

MAGNETIC FILTRATION MOBILE TESTING LABORATORY; CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

CEER - Magnetic Filtration Mobile Testing Laboratory, Technicon Reagents Corporation. MAGNETIC SEPARATION PROJECT (CENTER FOR ENERGY AND ENVIRONMENT RESEARCH) University of Puerto Rico, May 1979. Center for Energy and Environment Research

MAGNETIC FILTRATION MOBILE TESTING LABORATORY (CENTER FOR ENERGY AND ENVIRONMENT RESEARCH), 1970

MAGNETIC FILTRATION 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, Bled Des Arthur, MES. Block, Scientist, Magnetic Separations Project, Dev Juan W Bonnet, Jr. Center for Energy and Environment Research

MAGNETIC FILTRATION 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 Environment Research, Caparra Heights Station, San Juan, Puerto Rico 00935. Telephone: (809) 767-0338. Total Funding Requested: \$25,000. This project is an experimental evaluation project aimed 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 Environment Research is a part of the University of Puerto Rico, a non-profit institution for higher learning.

I. Project Overview

1.1 Introduction

Research and development projects aimed at relevant public health and welfare problems confronting Puerto Rico have led 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 due to large daily volumes, high BOD and elevated levels of TSS.

Water re-use after tertiary treatment is already projected as an alternative for the imminent problem of water scarcity: an effective, energy-conservative treatment method with very modest land area requirements called High Gradient Magnetic Filtration (HGMF). CEER has established an implementation program for island-wide use of HGMF.

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 the most urgent needs of Puerto Rico.
2. Help design and install effluent-specific flow systems for demonstration applications.
3. Test and monitor the operation of demonstration plants.
4. Evaluate the cost-benefit in demonstration plant applications.
5. Make recommendations concerning specific large-scale applications to industry and government source development.

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 strip chart 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 possible. The mobile plant includes laboratory, office and is possible. The nominal 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 relevant 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 Removal 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 18), BOD, Suspended Solids, pH, optical absorption and heavy metals.

FIGURE 1

1.4.2 Engineering Utilization of Results: Results of on-site testing at about 10 gallons per minute (gpm) 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 scale-up will be made, i.e., Project Scope 2.1 Sources of Pollution. A recently held workshop (Appendix A) was dedicated to the consideration of possible applications of magnetic separations to effluents associated with Puerto Rican industrial and domestic waste streams. Point sources, PRASA treatment plant sources (including effluent polishing), and non-point sources were identified as worthy of attention.

2.1.1 Point Sources: Point sources of pollution are usually identified within industrial processing or manufacturing. The following listing and comments apply to those point sources considered to be actual or potential problem effluents on the island.

2.1.1.1 Pharmaceuticals: Characterized by high BOD, COD, low DO, and high organics. These industries commonly use high amounts of rinsing water and biologically active components. Treatment methods include lagoons, sludge incineration, and chemical treatment.

2.1.1.2 Chemical Industries: These industries have high BOD, COD, low DO, and toxic components. High amounts of cooling water are common. Diverse treatments are found in combinations.

2.1.1.3 Distillers: These effluents are characterized by extremely high BOD, suspended solids, biologically active components, and significant coloration. Except for land disposal in one case, no treatment is given to this waste at present.

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

2.1.1.5 Food Processing: The typical waste from these industries includes high BOD, residual proteins, oils, solids, and odors.

2.1.1.6 Sugar Industries: The waste characteristics of these industries include high BOD, solids, organics, coloration, and odors. The treatment consists of oxidation and sedimentation lagoons. However, at best, the treatment is not complete.

2.1.1.7 Petrochemicals: The typical pollutants in these waters are high COD, low DO, solids, oil, organics, and coloration. Treatment methods are varied, consisting of biological treatment, oxidation lagoons, chemical treatment, and raw discharges in some cases.

2.1.1.8 Refineries

2.1.1.9

Textiles: The main problem associated with the textile industry on the island is the coloration of the waste streams. The main treatment, when given, is chemical in nature, consisting of adsorption by activated charcoal or by others.

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.

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 two aspects of water treatment plant effluents are

given below.

2.1.2.1 Sewage: Public treatment plants in Puerto Rico handle primarily domestic wastes. However, the wastes also include a significant fraction 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 wastes 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.

2.1.3.1 Agricultural Waste: 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.

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.

2.1.3.3 Mining Activities

In a greater 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 a period of time has elapsed, pollutants tend to decline in concentrations.

2.1.3.5 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 Possible Representative Source Survey in Puerto Rico

Although no formal agreements have yet been made with wastewater producing entities, the following list of tentative effluent streams seems to be the best candidates for immediate HEMP applications for Magnetic Filtration:

1. Raw or partially treated sewage.
2. Combined storm overflow.
3. Secondary activated sludge treatment plant effluent.

Note: The initial part of the text regarding herbicides, pesticides, and leachate seems incomplete. It's missing context and the information seems fragmented.

4. Aqueous distillery and brewery wastes.
5. Pharmaceutical wastes.

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

GW treatment data derived from these particular effluents could directly or indirectly benefit Puerto Rico in meeting impending EPA regulations aimed at zero discharge. In particular, EPA-sponsored tests in the 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.

II. OVERALL PROJECT BUDGET AND REQUISITE FUNDING

As proposed, this project will be developed utilizing the matrix technique of project management and staffing. During the 12 month period, personnel will be used for varying periods of time for discrete task assignments. It's possible they will be drawn 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 testing.

III. Estimated Budget for 12 months period

3.1.1 Personnel (task determined time)

- Principal Investigator 108 4,000.00
- Project Leader 508 10,000.00
- Scientist Assoc. 508 7,000.00
- Res. Asst. 1008 6,200.00
- 3% Grad. students 1008 5,400.00
- 3 x Consultants 1008 15,000.00
- Total Salaries 47,600.00

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
- Sub Total 104,716.00
- Overhead 40% 41,886.00
- Total Project, \$146,602.00

IV. 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...

The remaining \$109,000 necessary for financing this phase of the HGM project can be obtained from prominent industries on the Island. The CEER is very keen on securing the participation of industries that possess the most modern production facilities and have a sincere desire to adopt new techniques to ensure compliance with environmental regulations. Roche Products, Inc. seems to have developed highly modern production facilities where the HGM project could be integrated with minimal difficulty. They have also shown interest in the technique for the removal of fine suspended solids from certain effluents. Therefore, we request the participation of Roche Products, Inc. in this project phase at a funding level of \$25,000.

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- Physics of the Capture Process
- Features of the High Gradient Magnetic Filtration (HGMF)

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

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Title: RUM DISTILLERIES PROCESS WASTE (MOSTO)

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HGMF Results of Raw Sewage from Puerto Rico Obtained by Sala Magnetics Inc.

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HGMF Results on Spent Beer from Puerto Rico Obtained by Sala Magnetics Inc.

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

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EXECUTIVE SUMMARY

This report addresses the value of high gradient magnetic filtration to Puerto Rico's effluent pollution problems and 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 groundwater, 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 of EPA regulations, 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, viable solution.

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Break--- Flexible and cost-effective means to remove pollutants from wastewater. The HGMF system utilizes state-of-the-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.

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 on the island are

The text is distributed in such a way that it's obvious at 18 that industries are not the only source of pollution. In some cases, sewage treatment is ineffective, 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 current pollution levels of both surface and groundwater in Puerto Rico, as well as its aquatic recreational areas and beaches, are already severe. Increased population pressures will further aggravate the problem of pollution control.

The population density of Puerto Rico, an island 30 x 150 miles in size, is rated the 6th highest worldwide. Most of the population (about 90%) resides 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 significant challenge to the health, welfare, and lifestyle of Puerto Rico's 3.2 million inhabitants.

At many locations on the island, hazardous water pollutants from industry, municipalities, and communities are discharged into the environment with little or no treatment. In the past, numerous community activities and projects intended to minimize adverse health conditions and social and aesthetic effects associated with water contamination have been instituted. However, in general, they have not been successful.

Suspended solids (SS) are a major problem, along 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 introducing both sediments and pollutants with high BOD. Given the existing conditions on the island, it is evident.

"That conventional treatment management methods have failed to significantly reduce water pollution. New methods and 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).

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 conditions 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

The 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.

Direct land application of aqueous wastes may be effective for elimination of problem wastes if suitable land is available. Periodic surface flushing is generally a 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. 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 wastewater to a solid. Solar evaporation ponds may be used, but a several-day to one-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

The text should be revised as follows:

Applications are considered for each available best technology. In recent years, a new magnetic filtration technology, high gradient magnetic filtration, has been developed to remove micron-sized particles from a fluid stream at high flow rates. These high gradient magnetic separators or filters are designed to maximize the magnetic forces on fine, magnetic materials. They are capable of efficiently separating or filtering even weakly magnetic suspended solids or precipitates for which conventional magnetic separation techniques are ineffective.

Table 1: Treatment Technologies as Currently Practiced

Treatment Technologies | Comments

Anaerobic Contact | Re-aeration of discharge required; large investment for high BOD removal.

Aerobic Contact | Odor problem. May not treat chlorinated pesticide residues.

Aerobic Lagooning | Large land areas may be required.

Anaerobic/Aerobic Tank | May involve large land areas, high capital expenditures, and require highly trained operators.

Direct Land Application | Monitoring of disposal area necessary. Not feasible if long sewerage lines are needed. Large, managed crop land area required.

Evaporation | Sludge transport and disposal management more urgent. Can be energy-intensive and necessitate long hold up times.

This capability is the result of the development of a filamentary ferromagnetic matrix and a large volume, high-field magnet. The combination of an efficient magnet and high gradient matrix allows the economical generation of strong magnetic forces over a large surface area in the magnetic filter bed. Filtration can 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 particles.

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 are many times greater than gravitational forces. Municipal and industrial wastewater treatment by high gradient magnetic filtration with iron powder 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 oil refining, air filtration and the filtration of waters from nuclear power plants at various companies and research centers throughout the world. In the light of severe environmental problems associated 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 gradient magnetic filtration may be a useful alternative.

Section II 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

At a certain point, typically 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 wherein the matrix is continually moved through the magnetic field, allowing for fully continuous processing of slurries or liquids, which can be advantageous 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 a fluid moving in a 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 magnetic and drag forces, a great simplification of equations of predictive value can be achieved by introducing a quantity called the magnetic velocity (V_m).

For ferromagnetic particles in a low magnetic field (H_a), V_m is given by the equation $V_m = \frac{2(473)W_p W_a \mu_0 \mu H_a}{4\eta a y}$, where b is the particle radius, H_a is the applied magnetic field (amp/meter), 4×10^{-3} is the viscosity of the fluid, a is the radius of the wire, and y is in henry/meter.

The magnetic velocity (V_m) is extremely important because if the slurry enters the separator at a velocity equal to the magnetic velocity, the separation is extraordinarily effective. For example, if the wires have a radius of $50 \mu\text{m}$, if the particles have a radius of $2 \mu\text{m}$, and if the magnetic field (H_a) is 1.59×10^8 (A/m) (2000 gauss), then $V_m = 3.4$ cm/sec. If the fluid enters the separator at a velocity of 3.4 cm/sec, the separation will be extremely effective.

Of the separator and θ 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 consist of time to switch the magnet on and off and the time to flush the magnetics. For efficient operation, the feed time must be much greater than the dead time.

FIGURE 1: High Gradient Magnetic Separation Filter Showing Section of Matrix Wire

As an example, a typical filter will operate at 100 to 200 gpm/ft² and at a magnetic field strength of no more than 3 kG. It can process 4000 to 2000 gpm of feed, consuming no more than 25 kW of electric power. Solids removal is typically 75-95% depending on the particle characteristics, the flow rate per unit area and the magnetic field strength. The machine weighs 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 filtration 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 applications, cyclic

Devices are utilized. However, in certain cases where the density of solids in the feed stream is sufficiently large, fully continuous devices with a circular filter bed may be used.

AMU 2. SPECIFICATIONS OF TYPICAL HOME SYSTEMS REPRO COOLING WA

Feed Pressure | Power | Height | Volume | More

(Inches) (Abs) (Gpm) (Gpm) (Psi) (CC)

206 | 126 | 170,000 | 77 | 5,900-19,650 | 92

70,000 | 37.8 | 2,900- 9,670 | 8 | 56 | 55.5

45,000 | 15.2 | 1,540- 5,130 | 80 | 26 | 42.5

38,000 | 2.3 | 720 | 2,400 | 4.3 | 35.5

2,000 | 4.7 | 360- 1,200 | 3.5 | 36 | 28

5,900 | 2 | 200-670 | 2.6 | 22 | 20

2,800 | 190-300 | 2.3 | 34 | 16

Weight measured flange to flange.

Notes: The separators have a 15 cm axial matrix length and a maximum applied magnetic field strength of 5 kilogauss. To estimate filter velocity, divide desired throughput rate by matrix area.

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.

Section III: 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 utilized.

The text can be corrected as follows:

The process can 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 containing 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 magnetite surface 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, ore iron, cobalt, and nickel as well as oxides of these and other well-known relatively strong magnetic substances.

Page Break

Association of Seed and Impurity: The techniques used to associate magnetite particles with non-magnetic and dissolved materials include: Adsorption, Coagulation and Flocculation, and Coprecipitation.

Adsorption: In the adsorptive mode, magnetite adsorbs the non-magnetic particle or dissolved ion onto 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: Changes in the pH of the candidate stream may be used to produce opposite surface charges on the magnetite and the particulate impurity.

Coagulation and Flocculation: Inorganic coagulants, such as alum and ferric chloride, are added to a waste slurry. These coagulants act to neutralize surface charge and reduce any repulsive forces between the seed and the impurity particles, allowing the particles to agglomerate. Organic flocculants create bridges between particles and enhance the strength of inorganic flocs against shear forces.

Coprecipitation: This is a third method of effecting association. Coprecipitation of certain dissolved materials and ions produces insoluble compounds. This process generally involves a change in pH to create particulates that are sufficiently magnetic to be directly filtered in a high gradient magnetic filter. In addition to coprecipitation, dissolved materials (both organic and inorganic) may be removed by adsorption.

Hydroxides formed by flocculation 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 absorb 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 a fine particulate magnetite containing aluminum sulfate and a magnetite suspension in which the particles have been treated to produce coatings of organic polymer material.

Application Procedure: In practice, the seeding process... (text continues after page break)

The procedure is relatively straightforward. A generalized procedure will allow for pH adjustment of the influent to optimize coagulation. The next steps are the addition of an inorganic coagulant in a flash mixer, the 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 2-4 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 sludge is generally a small fraction of the feed stream.

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 waste 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 rates may be appropriate for certain applications where impurity disposal and/or sludge dewatering is not a problem.

Section IV - PRESENT WORLDWIDE APPLICATIONS OF HIGH GRADIENT MAGNETIC FILTRATION

The first high gradient magnetic filter was installed in the clay industry in 1969.

Since that time, 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 focused 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 wastewater 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.

Gradient. State of Full scale Development. Application | Full scale| Development| Research|
Country Application | Operating "| Planned

Storm Water. Process in which magnetite seeding.

The text is used.

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 gallon per day (mgd) plant for treatment of combined sewer overflow and sewage (CSO). 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 waste from an average-sized distillery will cost more than the values estimated for the 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 mgd flow are the costs to

"Operate a 25 MGD plant intermittently and do not necessarily reflect the cost to treat water with a plant designed specifically for lower throughput rates.

Section VI: Polluted Water Effluents in Puerto Rico

The following is a summary of information regarding general industrial groups on the Island, and the problems associated with their effluents. More detailed information can be obtained from the studies conducted by EO8 under the 208 programs (13).

Point Source Pharmaceuticals - High BOD, COD, TOW, 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, TOW, 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 land 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 complete.

Petrochemicals - High COD, TOW, solids, oils, 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 on the island is the coloration of the

Waste Streams - The main treatment, when given, is 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.

Puerto Rico Aqueducts and Sewers Authority Sewage - Public treatment plants in Puerto Rico handle primarily domestic wastes. However, the wastes also include a significant fraction of wastes from industries and commercial establishments. A significant number of treatment plants provide 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, due to illegal sewage 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, 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.

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 - To a larger extent than 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 runoff after a storm is where the concentrated fraction of pollutants is found. After a period of time has elapsed, pollutants tend to decline in concentrations.

In 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.

In 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.

Section VII: Rum Distilleries 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.

Treatment. Destileria Serrallés in Ponce, P.R., mixes its must with its own sugarcane field irrigation waters and disposes of it through land application. Regulatory agencies have reported some reservations (1) about this system due to its possible long-term effects on soil conditions and potential underground water contamination. Other rum producers on the island do not distill, and limit their production to the blending of selected alcohols.

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 can be reclaimed or pumped into water bodies, with its temperature regulated to prevent 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 timeframe was established was set forth in 1972; as part of this act, a permit issuance system titled 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. Moreover, it must remove from the discharge any pollutant 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. 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 the EPA will not bring them into 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 local distillers, a 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 application. It is unlikely that conventional anaerobic treatment alone would be able to treat waste sufficiently to achieve the reduction in BOD required since typical BOD removal in this step is only about 80%. Aerobic lagoon treatment alone would probably not be practical because the high oxygen demand of waste could not be transferred by the most.

Efficient surface aerators. For example, with an 80D 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 the 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 traditionally have contributed significantly to the economic infrastructure of the

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 on the island, without requiring an inordinate capital investment. Currently, the technologies available for controlling this problem are unlikely to provide a final solution that aligns with the environmental and economic needs of the island. We believe that allowing the necessary additional time to evaluate the promising magnetic filtration technology could benefit both the natural environment and the economic climate of the island.

Magnetic separation has been presented as a potential technique or an essential component of a hybrid system, capable of treating large volumes of low-nutrient, high Biological Oxygen Demand (BOD) wastes produced as by-products of the rum distilling industry.

With regard to the applicability of high gradient magnetic filtration to the treatment of mostos, it is based on successful tests on mostos and related effluents. Firstly, tests carried out on a wide variety of organic and inorganic wastewater have shown that the magnetite-seeding-high gradient magnetic filtration technique is highly effective in removing suspended solids, BOD, color, bacteria, and other criteria substances.

Secondly, tests performed by Sala Magnetics and the University of Salford on mostos samples demonstrated a reduction in total suspended solids, as well as a corresponding decrease in sample turbidity and color. Sala Magnetics has conducted tests using the magnetite seeding techniques on a wide variety of waters. Some results of these tests, including laboratory tests and continuous pilot plant studies, are summarized in Tables 4 and 5.

In addition to the striking increase in clarity observed in the tested streams, a virtual absence of odor in treated organically contaminated samples is often noted. Although the mostos waste, as described above, generally have higher...

Concentrations of suspended solids and 800 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 for 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. In laboratory tests carried out to determine treatability of an unknown effluent, the possible range of experimental conditions such as 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 Magnetism tests is shown in Table 6. The chemical #336.

RESULTS OF HOME LABORATORY TESTS PERFORMED BY SALA MAGNETICS INC., CAMBRIDGE, MASS.

Removal Water Type:

- Raw sewage 66% Suspended Solids or color
- Combined storm and sewage 95% Turbidity
- Paper Mill (aeration stabilization Basin) 93% Turbidity
- Spent Beer 97% Turbidity
- Surface water 99% Turbidity

"Adobe Systems Incorporated announces "Adobe CS08 X 842 Beta Test" in 2020. One of the key features is the ability to process sound (6:1) uninterrupted, enhancing user experience and increasing productivity. This feature is compatible with various operating systems, including iOS and Android. It is expected to be launched in the 3rd quarter of 2024.

In addition, Adobe has also announced the release of a new product entitled "Wine F". Further details about this product are yet to be disclosed.

Results of the High Gradient Magnetic Filtration (HGMF) tests by Sala Magnetism, influenced by varying test conditions, are as follows:

Test Conditions & Results:

pH	Suspended Solids	Particle Size	Description	Solids Reduction
---	---	---	---	---
3	1000	set at 1120 - 100 mg/1	No flocs	Not measured
7.2	3000	set at 1160 - 2500mg/1	Small flocs	Not measured
7.0	5000	Hercoflo 818 2500mg/1	No flocs	Not measured
4.0	5000	Hercoflo 049 2500mg/1	Large flocs	Not measured
Re	Sees	1120 - 100mg/1		

The 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 University of Salford.

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

The water quality of most of them appears to benefit from the magnetic filtration approach. In accordance with this increasing awareness and pressing environmental needs, CEER/UPR has established a magnetic filtration program to meet the following objectives:

- To provide a comprehensive state-of-the-art review of HGMF and its application, with emphasis on the needs of the people of Puerto Rico, the Puerto Rican Government, and industry in general.
- To help provide specific HGMF 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 industry.

HGMF Program Outline

The HGMF program at the CEER will encompass a large number of activities ranging from basic research at the molecular level to process development and demonstration applications. The elements of this broad research 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 control.
- 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 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 government and industry, preliminary experiments presented in this report have been funded by CEER's own developmental resources. Current Research and Development Efforts include 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 most, pH = 4.6, the particles were close to the zero point of charge. With the addition of HCT, the pH 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 must with a cationic flocculant in low concentration. Another possibility is to pre-coat the seed with a suspected look-alike polymer, before magnetic separation. An attempt was made to seed the must with the addition of magnetite at 3% by volume without the addition of any other chemical or 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.

The text discusses 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 summarized in Figure 4. In general, absorbance was higher for both untreated and treated samples at lower wavelengths,

but on 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 measured 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 analyzing 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 the application of this technology to the water pollution problems of Puerto Rico.

Figure 3: Comparative Graph of Light Absorbance in Untreated Mosto (M) and Magnetically Filtered Mosto (MMF)

Table 7: HARE Results on Raw Sewage from Puerto Rico obtained by Sala Magnetics, Inc., Cambridge, Mass.

Conditions:

- Alum: 140 mg/l
- Magnetite: 200 mg/l
- Polyelectrolyte Hercofloc 831: 0.5 mg/l
- Magnetic Field: 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.

Suspended Solids in run #1:

Feed: 137 mg/l

Magnetically filtered: 11.7 mg/l

Reduction in Concentration of Suspended Solids: 91.58%

Analysis of Suspended Solids in run #2:

Feed: 166 mg/l

Magnetically filtered: 12.7 mg/l

Reduction in Concentration of Suspended Solids: 92.38%

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 Field: 2.5 KG
Flow Velocity: 82 gpm/ft²
Residence mixing: 4 minutes
Matrix: expanded metal, 45 mil spacing
Sample volume: 1 liter

RESULTS:

Analysis of Suspended Solids:
Feed: 7415 mg/t
Magnetically Filtered: 2050 mg/1
Reduction in Concentration of Suspended Solids: 1728

TABLE 9 HOW Results on Spent Beer from Puerto Rico obtained by Sala Magnetics, Inc., Cambridge, Mass.

CONDITIONS:

Alun: 200 mg/t
Magnetite: 20 g/1
Polyelectrolyte: Hercofloc 831; 50 mg/1
Magnetic Field: 2x6
Flow Velocity: 82 gpm/ft² (initial)
Residence mixing: 4 minutes
Matrix: expanded metal with 45 mil spacers
Sample volume: 250 ml

RESULTS:

Analysis of Suspended Solids:
Feed: 29.3 g/1
Magnetically Filtered: Specific Reduction
Reduction in Concentration of Suspended Solids: 898-285

Figure 4: Comparative Graph of Light Absorbance in Untreated Pharmaceutical Waste (UPW) and Magnetically Filtered Pharmaceutical Waste (MTPW)

Absorbance: 400-300, 700
Wave Length [NM]: 462

Mobile Magnetic Filtration Trailer: Magnetic filtration is a developing technology and on-site demonstration of its potential for pollution control of many effluent streams has not yet been carried out. To bridge the information gap from bench test to full demonstration plants, CEER is planning the use of a small capacity (10 gpm) mobile magnetic filtration laboratory to be leased from Sala

Magnetics. The primary objective of this 12-month project is the on-site testing 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 including seed, polyelectrolyte concentration, matrix loading, residence times, magnetic field, and flow rates will be changed to assign effectiveness of filtration parameters to each type of waste. Influent and effluent will be analyzed continuously with respect to suspended solids, pH, apparent color, turbidity, settleable solids, BOD, CO, coliform bacteria, and heavy metals. The data obtained from this trial 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.

Section 1: 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 HMF is potentially a cost-effective and practical method to treat most wastes.

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 waste 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. HME 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 seeded water treatment have provided considerable information useful in the formation of design and size. Presented are the estimated capital, operation, and maintenance-related costs for a proposed integrated wet and dry weather flow treatment plant capable of processing.

The treatment facility has a peak flow of 25 million gallons per day. The design of this facility has been significantly upgraded from the one outlined in the earlier report (EPA-600/2-77-015). It now includes high-quality system components throughout, with reserve capacity and/or spare units as integral parts of the design.

Capital costs for the 25 MGD combined wet and dry weather flow treatment plant are summarized by subsystem in Table VII-1. The total estimated capital cost for this seeded water treatment system is just under 5.2 million dollars. The capital cost estimates do not include systems for seed recycling and alum recovery. These systems are planned for a full-scale facility, but at this time, too little process information is available to determine what should be included.

It is hoped that a demonstration-sized plant will be able to generate sufficient quantities of seeded sludge in the near future. This will allow for a 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 due to its site-specific nature.

Table VII-1: Capital Cost Estimates for a High Gradient Magnetic Filter-Based 25 MGD CSO/Sewage Treatment Facility

Subsystem Costs:

- De-gritting and Pre-screening: \$394,900
- Feed Pumping: \$297,600
- Flocculation Train: Y
- Chemical Feed: \$510,500
- High Gradient Magnetic Filters: \$990,000
- Backflushing: \$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 Estimated Costs: \$5,187,000

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

- Influent flow meter
- Partial coarse bar screen
- Rotary wedge wire screens (6)
- Entry pipe to plant

Bypass: Piping and Valving: Concrete troughs and pits; influent flow distributors; conveyor system; and grit hopper. 11 Flume.

TABLE VII-1, Part 2 (continued)

Feed Pumping System: Variable speed pumps; single speed pumps; support frames; piping for feed flow; and sump well.

Flocculation Train and Chemical System: Flocculators (3); flash mixers (6); static mixer (3); alum storage and delivery system; polyelectrolyte make-up and delivery system; magnetite slurry and delivery system; and support structures.

Magnetic Filters: High gradient magnetic filters (5); power supplies; indirect cooling systems; instrumentation; and support structures.

Backflush Equipment: Screw compressors (2); piping; valves; air receivers (5); stands, and concrete pads.

Filter Piping and Valving: Filter piping and valves; chemical rinse piping, tank, and valves; air line piping and valves; structures for piping; and test component.

Thickening and De-watering Systems: Thickener and rake; sludge pumps (2); surge tank; vacuum belt filters (2); conveyor sludge hoppers; piping for sludge; sump pump for thickener overflow; and overflow piping.

TABLE VII-1, 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; wiring and conduit; transformer and accessories; 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.

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.

The Engineering News-Record (ENR) index is 2700. Labor was calculated at \$13/hour, based on the 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 wastewater.

Operation and maintenance costs for the 25 million gallons per day (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, based on 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 the total estimated operating costs for seeded water treatment range from \$.23 per 1000 gallons of treated water. No costs have been included for the final disposal of sludge and grit, nor for sludge treatment chemical conditioning (should the latter prove necessary). The chemical demand and net operation costs could significantly change 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% 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 wastewater purification, although there will be one flow as they enter the facility (pre-treatment) and as they leave (chlorination and dewatering). The actual water/suspended solids separation occurs in one of 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

throughput is assumed to be 5.7 MGD. Figure VII-1 is a system design schematic.

PS Has process gas. Key to Figure VII-1 Description:

1. Turn Delivery Pump (2 spare)
2. Turn Storage Tank
3. Air Receiver for Screen control gate
4. Caustic Rinse Pump
5. Chlorination system
6. Caustic Storage Tank
7. Conveyor Feed Pump (2 spare)
8. Flocculator Tank System
9. Grit Hopper
10. Magnetic Filter
11. Magnetic Delivery Pump
12. Magnetite Screw Feeder
13. Magnetite Slurry Tank
14. Overflow Pump
15. Polyelectrolyte Make-up System
16. Polyelectrolyte Delivery Pump (2 spare)
17. Rotary Strainer
18. Screw Compressor
19. Sludge Hopper
20. Static Mixer
21. Sludge Pump (1 spare)
22. Surge Tank
23. Sump Well

Key to Figure VII-1 (continued):

24. Thickener
25. Vacuum Filter

Table VII-2 (continued)

1. Electrical Power \$0.055/kWh
2. Magnetic Filter (5) 15 KW each
3. Other Equipment 15 WH
4. 5 MGD operation
5. 25 MGD operation
6. Operator Labor: 32 man-hours/day \$15/hr
7. Maintenance Costs:
 - Mechanical Equipment and Physical Plant (3% of equipment cost)
 - Electrical Equipment.

Instrumentation, and Piping (22% of equipment cost) Total Labor and Maintenance Cost: 'TOTAL OPERATION AND MAINTENANCE (COST PER 1000 GALLONS): Cost in 7M 2032 039 042 son 092 oe 25 mc 024 039 008 1049 at TABLE VII-3 POWER CONSUMPTION FOR A 25 MGD

FACILITY are De-gritting and Pre-screening Feed Pumping 45 ft. head Chemical Makeup and Delivery Flocculator Chain Mixing Magnetic Filters Compressors Dewatering System Control Instrumentation and Bldg. Service Miscellaneous Total: so Energy Consumed in kWh 3 mp 8.2 40.0 26 9.0 35.0 12.0 25 MGD, 18.7 200.0 65 39.0 60.0 45.0 42.0 23.0 30.0 464.0

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 Storage Parameters Pumping Head for Feed Pumps 1 Pre-screening size Design Valve 84 in (214 cm) 6 in (15 cm) 0.3k yg 125 gpa/te" 8 (6800 gpm) /min 3 25 wep (1.1 m/sec) 5 MGD (,22 > sec) 5.7'9ø0 (25 9 feet) 100 g/t 500 gpm/ft² (73 m³/min) (39,300 gpm) 8s 3 2600 gal (20 n³) 10 psi 20 gpm/ft² (2.9 m/min) 100 g/t 200 mg/l 1.0 mg/l 2 mg/l 6 days at peak flows 30 days at dry weather flow 45 ft. (33 psi) 20 mesh (.84 mm)

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

Table VIII-4 gives the parameter values used in obtaining magnetic Filter and operational cost estimates for a 25 MGD facility. These values were

The text has been corrected as follows:

The selection was based on experimental data, prior experience in the field, flow requirements, and equipment design limitations. A combined wet and dry weather flow treatment plant inherently has a large reserve capacity that remains unused for a major portion of the year. For the 25 MGD peak flow system in question, it was arbitrarily assumed that during the course of a year there would be 30 storms producing a 25 MGD flow for an average of 10 hours each, or a total of 300 hours of CSO at a 25 MGD throughput rate, compared to 8460 hours of dry weather flow at 5 MGD. 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 consequence, 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 flow sheets presented in the past (i.e., the Mobile Pilot Plant Transfer 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 large alum residence tank. The floc chain, consisting of an alum residence tank, two 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 shown 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 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.

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 hydro tanks 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 automated. A bypass system has been included for emergency situations.