

for the Toland.

2.4.1.1 Pharmaceuticals:

High BOD, CoD, low DO, and high organics. High amounts of rinsing water and biologically active components. Treatment lagoons, sludge incineration and chemical treatment are commonly used in these industries.

ate

2 Chemical industries

High BOD, COD, low DO and toxic components. High amounts of cooling water are common in this type of industry. Divers treatment are found.

combinations of

211.3 Distillers

Extremely high BOD, suspended solids, biologically active components and significant coloration characterize these effluents. Except for land disposal in one case, no treatment is given to these wast

at present.

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Breweries

High BOD, suspended solids, biologically active components and high turbidity characterize these effluents.

2.1.1.5 Food Processing

High BOD, residual proteins, oils, solids and odors are the typical waste from these industries.

2.1.1.6 Sugar Industries

High BOD, solids, organics, coloration and odors are the characteristics of the effluent. Treatment consists of oxidation and sedimentation lagoons. At best treatment is not complete.

2.1.1.7 Petrochemicals

High COD, low DO, solids, oil, organics and coloration are typical pollutants in these waters. Treatment is varied, consisting of biological treatment, oxidation lagoons, chemical treatment, and raw water discharges in some

2.1.1.8 Refineries

21.1.9 Textiles

?The main problem associated with the textile industrie:

for the island is the coloration of the waste streams. Main treatment, when any is given, is chemical in nature, consisting of adsorption by activated charcoal or by ©

2.1.1.10 Electroplating

?The principal pollutants associated with this activity

are metals, such as mercury, chromium, lead, zinc, copper, etc. and some toxic agents such as cyanide and acid leachate, Treatment consists of pH adjustment, some chemical absorption, or principally terminal disposition of wastewaters into the nearest stream or sewer.

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2.1.2. Sewage Treatment Plants

Sewage treatment plants producing effluent which could be further

upgraded to irrigation or potable quality water are candidates for polishing

?treatment using magnetic separations. specific comments on 2 aspects of water

treatment plant effluents are given below.

2.4.2.1 Sewage

Public treatment plants in Puerto Rico handle primarily domestic wastes. However, the wastes include also a significant fraction of wastes from industries and commercial establishments. Some treatment plants offer inadequate treatment to the wastes.

2.1.2.2 Storm Sewers

Storm Sewers and combined sanitary ~ storm sewers present special pollution problems in Puerto Rico. Storm sewers collect wa

tes from

the streets and surface areas and, because of illegal sewerage line connections, untreated sanitary wastes as well. Combined sewers then discharge without,

treatment, both street runoff and pollution wastes.

2.1.3 Area Sources (Non-point Sources)

In most potentially polluting area sources the degree of control required for elimination of the threat is low, but the difficulties of treatment are great. The following general areas appear to be the most significant of the area sources.

2.4.3.1 Agricultural Wastes

Wastes from dairy farms, feedlots, agriculture and other associated activities are considered a serious water pollution problem in Puerto Rico. Significant pollutants are solids, nutrients, fertilizers, herbicides, pesticides and leachate. Very little control or treatment is associated with these activities.

2.1.3.2 Construction Run-off

The main problem associated with the construction industry is the lack of erosion control. During construction, sediment laden run-off is allowed to reach water bodies without any treatment.

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2.1.3.3 Mining activities

A larger measure than with the construction industry erosion is the main pollution result associated with mining activities. In a few isolated cases, some controls such as sedimentation lagoons are used.

2.1.3.4 Urban Run-off

High solids and coliform counts are associated with urban run-off. Normally, the initial run-off after a storm is where the main concentrated fraction of pollutants is found. After period of time has elapsed, pollutants tend to decline in concentrations.

2.4.3.5 Rural Communities

?These sources were, up until very recently, not considered as significant sources of pollutants. Recent studies have provided data indicating that sediments and organic pollutants in significant amounts

are generated by these communities, without any control or treatment given to these wastes.

2.1.3.6 Water Supplies

Small quantities of potentially toxic materials, are not removed by standard drinking water treatment plants.? In the case of well waters, some metals are found to be present. In surface waters, the pollutants found in the source stream are composed of a variety of products, ranging from ?exotic chemicals to viruses; not all are removed by treatment. After these waters are used, evaporation can concentrate the pollutants in the waste stream.

2.2 on Possible Representative sources

Survey in Puerto Rico

Although no formal agreements have yet been made with waste water producing entities, the following List of tentative effluent streams seems to be the best candidates for immediate HGMP applications:

for 4 Magnetic Filtration

- 1 Raw or partially treated sewage.
2. combined storm overflow.
- 3+ Secondary activated sludge treatment plant effluent.
4. aqueous distillery and brewery wastes.
5. Pharmaceutical wastes.

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7. Petrochemical industry effluents.
8. Electroplating waste solutions.
9. Water for upgrading to potable quality.
10. Sugar mill process wastes.

GW treatment data derived for these particular effluents would

Airectly or indirectly be of great benefit to Puerto Rico in necting
impending EPA regulations aimed at sero discharge. In particular EPA
?sponsored tests in continental U.S.A. and a 250 gpm throughput demonstration
Plant in Sweden have shown great potential for immediate application of HGMF
for both direct sewage and combined storm overflow treatment.

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EET. OVER ALL PROJECT BUDGET AND REQUISITE FUNDING

Tt As proposed to develop this project utilizing the matrix technique
of project management and staffing. During the 12 monthe period, personnel
will be used for varying periods of tine for discrete task assignnent:
possible they will be dravn from CEER and from organizations having relevant
?expertise on an available time basis. Also it is expected that participating
industries will make skilled personnel available on-site during effluent toa
ting.

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3:1. Estimated Budget for 12 months period

3.1.1 Personnel (task determined tine)

Principal Investigator) F.T.E. Scientist 108 4,000.00,

Project Leader) 508 10,000.00,

Seien. Assoc. 508 7,000.00

Res, Aest. 1008 6,200.00

3% Grad. students 1008 5,400.00

3 x Consultants 1008 15,000.00

Total Salaries 47,600.00,

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3:1.2 Operating expenses and services

Materials & Supplies (estimated) 4,500.00

3.1.3 Equipment and supplies

Rental & Shipping (Roundtrip), overhaul of

Salaciab. and Insurance 45,000.00

Total 104,716.00

Overhead 40% 41,886.00,

Total Project, \$146,602.00

3.2 Funding sources

The Puerto Rico Aqueducts and Sewers Authority has contributed

\$25,000 to cover part of equipment acquisition and indirect costs. The Center

for Energy and Environment Research has also contributed on the order of \$20,000

from its own development funds. It is hoped that the remaining \$109,000 necessary

for financing this phase of the HGM project can be obtained from prominent in-

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industries on the Island, The CEER is most anxious to secure participation

of industries having the most modern production facilities and also having

a sincere desire to apply new techniques to implement compliance with environ-

mental regulations. In as much as Roche Products, Inc. appears to have develop-

ed very modern production facilities to which HGMP could be adapted with a

minimum of difficulty, and it has also expressed an interest in the technique for fine suspended solids removal from certain effluents we request the participation of Roche Products, Inc. in this project phase at a funding level of \$25,000.

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HGMF Results on Spent Beer from Puerto Rico

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EXECUTIVE SUMMARY

This report addressing the value of high gradient magnetic filtration to Puerto Rico's effluent pollution problems is the outcome of intense discussion among CEER personnel and a select panel. This panel consisted of experts from Puerto Rico, the United States and the United Kingdom assembled for a special 3 - day workshop.

This effort reflects our great concern as well as our determination to alleviate the effects of water pollution and potable water shortages on the health and welfare of the people of Puerto Rico. The present level of contamination of Puerto Rico's fresh surface water and ground water as well as of its aquatic recreational areas and beaches is already alarming. Increased population pressures are expected to aggravate the problem of pollution control.

At several locations on the island, hazardous water pollutants from industry, municipalities and communities are discharged to the environment: with little or no treatment.

Increasingly strict application EPA regulations application, in response to the effluent treatment practices of the industrial sector are a subject of contention between the Agency and industry. In many cases conventional treatment methods have failed to provide significant water pollution control. If Puerto Rico is to meet zero discharge requirements by 1985, the development and demonstration of new water treatment technologies should be an urgent priority.

In a new program The Center for Energy and Environment Research of the University of Puerto Rico proposes to demonstrate a novel and powerful technology, called High Gradient Magnetic Filtration (HGMF) as an efficient,

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flexible and cost effective means to remove pollutants from waste waters. The HGMF system utilizes state of art technology and its applications worldwide now include:

Mineral Processing

Sewage Treatment

Paper Wastes

Power Plant Water Purification

Clay Purification

The advantages of this technology compared with conventional methods include overall cost savings, considerably smaller space and land area requirements, exceptionally high throughputs, reliable operation, low energy use and a very broad range of applicability.

Although the results of this investigation by the panel indicate that HGMF may provide a viable effluent treatment, a detailed systematic study of its application to a particular effluent is imperative. Research, development and pilot demonstration must be carried out prior to any successful implementation of the system. The Center for Energy and Environment Research has already initiated a comprehensive HGMF program to develop the technology to treat industrial wastes such as pharmaceutical plant effluents, distillery wastes (mostos) and sewage, in Puerto Rico.

The magnitude of the developmental task, however, calls for financial and technical help from appropriate government agencies, commercial organizations and industries which have an interest in finding solutions to Puerto

Rico's waste effluent problems.

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Section I

INTRODUCTION

Nearly all of the streams in Puerto Rico are heavily polluted.

Only in the upper sectors of some isolated streams are the waters safe to drink without intensive treatment. A significant percentage of coastal waters show a persistent violation of dissolved oxygen (DO) requirements

and coliform bacteria count restrictions. Some beach areas with recreational Potential have been closed to public access due to the presence of polluted waters. Pollutants transported by the rivers into the sea create serious accumulation of sediments on coastal reefs and at the mouths of rivers.

However, pollution problems in the island are distributed in such a way, that

At 18 obvious that industries are not the only source of pollution. Sewage treatment is, in some cases, ineffective thus causing local water pollution

Problems throughout the island. Indeed, a direct relationship has been found between population density, industrial growth and the degree of water pollution in an area (1, 2, 3, 4).

The present pollution levels for both Puerto Rico's surface and ground water, and its aquatic recreational areas and beaches are already severe and increased population pressures will aggravate the problem of pollution control even further. The population density of Puerto Rico, an island

30 x 150 mi. in size, is rated the 6th highest worldwide with most of the Population (ca. 90%) residing on a very narrow coastal plain. The large volume of waste generated by Puerto Rico's advanced industrialization programs, Population density pressures and a fragile coastal zone environment have all Combined to produce a grave challenge to the health, the welfare and the lifestyle of Puerto Rico's 3.2 million inhabitants,

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At many locations on the island, hazardous water pollutants from industry, municipalities and communities are discharged to the environment: with little or no treatment. In the past, a great number of community activities and projects aimed at minimizing adverse health conditions and at the Social and esthetic effects associated with water contamination have been instituted but, in general, they have not been successful.

Suspended solids (SS) are a major problem, together with low oxygen levels and a high Biochemical Oxygen Demand (BOD) in most water bodies. A significant amount of pollution is traceable to agriculture, mining, construction and other activities associated with poor erosion control practices. The eutrophication of lakes and reservoirs is the direct result of the introduction of both sediments and pollutants identified with high BOD.

In the light of the existing conditions on the island it is evident that conventional treatment management methods have failed to significantly

Reduce water pollution. New methods and new technological developments appear to be urgent priorities for the reclamation of polluted water to meet Puerto Rico's industrial, agricultural and potable requirements by 1985.

Law #142, of May 1st 1950, provides the legal basis for a Water Pollution Control program in Puerto Rico. As originally adopted, that law gave the Secretary of Health the power to monitor, plan, regulate, and take measures to control water pollution. These legal powers were transferred to the Puerto Rico Environmental Quality Board (EQB) in 1970. In 1973, the EQB adopted Water Quality Regulations. Most of the present water quality controls have been established on the basis of the present National Pollutant Discharge Elimination System administered by the U. S. Environmental Protection Agency (EPA) with the concurrence of EQB (1).

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Under this system, the responsibility for clean waters is divided between EQB and EPA. EPA controls effluent limitations based on available technology, and EQB deals with the quality of the receiving body of water.

Any discharge permit mandates the concurrence of both agencies on the con=

ditions of the permit.

Conventional treatment methods (5, 6) assumed to be the acceptable management practice for industrial wastes with high BOD and Total Suspended Solids (TSS) load include: anaerobic contact processes, a sequential combination of anaerobic followed by aerobic treatment; evaporation; and direct land application. In each case, ultimate disposal of the concentrated sludge residue remains as a follow-up step for complete treatment.

The anaerobic/aerobic contact process, is considered effective for the elimination of most pathogens if chlorination is subsequently carried out. BOD reductions of 90-95% of that of the influent are considered possible. A reasonably low level of TSS should also be possible with 90% removal considered achievable in most cases. Color and odor characteristics of the final products are acceptable, although if the anaerobic process is carried out in lagoons in contact with the atmosphere, offensive odors may be produced. For either process to remain energy efficient and not incur exorbitant operating costs, final aeration of wastes has generally involved lagooning which may impose unusual land space requirements on the process.

Anaerobic/aerobic sequential treatment is occasionally used and is traditionally associated with food processing industries. To avoid the spatial requirement of lagooning and odors, anaerobic treatment in closed tanks is a fairly acceptable alternative, although this step can introduce excessive capital and operating costs.

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Direct land application of aqueous wastes may be effective for elimination of problem wastes if suitable land is available. Periodic surface flushing is generally @ necessity to avoid salt build-up and soil deterioration although in some applications, the soil may actually benefit from the treatment in the short term (7). The long term effects of land application are not well established for high strength wastes where heavy metals and pesticides may accumulate in the soil.

Evaporation can be effective for drying relatively concentrated wastes. However sophisticated equipment with high maintenance costs and substantial energy requirements may be necessary. Evaporation is generally not cost effective for concentrating waste waters to a solid. Solar evaporation ponds may be used but a 5 day to 1 week holdup period may introduce a Problem of unusual land area requirements.

Connection of waste stream conduits to sewer lines for municipal treatment can only be used for low strength wastes. Unless specific agreements with local treatment authorities, pre-treatment of high strength wastes is required by U. S. EPA regulations. Table 1 summarizes some observations on conventional treatment methods. It should be noted that each process

Separately has its weaknesses, but there are applications for which each is
Considered best available technology.

In recent years a new magnetic filtration technology, high gradient
magnetic filtration, has been developed to remove micron size particles from
2 fluid stream at high flow rates. These high gradient magnetic separators
or filters have been designed to maximize the magnetic forces on fine, mag-
netic materials. They are capable of efficient separation or filtration of
even weakly magnetic suspended solids or precipitates for which conventional

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TABLE 1

Treatment Technologies as Currently Practiced

?Treatment Technol Comments

Anaerobic Contact Re-aeration of discharge required ;

large investment for high 80D re-

moval.

Aerobic Contact Odor problem. May not treat

chlorinated pesticide residues.

Aerobic Lagooning Large Tand areas may be required.

Anaerobic/Rerobic Tank May involve large land areas, high capital expenditures and require

highly trained operators.

Direct Land Apptication Monitoring of disposal area

necessary. Not feasible if Tong

sewerage ines are needed. Large,

managed crop Tand area required.

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Evaporation Sludge transport and disposal

management more urgent, Can be

energy intensive, Can necessitate

Tong hotd up times.

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magnetic separation techniques are ineffective, This capability is the result of the development of 2 filamentary ferromagnetic matrix and 2 large volume, high-field magnet. The combination of an efficient magnet and high gradient matrix permits the economical generation of strong magnetic forces over a large surface area in the magnetic filter bed. Filtration may be carried out economically, and at process rates of up to several hundred gallons per minute per square foot of fluid stream cross section (gpm/ft²).

Large scale industrial applications of this technology already exist for wastewater treatment in steel mills and steam condensate treatment in paper mills. Numerous large installations also exist in the clay ?industry for the separation of fine impurities from clay slurries.

For normally nonmagnetic colloidal material in polluted water, ?the addition of magnetic iron oxide powder (magnetite) along with a coagulant can form a combined particle sufficiently magnetic to be removed by high gradient magnetic filters. The machines provide a rapid filtration of many pollutants from water with a small expenditure of energy. They are more efficient than sedimentation because the magnetic forces on fine particles fare many times greater than gravitational forces.

Municipal and industrial wastewater treatment by high gradient ma

netic filtration with iron pander seeding is under active development in several countries. Applications include treating combined storm and sewer overflow, raw sewage and wastewaters from paper, petrochemical and other industries.

In addition to these industrial developments, the wide potential of high gradient magnetic separation and filtration has stimulated research efforts in of] refining, air filtration and the filtration of waters from nuclear power plants (8) at various companies and research centers through-

?ut the world. In the light of severe environmental problems associated

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with waste effluents in Puerto Rico and an apparent need for new technologies

?to deal with these problems it is the conviction of this Panel that high gra~

dient magnetic filtration may be a useful alternative.

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Section IT

PRINCIPLES OF MAGNETIC FILTRATION

Physics of the Capture Process (9510)

High gradient magnetic filters usually consist of a ferromagnetic wire wool filter bed (matrix), occupying 5-10% of space, magnetized by a uniform magnetic field so that high fields and high field gradients are produced throughout the matrix. These filters are so effective that even weakly magnetic particles of colloidal dimensions can be captured from a liquid containing the particles. As the thickness of particles captured in the matrix increases, the ability of the wire to further capture particles, decreases. At some point, usually determined by the process in question, the performance drops below acceptable limits. When this point is reached the feed to the filter is interrupted and the captured material is released from the matrix by switching off the applied magnetic field. The large demagnetizing factor of the wires in the matrix ensures that the residual magnetism in the matrix is small, facilitating the release of the particles. The cycle can then be repeated. Other systems have been developed where the matrix is continually moved through the magnetic field which allows fully continuous processing of slurries or liquids, an advantage in some applications.

A theory of capture for magnetic particles has been developed by considering the motion of magnetizable particles as if they are carried by

2 fluid moving in 2 uniform magnetic field applied perpendicular to the axis of a straight wire in the matrix. In all cases the field must be applied perpendicular to the axis of the wire in order to be effective.

In the analysis of the equations of motion of the magnetic particles

near the wires and under the influence of the magnetic and drag forces, @

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great simplification of equations of predictive value can be achieved by the introduction of a quantity called the magnetic velocity V_m (11). For ferromagnetic particles in a low magnetic field H_y , V_m is given by

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(473) $\frac{W_p}{W_a} = \frac{m_p}{m_a} \frac{GQ}{GQ}$

where b is the particle radius, H is the applied magnetic field (amp/meter)

4×10^{-4}

η is the viscosity of the fluid, a is the radius of the wire, and γ ,

henry/meter. The magnetic velocity V_m is very important because if the slurry enters the separator at a velocity equal to the magnetic velocity, the separation is extremely effective.

For example, if the wires have a radius of $50 \mu\text{m}$, if the particles have a radius of $1.59 \times 10^{-8} \text{ m}$ (2000

have a radius of $1.59 \times 10^{-8} \text{ m}$ and if the magnetic field H (in gauss) then $V_m = 3.4 \text{ cm/sec}$. If the fluid enters the separator at a velocity of 3.4 cm/sec , the separation will be extremely effective. If the particles have a radius of $614 \mu\text{m}$ then $V_m = 30.6 \text{ cm/sec}$. These are roughly the velocities at which it has been found possible to treat steel mill effluent water, that is approximately $100\text{-}350 \text{ gal/min/ft}^2$.

In this low field region there is little to be gained by using a higher field as the processing velocity and power consumption both increase with the square of the field so that the power per unit volume of processed slurry is constant. However, additional field requires a greater amount of iron in the magnet circuit which increases the capital cost per unit volume of slurry processed.

Experimental observations have shown that as the material captured on the wire builds up, long strings of captured particles grow away from the

wire, These strings act as additional capturing centers for particles and

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consequently, little loss of performance is noticed for a wire, as the captured material accumulates. Beyond a certain length of particle string further growth is not possible due to the fluid drag. When this point is reached, the separating capacity of the wire drops abruptly. In practice, the filter is backflushed well before this occurs.

The wires in a separator are assembled in a matrix and placed into a canister through which the slurry is passed, as shown in Figure 1. When the interaction between the wires and the particles is strong, the separator fills up from the front, and the feed part of the cycle ends before breakthrough of particles occurs. In a cyclic process, the field is switched off at this point and the captured particles can be removed from the system by flushing the canister with air, with an air-water mixture, a solvent or with water alone. The length of the feed cycle can be determined roughly by assuming that the wires can capture 3 to 4 times their own volume of material. This means that a loaded filter will contain about 20% by volume of captured particles.

The processing rate P is given by

where V is the slurry velocity (approximately Yq), A is the cross sectional

area of the separator and D is the duty factor. The duty factor is given by

$$D = \text{Feed Time} / (\text{Feed time} + \text{Dead time})$$

The dead time is part of the cycle when the feed is not flowing and may con-

sist of time to switch the magnet on and off and the time to flush the mag-

netics. For efficient operation the feed time must be much greater than the

dead time.

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FIGURE I

High Gradient Magnetic Separation Filter

Showing Section of Matrix Wire

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?As an example, a typical filter will operate at 100 to 200 gpm/ft?

and at a magnetic field strength of no more than 3 kG it can process 4000

£2000 gpm of feed, consuming no more than 25 kW of electric power. Solids

removal {s typically 75-95% depending on the particle characteristics, the

Flow rate per unit area and the magnetic field strength. The machine weight

45 approximately 70,000 lb. A more complete listing of capacity, weight and

Power consumption for magnetic separators in appropriate applications is

shown in Table 2.

Features of the High Gradient Magnetic Filtration (HGMF);

The high gradient magnetic Filtration process is based on the use

of very strong magnetic forces to capture magnetic particles on the edges of

filament wires that compose the matrix. The strength of the magnetic force

Generated allows even very fine particles of weakly magnetic materials to be

trapped effectively.

The process may be used to effect separations between more magnetic

?and less magnetic particles (solid-solid separations) or to effect a filtra-

tion of magnetic particles from a liquid or gas (solid-liquid or solid-gas

Separations). An extension of the process to the filtration of nonmagnetic

Particles and even dissolved materials may be attained by a flocculation of

these species with magnetic "seed" particles. This latter technique makes

high gradient magnetic filtration applicable to a wide variety of liquid

filtration problems.

High gradient magnetic filters include both cyclic and fully continuous devices. For most water treatment application, cyclic devices are Utilized; but in certain cases where the density of solids in the feed stream is sufficiently large, fully continuous devices with a circular filter bed

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. SPECIFICATIONS OP SYPICAL HONE SYSTEMS

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?Weight measured flange to flange

Notes: The separators have a 15 cm axial matrix length and a maximum applied magnetic

field strength of 5 kG.

estimate filter velocity, divide desired throughput rate by matrix area.

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continuously moving through the magnet for loading and for subsequent flushing may be used, In either design filamentary matrices with high void volumes are used. Strong magnetic forces in the matrix are able to hold trapped particles against drag forces even at high process velocities. The high void volume of the matrix, permits both large retention of trapped solids and low pressure drop across the matrix even at high process velocities.

The design of the magnetic circuit used to magnetize the matrices is optimized to minimize power and capital cost. In most water treatment applications, magnet power is only a fraction of the total system power demand. The operation of high gradient magnetic filter at high process velocities permits high unit capacities and small space requirements.

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Section IIT

PRINCIPLES OF MAGNETIC SEEDING FOR FILTRATION OF NON-MAGNETIC SUBSTANCES: ORGANIC AND NON-ORGANIC PARTICLES AND DISSOLVED MATERIALS

High gradient magnetic separation and filtration techniques may be extended to non-magnetic particles (organic and inorganic) and even dissolved materials. This is possible in high gradient magnetic filters because of the strong trapping forces which permit the capture of aggregations of non-magnetic particles which contain fine, strongly magnetic seed particles.

Basic Concept

The magnetic seeding technique involves the addition of a finely

Powdered magnetic seed material (usually magnetic iron oxide) to the stream to be filtered and some means to associate the magnetic particles with the non-magnetic or dissolved impurity.

Magnetic Seed

The magnetic seed material is generally magnetite, Fe_3O_4 , magnetic (black) iron oxide. While other magnetic materials may be used in certain cases, magnetite is the obvious choice for several reasons. First, it is strongly ferromagnetic; its induced magnetization is about 40% that of pure iron. Second, the type of magnetite required is relatively inexpensive (about \$25 per ton). Third, it is quite inert in most systems of interest. Finally, the surface of magnetite appears to be a good absorbent material.

Viruses, for instance, have an excellent affinity for the surface and in general the particles are easily incorporated into flocs formed by inorganic flocculants. Other possible seed materials include other less oxidized forms of iron, iron, cobalt, and nickel as well as oxides of these and other well-known relatively strong magnetic substances.

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Association of Seed and Impurity

The techniques used to associate magnetite particles with non-magnetic and dissolved materials include:

Adsorption

Coagulation and Flocculation

Coprecipitation

Adsorption: In the adsorptive mode magnetite adsorbs the non-magnetic particle or dissolved ion on to its surface or alternatively magnetite may be adsorbed on the surface of the impurity particle. The process is

governed by the usual dynamics of coagulation and the adsorptive forces include one or more components in the double-layer force system. To enhance the adsorptive mechanism, pH changes in the candidate stream may be used to produce opposite surface charges on the magnetite and the particulate impurity.

Coagulation and Flocculation: Inorganic coagulants (alum, ferric chloride) added to a waste slurry, act both to neutralize surface charge and reduce any repulsive forces between the seed and the impurity particles so that the particles may agglomerate. Organic flocculants create bridges between particles and enhance the strength of inorganic flocs against shear forces.

Coprecipitation: Coprecipitation of certain dissolved materials and ions to produce insoluble compounds is a third means of effecting association. The coprecipitation generally involves a change in pH to create particulates sufficiently magnetic to be filtered directly in a high gradient magnetic filter, In addition to coprecipitation, dissolved materials (organic

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and inorganic) may be removed by adsorption. Hydroxides formed by floccula-

tion produce large surface areas available for adsorption of ionic species and the capacity for adsorption of ions by oxide surfaces is well known. Indeed, it appears that even the small natural layer of hydroxide existing in naturally occurring iron oxides in boiler water can adsorb calcium and magnesium ions sufficiently. It is observed that hardness is reduced when these waters are treated by high gradient magnetic filters without any addition of chemicals. An obvious extension of these methods to dissolved material removal is precipitation followed by flocculation of the resulting suspension with magnetic seed.

Combination materials: In addition to the flocculants mentioned above several promising flocculant-seed natural combinations have been developed for high gradient magnetic filtration. These include an aluminum sulfate-containing fine particulate magnetite and a magnetite suspension in which the particles have been treated so as to produce coatings of organic polymer material.

?Application Procedure

In practice, the seeding procedure is relatively straight-forward.

?A generalized procedure will allow for pH adjustment of the influent to op-

optimize coagulation. The next steps are the addition of an inorganic coagulant

in a flash mixer, addition of the magnetite seed to the flash mixer and

Finally the addition of the polyelectrolyte. The resulting dosed influent

is allowed to grow flocs under slow speed agitation. The detention time for

Flocculation is 1 to 4 minutes. The flocculator overflow passes directly to

the high gradient magnetic filter. The operation of the filter is similar

to that for direct magnetic filtration. The sludge is backflushed either

Periodically in a cyclic device or continuously, in a carousel device. The

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Sludge is generally a small fraction of the feed stream.

Sludge

Treatment of the sludge will depend on the particular application.

an intermediate step of settling to increase solids content, direct vacuum filtration or immediate disposal are alternatives. In most applications magnetic seed usage is of the same magnitude as that of the alum and does not require recovery. Indeed allowing the magnetite to remain with the sludge can enhance the density and further treatability of the sludge. Seed recovery may be required to meet EPA standards for solid wastes disposal. If magnetite seed recovery is desirable it may be accomplished in several ways?

chemical dissolution

magnetic stripping

incineration

washing

Chemical dissolution of magnetite is similar to the currently preferred process for alum recovery. Magnetic stripping involves a solid-solid separation in a second high gradient magnetic separator. Incineration involves burn-off of organic material to recover the regenerated seed. Washing at different pH's may be appropriate for certain applications where impurity disposal and/or sludge dewatering is not a problem.

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Section IV

PRESENT WORLD-WIDE APPLICATIONS OF HIGH GRADIENT MAGNETIC FILTRATION

The first high gradient magnetic filter was installed in the clay industry in 1969. Since that time the technology has become fully accepted by the clay industry with numerous large scale installations of magnetic filters in the United States, Britain, and Czechoslovakia. Application developments since 1969 have focussed on the processing of minerals and water treatment. This development work has led, at the time of writing, to additional full scale installations now functioning, in the steel and paper industry. Many other potential applications exist for water treatment and chemical processing. The current status of high gradient magnetic filtration is summarized in Table 3.

In the water treatment applications the largest industrial units are employed for the filtration of steel mill process water. At Kawasaki Steel in Japan a 2 meter diameter device filters 4000 gpm of water from a 98S scrubber. The system requires only a small space in the plant, uses low power (50 kW), and operates fully automatically with little maintenance. Figure 2 shows the Kawasaki HGMF plant after installation.

The use of magnetite seeding and high gradient magnetic filtration for treatment of waste water containing dissolved and nonmagnetic solids has

been demonstrated on a small scale in the United States by Sala Magnetics under sponsorship of the EPA (11), on a pilot plant scale and, more recently, in Sweden on a larger scale. The demonstration plant in Sweden mounted in

an 8 by 25 ft. container includes chemical dosing, flocculating equipment high gradient magnetic filter and a small backflush settling tank. This system has a capacity of 250 gpm and has been demonstrated for tertiary and Secondary-tertiary sewage treatment,

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Process in which magnetite seeding is used.

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Section V

ECONOMICS OF MAGNETIC FILTRATION

The costs of installed high gradient magnetic filters will obviously vary from plant to plant, and be dependent upon, among other factors, the relative concentration of the waste to be treated, the flow rate of waste, and other site-specific conditions. The most thorough economic analysis of the process published in the literature is for a 25 million gallons per day (mgd) plant for treatment of combined sewer overflow and sewage (C50). The cost accounting was based on the results of detailed pilot plant tests (11). Because of the importance and detail of this

analysis the complete text is reproduced in Appendix A and is summarized below.

The installed capital cost of the plant including chemical addition, sludge dewatering, effluent chlorination equipment and magnetic filters was estimated at \$5.187 million for the 25 mgd plant. Operating and maintenance costs were estimated at \$0.175 per 1000 gallons of treated water. It is interesting to note that of the total power cost of \$0.024 per 1000 gallons only 13% is used to operate the magnets and this is less than one third the power to pump water through the entire system, (45 ft head loss). Combining the capital, operating and maintenance costs, the total cost of treated effluent would be \$0.234 per 1000 gallons (depreciating capital over a plant life of 20 years at 8% annual interest rate by the capital recovery factor method).

The cost per 1000 gallons of water treated will vary inversely with the size of the treatment plant. Hence, to treat wastes from an averaged sized distillery will cost more than the values estimated for the

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25 mgd plant. However, a superficial analysis of the major cost components, such as chemical costs which will remain approximately constant regardless

of plant size, indicate the costs will not vary significantly from those

shown. It should be noted that in Appendix A the operating costs at 5.7 mod

?Flow are the costs to operate a 25 mgd plant intermittently and do not neces
sarily reflect the cost to treat water with a plant designed specifically for lower

?throughput rates.

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Section VI

POLLUTED WATER EFFLUENTS IN PUERTO RICO

The following is a summary of information regarding general in-

dustrial groups on the Island, and the problems associated with their effluents.

More detailed information can be obtained from the studies conducted by E08

under the 208 programs (13).

Point Source

Pharmaceuticals - High BOD, COD, TSS, and high organics. High amounts of rinsing water and biologically active components.

Treatment lagoons, sludge incineration and chemical treatment are commonly used in these industries.

Chemical Industries - High BOD, COD, TSS and toxic components.

High amounts of cooling water are common in this type of industry.

Diverse combinations of treatment are found.

Distillers - Extremely high BOD, suspended solids, biologically active components and significant coloration characterize these effluents, Except for TSS disposal in one case, no treatment

is given to these wastes at present.

Breweries - High BOD, suspended solids, biologically active components and high turbidity characterize these effluents.

. Food Processing - High BOD, residual proteins, oils, solids and odors are the typical waste from these industries.

: Sugar Industries ~ High BOD, solids, organics, coloration and odors are the characteristics of these wastes. Treatment consists of

oxidation and sedimentation lagoons. At best treatment is not

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complete.

Petrochemicals - High COD, Yow 00, solids, of, organics and coloration are typical pollutants in these waters. Treatment is varied, consisting of biological treatment, oxidation lagoons, chemical treatment, and raw discharges in some cases.

Refineries - Characteristic wastes and treatment are very similar to the ones associated with petrochemical industries.

Textiles - The main problem associated with the textile industries

in the island is the coloration of the waste streams. Main tre

ment, when any ts given,

s chemical in nature, consisting of

absorption by activated charcoal or by resins.

Electroplating - The principal pollutants associated with this activity are metals, such as mercury, chromium, lead, zinc, copper etc. and some toxic agents such as cyanide and acid leachate.

Treatment consists of pH adjustments, some chemical absorption, or principally terminal disposition of wastewaters into the nearest stream or sewer.

P.R., R.R. and Sewers Authority

Sevage - Public treatment plants in Puerto Rico handle primarily
nt

domestic wastes. However, the wastes include also a significant fraction of wastes from industries and commercial establishments.

A significant number of treatment plants offer inadequate treatment to the wastes.

Storm Sewers - Storm Sewers and combined sanitary - storm sewers present special pollution problems in Puerto Rico. Storm sewers

collect wastes from the streets and surface areas and, because of ????

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Illegal sewerage line connections, untreated sanitary wastes as well, Combined sewers then discharge without treatment, both street runoff and pollution wastes.

: Area Sources

Agricultural Wastes - Wastes from dairy farms, feedlots, agricul

ture and other associated activities are considered a serious water pollution problem in Puerto Rico. Significant pollutants are solids, nutrients, fertilizers, herbicides, pesticides and Teachate. Very little control or treatment is associated with these activities.

construction run-off

The main problem associated with the construction industry is the lack of erosion control-During construction, sediment laden run-off is allowed to reach water bodies without any treatment.

Mining Activities

In a larger measure than with the construction industry erosion is the main pollution result associated with mining activities. In a few isolated cases, some controls such as sedimentation lagoons are used.

Urban run-off

High solids and coliform counts are associated with urban

run-off. Normally, the initial run-off after a storm is where the rain concentrated fraction of pollutants is found. After a period

of time has elapsed, pollutants tend to decline in concentrations.

Urban Communities

These sources were, up until very recently, not considered

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as significant sources of pollutants. Recent studies have provided data indicating that sediments and organic pollutants in significant amounts are generated by these communities, without any control or treatment given to these wastes.

Water Supplies

Small quantities of potentially toxic materials, are not removed by standard drinking water treatment plants, In the case of well waters, some metals are found-to be present. In surface waters, the pollutants found in the source stream are composed of

2 variety of products, ranging from exotic chemicals to virus not all are removed by treatment. After these waters are used, evaporation can concentrate the pollutants in the waste stream.

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Section VII

RUM DISTILLERTES PROCESS WASTE (MOSTO)

Molasses from sugar production is the principal raw material utilized in the fermentation process for the production of rum. After fermentation, the product is distilled to the required alcohol concentration.

The fusel oils, and heads from the distillation, fermenter bottoms, yeast from fermenter beer and other sources are mixed together to form what is known as "mosto". Analyses of typical mosto samples indicate BOD's of about 33,000 mg/l and TSS of about 18,000 mg/l, pH from 4.0 to 5.5, high coloration and viscosity. Such high concentrations of BOD and TSS tend to eliminate conventional treatment processes as cost effective alternatives.

In Puerto Rico the main sources of mosto are the three principal RUM producers of the island,

Bacardi Corp. at Palo Seco, discharges its mosto without treatment into Boca Vieja bay by means of a pipeline in amounts from 300,000 to 1,000,000 gpd.

Puerto Rico Distilling Corp. at Arecibo discharges mosto by a short pipe to the coast without treatment.

Destileria Serratles in Ponce, P. R., mixes its mosto with its own sugar cane field irrigation waters and disposes of it by land application.

Regulatory agencies have reported some reservations (1) about this system due to its possible long term effects on soil conditions and underground water contamination.

Other rum producers on the island do not distill, and limit their

Production to the blending of selected alcohols.

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Environmental Protection Agency Regulations

The U. S. Environmental Protection Agency (EPA) has promulgated regulations aimed at returning water bodies to a condition it considers safe for recreational and commercial use by the U. S. public. According to its schedules, ocean dumping of untreated wastes will be unacceptable by 1985. Consequently, concentrated sludge separation from aqueous wastes will be necessary. The purified water will be reclaimed or be pumped into water bodies with its temperature precluding possible thermal pollution of the water body.

The dewatered sludge may be incinerated, land dispersed, accommodated in sanitary landfills, or composted and used for agricultural purposes. Generally, in the latter case, liming must be carried out to limit heavy metal uptake from the sludge into the agricultural produce. In the case of aqueous wastes with high BOD, pre-treatment reduction may be demanded by municipal sewage plants before accepting industrial wastes for treatment.

The historical sequence of EPA regulations provides for the best

practicable treatment by July of 1977. The Congressional Act upon which this compliance time frame was established was set forth in 1972; as part of this act, a permit issuance system entitled National Pollutant Discharge Elimination System (NPDES) was established. During the interim period 1972-1977, dischargers which received NPDES permits were expected to comply with EPA regulations on a programmed basis arranged between recipients and EPA-the so called compliance schedule. More recently promulgated EPA regulations aim at resource recovery and the so-called "zero discharge", meaning that all wastes are to be treated to the extent that any discharge to the environment must

meet as a minimum, locally established water quality criteria, and, moreover,

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must remove from the discharge any pollutant that is not present in the receiving water body.

Distillation Industry Waste Treatment in Puerto Rico

Distilling industries in Puerto Rico have been obliged to face the

problem of high BOD in their waste-mostly. With one exception, none of Puerto Rico's rum distilling industries is currently in compliance with EPA rulings.

In one case an NPDES has been accepted but a schedule has not been followed.

It is not certain how long the present situation can continue before EPA compels the industries to install pollution control equipment and there are

reasons to believe that even those treatment systems considered and proposed by several distilling companies to EPA will not bring them into the NPDES compliance. For these industries, in particular, zero discharge would appear to be an extremely difficult goal to meet.

Conventional Treatment Methods

A recent report by the Water Resources Research Institute of

Mayaguez A & M Campus of the University of Puerto Rico (13) indicates that in the case of 2 Total distillers, reduction of daily average BOD load by 90%, and daily average SS load by 99% would be necessary to comply with provisions of the NPDES permit issued to one of them. Standard treatment methods proposed by the distilling industries include: conventional anaerobic contact process, sequential anaerobic/aerobic treatment, evaporation and direct and application. It is unlikely that conventional anaerobic treatment alone would be able to treat mosto sufficiently to achieve the reduction in BOD required since typical BOD removal in this step is only about 80%, Aerobic Tagoon treatment alone would probably not be practical because the high oxygen demand of mosto could not be transferred by the most efficient surface aerators.

For example with a BOD of 30,000 mg/liter -typical of mosto- and a

flow rate of 300,000 gallons of mosto per day (200 gal/min) a transfer

of 37 tons of oxygen per day would be required. Using surface aerators to achieve this transfer would necessitate 1,540 horsepower - in surface aerators rated at 2 lbs of oxygen transfer per hour per horsepower. At an electric power cost of \$0.03 /kwhr, it would cost about \$2.75 /1000 gal treated, an exorbitant treatment expense.

While activated sludge aerobic processes should not be discounted ?out of hand, the volume of solids might make the process unwieldy and difficult to manage routinely.

Sequential anaerobic/aerobic treatment may be useful but suffers from possible requirements of extensive land areas, heavy capital investment and may necessitate permanent employment of highly trained operators.

Evaporation is an energy intensive process which would necessitate development of large sludge dumping areas, disposal management systems and a large primary holding area.

Direct land application is already in use by one distilling company, apparently meeting the NPDES criteria, Land application may be a viable short term solution provided that the distillery is located near a sufficiently large area of agricultural land, Monitoring both salt build-up in soils and

possible perfusion to aquifers must be undertaken for this alternative to be considered for routine disposal. Long sewerage lines with accompanying maintenance problems and control of sewerage line right-of-way can make this, method - unfeasible in Puerto Rico. Finally, land application requires a year-round commitment to uninterrupted irrigation.

?The excessive operating costs and land use requirements implied by
?the expansion of one of the current treatment technologies mentioned above

could lead to operating difficulties of P. R. distilling industries which

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traditionally have contributed significantly to the economic infra-structure of the Island,

It seems to us that there is a growing body of evidence indicating that a new technique or an original approach could yield the answer to the problem of land area and operating expense without an inordinate capital investment. At present, technologies available for the control of this Problem are not going to provide a final solution compatible with the

environmental and economic needs of the Island. We feel that provision of necessary additional time needed to evaluate promising magnetic filtration technology would benefit both the natural and economic ambient of the Island. Magnetic separation has been presented as a possible technique or an essential component of a hybrid system which will be capable of treating large volumes of low-nutrient, high BOD wastes produced as by-products of the rum distilling industry.

Applicability of High Gradient Magnetic Filtration to Mostos Treatment

The applicability of high gradient magnetic filtration to the mostos problem is based on successful tests on mostos and related effluents. First, in tests carried out on a wide variety of organic and inorganic waste waters the magnetite-seeding-high gradient magnetic filtration technique has been shown to be highly effective in the removal of suspended solids, turbidity, color, bacteria and other criteria substances. Second, in tests carried out by Sala Magnetics and the University of Salford on mostos samples, total suspended solid reduction and a corresponding decrease in sample turbidity and color were observed.

Sala Magnetics has carried out tests with a wide variety of waters

using the magnetite seeding techniques, some results of these tests are

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summarized in Tables 4 and 5. These results include Laboratory tests as well as continuous pilot plant studies. In addition to the striking visual results of clarity increase in the streams tested, a virtual absence of odor in treated organically contaminated samples is often noted. Although the mosto waste as described above, in general, have higher concentrations of suspended solids and 800 they are similar in many respects to waste and polluted waters successfully treated by magnetite seeded-high gradient magnetic filtration techniques.

Direct evidence of the treatability of mostos by the mag-seed high gradient technique has been obtained in recent tests at Sala Magnetics Inc. and at the University of Salford. In a brief series of unsponsored tests of mosto carried out by Sala Magnetics in early 1978 for Schenley Distilleries no positive evidence of suspended solids or 800 reduction was obtained. However in a later more extensive effort for the CER more appropriate coagulation and flocculation conditions were used.

1m laboratory tests carried out to determine treatability of an unknown effluent, the possible range of experimental conditions--coagulant type and concentration, magnetite seed concentration, polymer type and concentration, and flocculation type--is very broad. Although some general experimental methodology to determine appropriate conditions has been developed, these efforts remain largely a trial and error procedure which may require

considerable time, particularly if the range of appropriate conditions within the parameters available is relatively narrow, as it often is for more difficult effluent streams such as mostos. Given this reality, it is understandable why preliminary tests yielded no positive results but later, more extensive trials, showed several promising combinations. A sampling of results from the Sala Magnetics tests is shown in Table 6. The chemical

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RESULTS OF HOMP LABOPATORY TESTS PERFORMED

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Removal

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?Suspended or or

Solids color cop

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Results of HGMF of mstos by Sala Magnetics
as affected by test conditions

?Test Conditions Results

pa] atu Por E Description ?Suspended

ea/)) Solids Reduction

3@ | 1000 | sete 1120 - 100 m5/1 | no flocs not measured

7.2 | 3000 | sets 1160 - 2500mq/1 | small flocs not measured

7.0 | 5000 | Hercoftoe 818

25009/1 m0 flocs not measured

4.0 | 5000 | ercofice 049

2500/1 large flocs re

| sees 1120 - 100mg/1

---Page Break---

concentrations are clearly not optimized but the reduction of suspended solids
?in one trial gives a good indication of the feasibility of the approach. The
tests at Sala are supported by the earlier tests carried out at the Univer-
sity of Salford.

---Page Break---

Section VIII

CEER EFFORTS IN THE FIELD OF HGMF

Work Objectives and Scope of the HGMF Program

High Gradient Magnetic Filtration is receiving increasing attention
from various industries as a means for reducing the levels of contaminants
from plant effluent streams. Although the problems are different in each
particular system, the water quality of most of them appears to benefit from
the magnetic filtration approach.

In accordance with this increasing awareness and pressing environ

rental needs CEER/UPR has established a magnetic Filtration program to meet the following objectives.

To provide a comprehensive state-of-the-art review
of HOME and its application with emphasis on the needs
of the people of Puerto Rico, the Puerto Rican Govern
ment and industry in general.

+ To help to provide specific HOME system designs for
demonstration plant applications.

To test and help monitor the demonstration plants.

+ To evaluate the demonstration plant applications on a
cost-benefit basis.

+ To make specific recommendations to government and in-
dustry.

HGNE Program Outline

The HGMF program at the CEER will encompass a large number of acti-
vities ranging from basic research at the molecular level to process develop-
ment and demonstration applications. The elements of this broad research

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program are listed below:

Program Elements

1) Chemistry of selected effluent stream

~ Surface chemistry of particles.

Interaction with coagulants and flocculants.

Particle seed interaction ; floc stability.

pH contro.

Seed material and chemistry of separation of magnetic seed materials
from flocs for reuse.

2) Magnetic separation studies

= Matrix design.

Flow rate, magnetic field, loading.

= Operational modes (continuous, intermittent).

= Backflushing and cleaning of matrix.

3) Sludge treatment

=. Properties of the resulting sludge

= Thickening and dehydration methods.

= Seed recovery.

= Ultimate disposal.

4) Demonstration or Testing

= System automation advantages testing.

= System design.

= System installation and operation.

= Sludge treatment.

- Cost/Benefit analysis.

?The Center is committed to the short and long term implementation

---Page Break---

of HGMF and is presently in the process of developing the time schedule and

resources needed for the above outlined program. An effort of this scale

will require substantial economic support from the local and federal govern-

rent and industry. Preliminary experiments presented in this report have been funded by CEER's own developmental resources.

Current Research and Development Efforts

Preliminary Experiments at the University of Salford, U. K. and

sala Magnetics, Cambridge, Mass, U.S. A

[At the University of Salford rum stops containing 0.09% mercuric chloride as a preservative were received. The surface chemistry of the suspended particles was examined. It was found that at the mostos pH = 4.6 the particles were close to the zero point of charge. With addition of HCT the pi was adjusted to 4 and the particles became slightly positive. With a further adjustment to pH = 3, the mobility of the particles was measured as 5 um/sec/volt which is a low value, indicating a small positive surface charge. Using potassium hydroxide, the pH was increased to 7 where the particles have a weak negative surface charge. The seed having a strong positive charge would therefore be effective at pH = 7. Since the particle surface charge is not a strong function of pH it was concluded that the system was not charge stabilized but stabilized perhaps by hydrophilic natural polymers, such as dextrans and cellulose. This indicated that in order to use the seed at pH = 4.6, it must be added to the mostos with a cationic flocculant in low concentration. Another possibility is to pre-coat the seed with a suspected look-alike polymer, before magnetic separation.

?in attempt was made to seed the mostos with the addition of mag-

netite at 3% by volume without the addition of any other chemical or

toe

---Page Break---

coagulant. The absorbances of both the treated and untreated waste were measured as a function of wavelength throughout the visible spectrum

(Figure 3). In general, the absorbance of the untreated sample had three times the absorbance of the treated samples at all wavelengths, with absorbance generally higher at shorter wavelengths.

Magnetic filtration tests were performed by Sala Magnetics, Inc., Cambridge, Mass on three typical but different potential sources of pollution from the Island: domestic raw sewage, rum slops and pharmaceutical wastes (spent beer). Preliminary unoptimized results obtained for raw sewage, rum slops and pharmaceutical waste yielded reductions of suspended solids of 92.3% 72.0% and 89.0%, respectively. The batch processing data, as well as the results from Sala for these effluents, are summarized in Tables 7, 8, and 9, Turbidity measurements of the untreated versus the treated spent beer are sunmarized in Figure 4. In general absorbance was higher for both

untreated and treated samples at lower wavelengths, but on the average, treatment by magnetic filtration reduced the absorbance by a factor of more than 7, the average absorbance of the treated spent beer waste actually measuring only 13% of that observed for the untreated spent beer. Analysis of Kjeldahl nitrogen on untreated and treated samples of pharmaceutical waste showed a reduction of 52.3%. When analysing the data given above, it should be kept in mind that these numbers represent only preliminary results and that these can be substantially improved by varying some of the filtration parameters. The results of this preliminary evaluation tend to indicate a good potential for application of this technology to the water pollution problems of Puerto Rico.

---Page Break---

Figure 3

Comparative Graph of Light Absorbance in Untreated Mosto (iM) and Magnetically Filtered Mosto (MMF)

a

1s 700

650

1s 600

50

13 500

450

2 400

?

a

10) ?Absordonces corrected using diluti

tector

|

28, 1978

wove Length [NM]

ote

---Page Break---

TABLE 7

HARE Results on Raw Seuege from Puerto Rico obtained by
Sala Magnetics, Inc., Cambridge, Mass.

CONDITIONS

Alun 140 mg/1

Magnetite 200 mg/1

Polyelectrolyte Hercofloc 831, 0.5 mg/1

Magnetic Field 2 2 KG

Flow Velocity 82 gpm/ft?

Residence mixing + 2,5 minutes

Matrix + (#57) expanded metal,

R-type, 45 mil spacing

Sample Volume : 2 liters

RESULTS,

There were two separate runs done for this particular waste

Analysis of Suspended Solids in run #1 in:

Feed 137 mg/1

Magnetically filtered 11.7 mg/1

Reduction in Concentration

of Suspended Solids 91.58

Analysis of Suspended Solids in run #2 in:

Feed 166 mg/1

Magnetically filtered 12.7mg/1

Reduction in Concentration

of Suspended Solids : 92.38

---Page Break---

TABLE 8

HQ Results on mostos from Puerto Rico obtained
by Sala Magnetics Inc., Cambridge, Mass.

CONDITIONS

Alun 70

Magnetite 5 g/t

Polyelectrolyte + Hercofloc 849; 250 mg/t

Betz 1120, 100 mg/t

Magnetic Fied] 2.5 KG

Flow Velocity 82 gpm/ft²

Residence mixing : 4 minutes

Matrix : expanded metal, 45 mil spacing

Sample volune : 1 liter

RESULTS.

Analysis of Suspended Solids in:

Feed 7415 mg/t

Magnetically Filtered + 2050 mg/1

Reduction in Concentration

?of Suspended Solids 1728

---Page Break---

TABLE 9

? HOW Results on Spent Beer from Puerto Rico obtained by
Sala Magnetics, Inc., Cambridge, Mass.

CONDITIONS

Alun 200 mg/t

Magnetite : 20 8/1

Polyelectrolyte : Hercofloc 831; 50 mg/1

Magnetic Field 2 2x6

Flow Velocity : 82 gpm/ft? (initial)

Residence mixing : 4 minutes

Matrix : expanded metal with 45 mil

spacers

Sample volume 250 ml

RESULTS

Analysis of Suspended Solids in:

Feed : 29.3 g/l

Magnetically Filtered : 285

Reduction in Concentration

% of Suspended Solids 89.8

285=

---Page Break---

4

Fig

Comparative Graph of Light Absorbance in Untreated
Pharmaceutical Waste (UPW) and Magnetically Filtered
Pharmaceutical Waste (MTPW)

Absorbance

400 ?300 ery 700

Wove Length [NM]

462

---Page Break---

Mobile Magnetic Filtration? Tratler

Magnetic filtration is a developing technology and on-site demonstration of its potential for pollution contro! of many effluent streams has not yet been carried out. To bridge the informatio gap from bench test ?to full demonstration plants CEER is planning the use of a small capacity (10gpm) mobile magnetic filtration laboratory to be leased from Sala Mag- netics. The primary objective of this 12 month project is the on-site tes- ting of various effluent streams. To accomplish this, the trailer will be stationed at selected sites of discharges in Puerto Rico for a period of

one week, During the testing period various parameters each, including seed, polyelectrolyte concentration, matrix loading, residence times, magnetic field and flow rates will be changed to assign effectiveness of filtration para-

eters to each type of waste. Influent and effluent will be analyzed

continuously with respect to suspended solids, pH, apparent color, turbidity, settleable solids, 800, CO coliform bacteria and heavy metals. The data obtained from this trailer will then be utilized to develop the criteria for the applicability of HMF to treat industrial waste streams surveyed, to form the basis for pilot plant design studies and to chart future research and

development directions.

sh7=

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Section 1x

CONCLUSIONS,

The High Gradient Magnetic Filtration is a new technology to treat industrial, domestic and commercial waste effluents. Data from presently operating and full scale HGMF plants indicate a cost effective and reliable performance. Although HGMF has not yet been fully tested for treatment in

Puerto Rico enough evidence has been collected to suggest that it be considered as a viable new process to complement and/or replace some of the conventional methods.

In particular this Panel concludes that HGMF is potentially a cost effective and practical method to treat mostos. It should be stated however, that a rigorous research development and demonstration program must be assembled to implement this method successfully.

The Center for Energy and Environment Research has already initiated the first phase of this program and has demonstrated the feasibility of mostos treatment on a bench scale. For a full scale development of the program other resources from the government and industry will have to be allocated.

HGMF can be developed into a powerful new method that will permit a large fraction of the industries in Puerto Rico to comply with the zero discharge EPA regulations by 1985.

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APPENDIX A

Economics of Magnetic Filtration

The data generated in this and previous of seeded water treatment have provided considerable information useful in the formation of design and size presented the estimated capital, operation and maintenance-related costs for a proposed integrated wet and dry weather flow treatment plant capable of processing 25 million gallons per day at peak flow. The design of this treatment facility has been upgraded considerably from the one outlined in the earlier report (EPA-600/2-77-015), and includes high-quality system components throughout, with reserve capacity and/or spare units as integral parts, of the design.

CAPITAL costs

Capital costs for the 25 MSD combined wet and dry weather flow treatment plant are summarized by sub-system in Table VII-1. The total estimated capital cost for this seeded water treatment system is Just under 5.2 million dollars. Not included in the capital cost estimates are systems for seed recycling and alum recovery. These systems are contemplated for a fullscale facility, but at this time too little process information is available for a determination of what should be included. It is hoped that a demonstration size plant will be able to generate sufficient quantities of seeded sludge, in the near future, for proper evaluation of various process alternatives in the recovery and reuse of the magnetite seed and/or the Aluminum sulfate incorporated therein. The cost of land has not been estimated because of its site-specific nature.

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?TABLE VII-1 CAPITAL COST ESTIMATES FOR A HIGH GRADIENT MAGNETIC FILTER BASED 25 MGD CS0/SENAGE TREATMENT FACILITY.

ta

Subsystem se

De-gritting and Pre-sereening \$394,900

Feed Pumping 297,600

Fioceulation Train Y Chemical Feed 510,500

High Gradient Magnetic Filters 990,000

Backfiusing "141,300

Filter Piping and Valving 527,400

?Thickening and Dewatering 265, 600

Disinfection 86,900

Electrical 337,100

Automatic Process Control & Monitoring 258,700

Physical Plant Construction 490, 000,

subtotal: \$4,100,000

construction Contingency 10% 410,000

subtotal: \$4,800,000

Engineering and Administration 15 677,000

TOTAL ESTDAATED COSTS: \$5,187,000

Pare

A breakdown of the subsystem components on which the above cost estimates were made is given below.

+ influent flow meter (Parsi

1 coarse bar screen;

1 rotary wedge wire screens (6);

1 entry pipe to plant

2 bypass: piping and valving:

[concrete troughs and pits:

influent flow distributor

conveyor system; and

grit hopper.

11 flume);

---Page Break---

TABLE VII-1, Part 2 (continued)

Feed Pumping System

variable speed pumps;

single speed pumps

Support frames;

pipework for feed flow; and

: 2 Sump well

Flocculation Train and clarifier System

+ Flocculators (3)

2 Flash mixers (6)

2 static mixer (3);

1 alum storage and delivery system;

1 polyelectrolyte make-up and delivery system;

Bagnetite slurry and delivery system; and

support structures

Magnetic Filters

High gradient magnetic filters (5)s

Pover supplies;

Indirect cooling systems;

Anserumentation; and

Support structures.

Blackflush Equipment

screw compressors (2);

pipings;

valves. (55

air receivers (5);

stands and concrete pads

and

Filter Piping and Valving

= filter piping and vatvess

2 chemical rinse piping, tank and valves;

2 air Line piping and valves;

2 structures for piping: and

1 test component.

?Thickening and De-watering Syetens

thickener and rake;

sludge pumps (2);

surge tank;

wacium belt filters (2)

conveyor

sludge hoppers

Piping for sludge;

Sup pump for thickener overflow; and
overflow piping.

953"

---Page Break---

TABLE VIT-L, Part 2 (continued)

Disinfection System

hypochlorite storage tank;

chlorine diffusers:

metering pumps;

residual chlorine analyzer;

chlorine piping;

contact chambers (3); and

outfall piping.

Electrical system

+ motor control centers;

2 wiring and conduit;

1 transformer and accessories:

1 electrical boxes, etc.

micro-processor controller, including

= flow metering:

= alarms;

Differential recording

= interface capability;

and

sampler:

analyzers; and

monitoring system.

Physical Plant Construction

Building of approximately 16,500 ft², including:

+ piping;

electrical system;

Lighting:

office facilities

control room;

laundry;

Ste

---Page Break---

Installation costs were based on estimates from equipment suppliers, the Chemical Engineer's Handbook (Perry), and the Richardson Rapid system. Capital costs are represented at an Engineering News Record (ENR) index of 2700. Labor was figured at \$13/hour, based on an ENR of March 9, 1978.

No provisions have been made for the equipment and operational costs associated with the disposal of either the dried sludge cake or the grit removed from the waste water.

(OPERATION AND MAINTENANCE COSTS

operation and maintenance costs for the 25 MGD facility are estimated in Table VII-2 in dollars per 1000 gallons of water treated using an assumed average flow of 5.7 MGD and a continuous flow of 25 MGD over the course of a year.

The chemical and electrical costs shown are approximate, current local prices for the Cambridge, Massachusetts area. Operator labor is based on 24 hours/day monitoring of the facility plus an 8 hours shift for routine maintenance. The freight costs for the chlorine are included in the chemical costs; polyelectrolyte freight costs are considered insignificant.

From the table it will be seen that total estimated operating costs for seeded water treatment range from \$.23 per 1000 gallons of treated water.

Costs have been included for final disposal of sludge and grit, and for sludge treatment chemical conditioning (should the latter prove necessary). The chemical demand and net operation costs could change significantly if seed recycling or alum recovery are incorporated into the flowsheet.

Power consumption for a system running at 5 MGD and at 25 MGD is shown in Table VII-3. The magnetic filters specified for this system are

55°

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more efficient than those units previously specified, and will therefore

require only about 12 percent of total plant energy consumption.

DESIGN CONSIDERATIONS

The treatment plant will include three main flow streams for waste water purification, although there will be one flow as they enter the facility (pre-treatment) and as they leave (chlorination and de-watering). The actual water/suspended solids separation occurs in one five high gradient magnetic Filters (the fifth is considered a spare). The first filter is available to handle normal dry weatherflow, estimated in this instance at 5 MGD, and the remaining four filters operating at a maximum flow rate of 125 gpm/ft² are available to handle the 25 SD peak storm flow. When all five filters are activated, the maximum capacity of the system will be 32 MGD, and average annual through put is assumed to be 5.7 MGD. Figure VII-1 is a system design schematic.

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PS Hass eas ocess gael

geass

se

EY TO FIGURE VII-1

Dessription

?tun Delivery Pump (2 spare)

?Num Storage Tank

Aix Receiver

far Screen

control cate

Caustic Rinse Pump

Chlorination system

Caustic Storage Tank

conveyor

Feed Pum (2 spare)

Ploccutator Tank System

Grit Hopper

Magnetic Pitter

Magnetic Delivery Pump

Magnecite Screw Feoder

Magnetite Sturry Tank

over-fl0~ Pump

Polyelectrolyte Make-up System

Polycelectrolyte Delivery Pump (2 spare)

Rotary Strainer

Screw Compressor

Stuige Hopper

Static Mixer

Studge Pump (1 spare)

Surge Tank

Sump Welt

258:

---Page Break---

KEY To FIGURE VI1-1 (continued)

1 ? ?Thickener

2 , Vacuum Filter

?TABLE VII-2 OPERATION AND MAINTENANCE COST ESTIMATES FOR A HIGH GRADIENT
MAGNETIC FILTER BASED 25 MCD CSO/SEWAGE TREATMENT FACILITY.

sn \$ per 1000 gai

ae 5.7 wep 25 moo

Chemicals:

Mun Giquid, 502) 100 mg/1 042 042

\$100/éry ton

5.1006,

\$.27/al-

sont

Magnotite (commercial grade, ~325 mesh) .030 +030

200 me/

\$35/ton

\$.018/18

\$1029/Ke.

+ Polyelectrolyte (Hereofloce #31, ot son

axfonie) Taft

81.36/16

\$3, 00/eg

Chlorine (15% Sodium Hypochlorite,

Witchlor 2) 1 mg/t

8.30/¢a1

s.079/3

\$1529/kg availabe C1,

Gelivered price)

Total Chemical Costs: 087 -087

Chemical Freight Costs:

Alum for 50 mi or 80 kx 007 -007

§-05/gal

5013/1,

+ Yagwatite for 200 af oF 222 fn +008 +008

ues

-OL1/kg. (estimated)

Total Freight Casts: a a

592

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TABLE VII-2 (continued)

ten

Hectrical Power §.055/kih

+ Magnetic Filter (5) 15 KW ea,

Other Equtpaent

15 WH 5 McD

?ou iw 25 Nop

operator Labor:

32 manchours/day §15/he

Maintenance Coste:

Mechanical Bqutment and

Physical Place (32 of equipment cost)

+ Hlectrical Equipment, Instre-

mentation, and Piping (22 of equip-

ent cost)

otal Labor and Maintenance Cost:

?TOTAL OPERATION AND MAINTERANCE.

(COST PER 1000 GALLONS:

Cost in

7M

2032

039

042

son

092

oe

25 mc

024

039

008

1049

aT

TABLE VII-3 POVER CONSUMPTION FOR A 25 MCD FACILITY

ae

Devgritting and Pre-screening

Feed Pumping 45 ft. head

Chemical Makeup and Delivery

Hloceuletor Chain Mixing

Magnetic Filters

Compressors

Dewatering Syston

Control Instrumentation and Bldg. Service

Miscellaneous

?ToraL: so

Energy Coneuned in Kith

3 mp

8.2

40.0

26

9.0

35.0

12.0

25 MoD,

18.7

200.0

65

39.0

60.0

45.0

42.0

23.0

30.0

464.0

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TABLE VII-4 ASSUMED PARAMETER VALUES FOR A 25 MGD SYSTEM

Item

Magnetic Filters

+ Bore

Length

+ Magnetic Field Strength

Maximum Flow Rate through Matrix

Waste Water Characteristics

+ Maximum Storm Flow

+ Nominal Dry Weather Flow

1 Average Flow over 1 Year

Backflush Flow Flux Rate through

Matrix

+ Backflush Duration

Backflush Volume

Maximum Pressure Drop before Backflush

Caustic Rinse Flow Rate through Matrix

Mixing and Residence Times

+ G Factor for Flash Mixer

1G Factor for Flocculator

1 Reynolds Number for Static Mixer (21 in)

1 Total Mixing Residence Time

Chemical Dosage.

+ Alum Concentration

{ Magnetite Concentration

+ Polyelectrolyte Concentration

Chlorine Concentration

Chemical Storages

Parameters

Pumping Head for Feed Pumps

1 Pre-screening size

Design Valve

84 in (214 cm)

6 in (15 cm)

0.3k yd

125 gpa/te? 8

(6800 gpm)

/min)

3

25 wep (1.1 m/sec)

5 MoD (,22 > sec)

5.7'9ç0 (25 9 fees)

100 g/t

500 gpm/fe? (73 m*/min)

(39,300 gpm)

8s 3

2600 gal (20 n°)

10 pit

20 gpn/te?

(2,9 m/min)

100 g/t

200 mg/1

1.0 mg/t

2 mg/l

6 days at peak flows 30 days
at dry weather flow

45 fe. (33 pei)

20 mesh (.84 ma)

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FIGURE VIT-2 TOP AND SIDE VIEWS OF ALUM RESIDENCE/FLASH MIX/
FLOCCULATOR RESIDENCE TANK CHAIN FOR THE 25 MGD
SEEDED WATER TREATMENT SYSTEM

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Table VIII-4 gives the parameter values used in obtaining magnetic Filter and operational cost estimates for a 25 MSD facility. These values were chosen on the basis of the experimental data, previous experience in the field, flow requirements, and equipment design limitations.

A combined wet and dry weather Flow treatment plant has an inherently large reserve capacity which remains unused for a major portion of the year.

For the 25 MGD peak flow system in question, it was arbitrarily assumed that

in the course of a year there would be 30 storms producing a 25 NGD flow for an average of 10 hours each, or a total of 300 hours of CSO at a 25 MED

throughput rate, compared to 8460 hours of dry weather flow at 5 NGD. Although these are assumed values, and may not be representative for a given location, the fact remains that in this type of treatment facility, a large amount of equipment must be regularly maintained for only sporadic use. As a conse-

quence, operation and maintenance costs are relatively high in proportion to the number of gallons treated.

The system shown in Figure VII-1 is similar to the seeded water treatment flowsheets presented in the past (i.e., the Mobile Pilot Plant Trafter design and the 25 MD system outlined in Figure X-1 of EPA publication EPA-600/2-77-015), with a few design changes. For example, static mixers have been added for initial alum dispersal prior to the Targe alum residence tank. The floc chain, consisting of an alun residence tank, to flash mixers for polymer and magnetite addition, and a larger flocculator for final residence are sized for a total of 5 minutes mixing time, A detail of this system is show in Figure VII-2. The pressure head created by the alum mix/flash mix/flocculator tank unit is now designed to be used in place of the filter pump suction head used in previous designs to draw the chemically pretreated water through the magnetic filters. Thus, there is no longer a need for filter pumps in the

63°

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t

.

system.

Another change is with the magnetic filter design which affects the backflush system

each magnetic Filter now has its own hydrotank for backflushing incorporated as an integral part of the magnetic filter canister (forward flow) plumbing. In this way, such extra plumbing and valving have been eliminated, as well as the extra control provisions for filling the hydrotanks with filtered water. This latter operation is now accomplished automatically, in a passive manner, with each Filter cycle. Other Features have been included in the design to make the system both dependable and foolproof. The design is conservative, and spare pumps assure adequate back-up; the process control system is versatile and completely automatic

and a bypass system has been included for emergency

situations.

6h

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