CEER-C-027

CHR 7

wn

AN ASSESSMENT OF MAGNETIC FILTRATION:

ANEW APPROACH TO PUERTO RICO'S

EFFLUENT POLLUTION PROBLEMS

Report of a Select Panel

?San Juan, Puerto Rico

March 21-28, 1979

Coordinator: Dr. Ugur Ortabasi

2 CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

BPN nivenrny oF puenro nico US DEPARTMENT OF ENERGY

é

---Page Break---

CEER -C-27

AN ASSESSMENT OF MAGNETIC FILTRATION:

?ANEW APPROACH TO PUERTO RICO'S

EFFLUENT POLLUTION PROBLEMS

Report of a Select Panel

?San Juan, Puerto Rico

March 21-28, 1978

Coordinator: Dr. Ugur Ortabasi

CENTER FOR ENERGY AND ENVIRONMENT RESEARCH

---Page Break---

Section

1

. u

MI

wv

Wr

vit

?__________________pistitation-industry-kaste Treat:

?CONTENTS,

16

v

18

20-31

2-23

2-27

24 - 25

25 - 26

26 - 27

28-37

29 - 30

32

- 3

7

---Page Break---

vir

IK

XI

CONTENTS (Cont..)

---Page Break---

Figure

LIST OF FIGURES

Title

---Page Break---

LIST OF TABLES

High Gradient Magnetic Separation and

Filtration Applications

Results of HGMF Laboratory Test Performed

at Sala Magnetics Inc., Cambridge, Mass.

Results of HGMF of Mosto Obtained by Sala

Magnetics Inc., Cambridge, Mass.

HGMF Results of Raw Sewage from Puerto Rico

Obtained by Sala Magnetics Inc.

HGMF Results on Mosto from Puerto Rico

Obtained by Sala Magnetics Inc.

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.

wv

B

ct

34

5

36

4B

---Page Break---

LIST OF PARTICIPANTS

+ Members of ?the Select Pane}

Dr, Arthur NeB. Block

Scientist II

Center for Energy and Environment Research

Terrestrial Ecology Division

Caparra Heights Station

San duan, Puerto Rico 00935

Eng. Rafael Cruz Pérez

President,

Environmental Engineering Consultant

Violeta No. 153

Urb. San Francisco

Rio Piedras, Puerto Rico 00927

Eng. John R. Harland

Seton, Johnson and Odell, Inc.

317 S. W. Alder St.

Portiand, OR. 97208

Dr. John A. Oberteuffer

Vice-President,

Sala Magnetics, Inc.

247 Third Street

Cambridge, MA. 02142

Ms. Marfa Beatriz Riesco

Scientist I

Center for Energy and Environment Research

Solar Division

Caparra Heights Station

San Juan, Puerto Rico 00935

Dr. James H. P. Watson

Sr. Res. Fellow

Dept. of Pure and Applied Physics

University of Salford

Salford, United kingdom

Contributors

Prof. Ralph A. Mitchell

Division of Applied Sciences

Harvard University

Canbridge, Massachusetts 02138

Dr. Jorge Santiago

Department of Physics

University of Puerto Rico

Rfo Piedras, Puerto Rico 00931

---Page Break---

EXECUTIVE SUMMARY

This report addressing the value of high gradient magnetic filtra- ?tion to Puerto Rico's effluent pollution problems is the outcome of intense discussion anong CER personnel and a select panel. This panel consisted of experts from Puerto Rico, the United States and the United Kingdom as- senbled 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. In- ccreased population pressures are expected to aggravate the problem of pollution control.

[At several locations on the island, hazardous water pollutants from industry, municipalities and comunities 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 1s 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,

---Page Break---

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 meth~ ods 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 systenatic study of its application to a particular effluent is imperative. Research, development and pilot demonstration must be carried out prior to any success~ ful implementation of the system. The Center for Energy and Environment Research has already initiated a comprehensive HGF 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 organiza- tions and industries which have an interest in finding solutions to Puerto

Rico's waste effluent problens.

---Page Break---

Section T

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 (00) requirenents 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 problens in the island are distributed in such away, that. it is 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,

nd 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 isTand

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 vol-lune 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 1ife-style of Puerto Rico's 3.2 million inhabitants. .

---Page Break---

?Mt many locations on the island, hazardous water pollutants from industry, municipalities and conmunities are discharged to the environment. with Tittle or no treatment. In the past, a great nunber of community acti-vities 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 Denand (B00) in most water bodies. A ?Significant amount of pollution is traeceable to agriculture, mining, con-struction and other activities associated with poor erosion control practices. The eutrophication of lakes and reservoirs is the direct result of the in-troduction 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 managenent 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 requirenents by 1985.

Law #142, of May Ist 1950, provides the legal basis for a Nater Pollution Contro} 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 Tegal powers were transferred to the Puerto Rico Environmental Quality Board (EQ) 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 adninistered by the U. S. Environmental Protection Agency

(EPA) with the concurrence of £98 (1).

---Page Break---

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 80D and Total Suspended Solids (TSS) Toad include: anaerobic contact processes, a sequential combination of anaerobic followed by aerobic treatment; evaporation; and direct Jand application. In each case, ultimate disposal of the concentrated sludge residue remains as 2 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% renoval consid~ ?ered achievable in most cases. Color and odor characteristics of the final products are acceptable, although 1f the anaerobic process is carried out ?in lagoons in contact with the atnosphere, offensive odors may be produced. For either process to remain energy efficient and not incur exorbitant opera ting costs, final aeration of wastes has generally involved Tagooning which may impose unusual land space requirenents on the process.

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

capital and operating costs.

---Page Break---

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 sone applications, the sofl 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 requirenents may be necessary. Evaporation is generally not cost effective for concentrating waste waters to a solid. Solar evapora-?tion ponds may be used but a 5 day to 1 week holdup period may introduce a problem of unusual land area requirenents.

Connection of waste stream conduits to sewer lines for municipal

treatment can only be used for low strength wastes. Unless specific agre-

ements with Tocal treatment authorities, pre-treatment of high strength

wastes is required by U. S. EPA regulations. Table 1 summarizes sone observa-

?tions 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 @ new magnetic filtration technology, high gradient

magnetic filtration, has been developed to remove micron size particles from

a 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

ate

---Page Break---

TABLE 1

?Treatment ?Technologies ag Currently ?Practiced

Treatment Technology Comments

Anaerobic Contact. Re-aeration of discharge required ;

large investment for high BOD re-

: nnoval.

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 Tong

Sewerage lines are needed. Large,

managed crop land area required.

Evaporation Sludge transport and disposal

: management more urgent. Can be

energy intensive. Can necessitate

Jong hold up times.

---Page Break---

nagnetic separation techniques are ineffective. This capability is the re-
sult of the development of a filamentary ferromagnetic matrix and a large
volume, high-field magnet. The conbination of an efficient magnet and high
sradient 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 (gpn/#t?)

Large scale industrial applications of this technology already
exist for wastewater treatment in steel miTls and steam condensate treat
went in paper miT1s. Munerous large installations also exist in the clay
?industry for the separation of fine impurities from clay slurries.

For normally normagnet ic colloidal material in polluted water,

the addition of magnetic tron oxide powder (magnetite) along with a coagulant

can form a conbined particle sufficiently magnetic to be renoved by high

gradient magnetic filters. The machines provide a rapid filtratfon of many

pollutants fron 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 mag

netic fiTtraton with fron powder seeding is under active development in se

veral countries. Applications include treating combined stom and sever

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 stinulated research

efforts in of} refining, air filtration and the filtration of waters from

nuclear power plants (8) at various companies and research centers through-

out the world. In the light of severe environmental problens associated

---Page Break---

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.

oa

---Page Break---

Section I1

PRINCIPLES OF MAGNETIC FILTRATION

Phystes of the Capture Process (9,10)

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 Hquids, an advantage in sone 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 the magnetic and drag forces, @

---Page Break---

great simplification of equations of predictive value can be achieved by the introduction of a quantity called the magnetic velocity Vy, (11). For fer= ronagnetic particles in a low magnetic field Hy» Vq 1S given by

pH?

Vy = 4/3) wba ee eee

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

is the radius of the wire, and, = 47x 1077

?Tis the viscosity of the fluid,

henry/meter. The magnetic velocity V, 1s very important because if the slurry enters the separator at a velocity equal to the magnetic velocity, the separa- tion is extremely effective,

For exemple, if the wires have a radtus of S0jum,if the particles have a radius of 2jm and if the magnetic Field Hy = 1.59 x 10° (A/m) (2000 gauss) then V,, = 3.4 cm/sec. If the fluid enters the separator at a velocity of 3.6 cn/ sec, the separation will be extrenely effective. If the particles have @ radius of 44m then Vy = 30.6 cm/sec. These are roughly the velocities at which it has been found possible to treat steel mill effluent water, that is approximately 100-350 gal/minstt?.

Im this low field region there 1s Tittle to be gained by using @ higher Field as the processing velocity and power consumption both increase with the square of the field so that the power per unit volune of processed slurry 1s constant. However, additional field requires a qreater anount of fron in the magnet circuit which increases the capital cost per unit volune of slurry processed.

Experimental observations have shown that as the material captured on tile wire builds up,tong strings of captured particles grow away fron the

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

---Page Break---

consequently, Tittle loss of performance 4s noticed for a wire, as the captured material accumslates. Beyond a certain length of particle string further ?roth is not possible due to the Fluid drag. When this point 1s reached,

the separating capacity of the wire drops abruptly. In practice, the filter 4s backflushed well before this occurs.

?The wires in a separator are assembled in a matrix and placed into ?canister through which the slurry is passed, as shown in Figure 1. When the interaction between the wires and the particles {s strong, the separator 4115 up from the front and the feed part of the cycle ends before breakthrough of particles occurs. If a cyclic process, the Field is? switched off at this point and the captured partictes can be removed from the system by Flushing the canister with air, with an air-water mixture, 2 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 tines their on volune of mater?al. ?This means that a Toaded filter will contain about 20% by volume of captured particles.

The processing rate is given by

were Vp is the slurry velocity (approximately Yq), A fs the cross sectional area of the separator and O 1s the duty factor. The duty factor 1s given by

?D = Feed Time/ (Feed time + Dead time)

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

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

netics. For effictent operation the feed tine must be much greater than the

dead time.

10°

---Page Break---

FIGURE =

High Gradient Magnetic Separation Filter

Showing Section of Matrix Wire

ele

---Page Break---

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-

8000 gpm of feed, consuming no more than 25 kW of electric power. Solids renoval is typically 758-95 depending on the particle characteristics, the flow rate per unit area and the magnetic field strength. The machine weight is approximately 70,000 1b. 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 (HGHF]

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 conpose 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-Tiquid 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 nigh gradient magnetic filtration applicable to a wide variety of liquid filtration problens.

High gradient magnetic filters include both cyclic and fully con~

tinuous 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

---Page Break---

?ranue 2

SPBCIPICATIONS OF TYPICAL HONE SYSTENG

os COOLING Ws

IMs TONS, svsrac | warnrx PRESSOR | POWER

WOR Levin? TFG) © wero | aman | ranoucupur | voumns| Dror | neor

(inches) (abs) (#2) | nance (gpa) (gpm) |_tpst) | eacxvay

162_| 206 | 126 | 170,000 27 _| s,900-19,680 | 9.2 | 54 75,

x20 [tay | 32. 70,000 37.8 | 2,900- 9,670 | 6.8 | $6 55.5

2 [ua sa_| 48,000 19.2 | 1,580- 5,130 0 | 26 42.5

no 69 38,000 9.3 | 720- 2,400 4.3 | 22 35.5)

so_| 75. 65 9,000 4.7_ | 360- 1,200 3.5 | 36 26

aw | es | 6 5,900 2 200-670) 2.6 | 2 20

33 | 52 72 2,000 0.83 | 190-300 2.3 | 30 16

2 | a 38 750 0.06. s-18 a2 | 40 9.4

Height measured flange to flange

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

field strength of 5 kélogaus

?To estinate fitter velocity, divide desired throughput rate by matrix area.

oo

---Page Break---

continuously moving through the magnet for loading and for subsequent flushing may be used. In either design fiTanentary 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 Tow 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 smalT space requirenents.

elt

---Page Break---

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 dis-solved 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 sone means to associate the magnetic particles with the

non-magnetic or dissolved impurity.

Magnetic Seed

The magnetic seed material is generally magnetite,Fe,0,, 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 Tess 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

Coprecipitation

Adsorption: In the adsorptive mode magnetite adsorbs the non-magnetic particle or dissolved fon on to-its surface or alternatively magnetite ray 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 im-

purity.

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: Coprecipttation of certain dissolved materials

and ons to produce insoTuble compounds 1s a third means of effecting associa

tion. The coprecipitation generaTly involves a change in pH to create parti

cvlates sufficiently magnetic to be filtered directly in a high gradtent mag-

netic filter. In addition to coprecipitation, dissolved materials (organic

---Page Break---

?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 1s well known.

Indeed, it appears that even the small natural layer of hydroxide existing in naturally occuring fron oxides in boiler water can adsorb calcium and mmagnesiun 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 extention of these methods to dissolved material renoval 1s 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.

Aoplication Procedure

In practice, the seeding procedure 1s relatively straight-forvard.

A generalized procedure witl allow for pit adjustment of the influent to optimize coagulation. The next steps are the addition of an inorgante 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 stow speed agitation. The detention tine for

Alocculation 1s 2-4 minutes. The flocculator overflow passes directly to

?the high gradient magnetic filter, The operation of the Filter 4s similar

to that for direct magnetic Filtration. The sludge 4s backflushed either

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

?Us

---Page Break---

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 iimegiate disposal are alternatives. In nost applications

ragnetic seed usage is of the same magnetude as that of the alun and does

not require recovery. Indeed allowing the magnetite to renain with the

sludge can enhance the density and further treatability of the sludge.

ed 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 {s similar to the currently preferred process for alun recovery. Magnetic stripping involves a solid-sotid separation in a second high gradient magnetic separator. Incineration involves burn-off of organic material to recover the regenerated seed. Washing at different pit's nay be appropriate for certain applications where impurity disposal and/or

sludge dewatering is not a problen.

---Page Break---

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 tine.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 sumarized in Table 3.

In the water treatment applications the largest industrial units are employed for the filtration of steel mil] process water, At Kawasaki Steel in Japan a 2 meter diameter device filters 4000 gpm of water from a gas scrubber. The system requires only a small space in the plant, uses Tow power (50 kN), 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,nore recently,

fn Sweden on a larger scale. The denonstration plant in Sweden mounted in

an 8 by 25 Ft. container includes chemical dosing, flocculating equipment

high gradient magnetic filter and e small backflush settling tank. This

system has a capacity of 250 gpm and has been demonstrated for tertiary and

secondary-tertiary sewage treatment.

---Page Break---

ante 3

cation and Filtration ipolications

State oF Full scale

Skeord] RatER | ae] tm] meme]

Application Operating Planned

rere Sm

a np fo fe lems

es re ee

?Steel Mill Japan, USA,

cam ~ |» | « [[@

ni eo

oe

er ype) Tee

Ba

vert 7 f* |e

? | ® [gam

Bs

?Storm Water*

oan x | fm

?eer ain

aa x | [eve

Coal Desul furization| x UA

Ta it a

Virus Removal* x ?USA

Process in which magnetite seoding 1s used.

---Page Break---

---Page Break---

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, anong other factors, the relative concentration of the waste to be treated, the flow rate of waste, and other site-specific conditions. The most thorough econonic analysis of the process published in the Titerature is for a 25 million gallon per day (mgd) plant for treatment of conbined 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 er 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 Toss). Conbining 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 mostos from an

averaged sized distillery will cost more than the values estimated for the

2200

---Page Break---

25 mgd plant. However, a superficial analysis of the major cost components,

such as chenical costs which will renain approxinately 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 neces-

sarily reflect the cost to treat water with a plant designed specifically for lower

?throughput rates.

---Page Break---

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 problens associated with their effluents.

Nore detailed information can be obtained from the studies conducted by E98

under the 208 programs (13).

Point Source

Pharmaceuticals ~ High B00, COD, Yow 00, and high organics. High amounts of rinsing water and biologically active components. Treatment lagoons, sludge incineration and chentcal treatment are commonly used in these industries.

Chenical_ Industries - High B00, COD, Tow 00 and toxte components. High anounts of cooling water are comon in this type of industry. Diverse conbinations of treatment are found.

Distillers - Extremely high 80D, suspended solids, biologically active components and significant coloration characterize these effluents. Except for land disposal in one case, no treatnent

4s given to these wastes at present.

Brower

~ High 800, suspended solids, biologically active com ponents and high turbidity characterize these effluents.

Food Processing - High 800, residual proteins, ofts, solids and odors are the typical waste from these industries.

Sugar Industries - High 800, solids, organics, coloration and odors are the characteristics of these wastes. Treatnent consists of

oxidation and sedimentation lagoons. At best treatment is not

=2he

---Page Break---

complete.

Petrochemicals

High COD, 1ow 00, solids, of1, 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 treatnent are very similar to the ones associated with petrochemical industries.

Textiles - The main problen associated with the textile industries in the island is the coloration of the waste streams. Main treat- ment, when any is 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, Tead,zinc, copper, ete, and some toxic agents such as cyanide and acid leachate. Treatment consists of pH adjustments, some chenical absorption,

or principally ?terminal disposition of wastewaters into the nearest stream or sewer.

PR, Aqueducts and s

Sewage ~ Public treatment plants in Puerto Rico handle primarily

Authority

donestic wastes. However, the wastes include also a significant fraction of wastes fron industries and comercial establishnents. A significant nunber of treatment plants offer inadequate treat-nent to the wastes.

Stom Sewers. - Storm Sewers and conbined sanitary - storm sewers Present speciat pollution problems in Puerto Rico. Storm sewers

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

---Page Break---

ilegal sewerage Tine connections, untreated sanitary wastes as

well. Conbined sewers then discharge without treatment, both

street runoff and pollution wastes.

Area Sources.

Agricultural Mastes - 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

Jeachate. Very little control or treatnent is associated with

these activities.

Construction run-off

?The main problem associated with the construction industry

is the Tack of erosion control.During construction, sediment Taden

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 acti-

vities. In a few isolated cases, some controls such as sedimenta-

?tion Tagoons are used.

Urban run-off

High solids and coliform counts are assoctated 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 tine has elapsed, potTutants tend to decline in concentrations.

Rural Communities

These sources were, up until very recently, not considered

---Page Break---

as significant sources of pollutants. Recent studfes have Provided data indicating that sedinents and organic pollutants ?in significant anounts are generated by these communities, with-out any contro! or treatment given to these wastes.

Water Supplies

Small quantities of potentiatly toxic materials, are not re-moved 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 conposed of 4 variety of products, ranging from exotic chemicals to viruses: not a11 are removed by treatment. After these waters are used,

evaporation can concentrate the pollutants in the waste stream,

---Page Break---

Section VIT

?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 1s known as ?nosto". Analyses of typical mosto samples indicate B00's of about 33,000 ng/1 and TSS of about 18,000 mg/1, pl frah 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 anounts 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.

Destilerfa Serralies in Ponce, P. R., mixes its mosto with its ovn 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.

---Page Break---

Environmental Protection Agency Regulations

?The U. S. Environmental Protection Agency (EPA) has promulgated

regulations ained 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 wil1 be unaccentable by 1985, Conse~ quently, concentrated sTudge separation from aqueous wastes wil1 be neces

sary, 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, accomodated ?n sanitary land-fiT1s, or conposted and used for agricultural purposes. Generally, in the latter case, Timing must be carried out to limit heavy metal uptake from the sludge into the agricultural produce. In the case of aqueous wastes with high 800, pre-treatment reduction may be denanded by municipaT 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 whch this compliance tine 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 programed 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,

---Page Break---

?must remove from the discharge any pollutant that is not present in the re~

ceiving water body.

Distillation Industry Waste Treatment in Puerto Rico

Distilling industries in Puerto Rico have been obliged to face the

problem of high B0D in their waste-mosto. 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 contro! equipment and there are reasons to believe that even those treatment systems considered and proposed by Severat distiT1ing companies to EPA will not bring them into the NPDES compliance. For these industries, in particular, zero discharge would appear to be an extrenely difficult goal to meet.

Convento

?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, reduction of datly average BOD Toad by 90%, and daily average TSS 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 land application. It 1s unlikely that conventional anaerobic treatment alone would be able to treat mosto sufficiently to achieve the reduction in 800 required since typical 800 renoval in this step is only about 802. Aerobie Tagoon treatment atone would probably not be practical because the high oxygen denand of mosto could not be transferred by the most effictent surface aerators.

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

---Page Break---

flow rate of 300,000 gallons of mosto per day (200 gat.

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 Tbs 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 requirenents 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 Targe sludge dumping areas, disposal ?management systens and @ large primary holding area.

Direct land application is already in use by one distilTing company, apparently meeting the NPDES criteria. Land application may be a viable short term solution provided that the distillery is located near a sufficiently Jarge area of agricultural land. Monitoring both salt build-up in sotis and possible perfusion to aquifers must be undertaken for this alternative to be considered for routine disposal. Long sewerage Vines with accompanying maintenance problems and control of sewerage Tine right-of-way can make this method - unfeasible in Puerto Rico. Finally, land application requires a

year-round conmitnent to uninterrupted irriaation.

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

---Page Break---

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

Tt seons to us that there is a growing body of evidence indicat ing that a.new technique or an original approach could yield the answer to the

Problen of land area and operating expense without an inordinate capital investment. At present, technologies available for the control of this Problen are not going to provide a final solutton compatible with the ?environmental and economic needs of the Island. Me feel that provision of necessary additional time needed to evaluate promising magnetic filtration technology would benefit both the natural and economic anbient 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 Tov-nutrient, high BOD wastes produced as by-products of the rum distil1ing

industry.

Licability of High Gradient Magnetic Filtration to Nostos Treatment,

The applicability of high gradient magnetic filtration to the mostos Problem 4s 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, 80D, color, bacteria and other criterfa substances. Second, in tests carried out by Sala Magnetics and the University of Salford on mostos samples, total suspended sol44 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

---Page Break---

sumarized 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 80D they are similar in many respects to waste and polluted waters successfully treated by magnetite seeded-high aradient 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 BOD reduction was obtained. However in a later more extensive effort for the CEER more appropriate coagula- ?tion and flocculation conditions were used.

In laboratory tests carried out to determine treatability of an

unknown effluent, the possible range of experimental conditions--coagulant type and concentration, magnetite seed concentraton, polymer type and con~ centration, and flocculation type--is very broad. Although some general ex- Perimental methodology to determine appropriate conditions has been develop- ed, these efforts remain largely a trial and error procedure which may require considerable time, particularly if the range of appropriate conditions with in the parameters available is relatively narrow, as it often is for more difficult effluent streams such as mostos. Given this reality, it is under- standable why preliminary tests yielded no positive results but later, more extensive trials, showed several promising combinations. A sampling of re- sults from the Sala Magnetics tests is shown in Table 6. The chemical

---Page Break---

mane 4

[RESULTS OF GM LABORATORY TESTS PERFORED

[AE SALA YAGNETICS INC., CAMBRIDGE, MASS.

Renova,

water Type

Raebaaey BoP

?Suspended oF or

solids. color ?coo.

sewage o 60-75

(eurbsaity) (coo)

Combined stor Fa 93 90-98

and sewage. (earbtaiey) (coo)

Paper i21

Geration stabsai~ 9 9 a

zation Basin) (eurbiaity) (coo)

Spent Beer 8 7

(earbiaity) =

Surface Water

' 99 99 ~

---Page Break---

"21 "ox vous20303 905 ay

ssoreuyasox90un oxe sozh$y3 TeAowes

1apes0d Sag

1m (G21) WoFANTED arenbopeuy Ee osesnIa" you sy uNoUs SaoU poody

16 40 BUFTOKD PoeTTEGeas snonuyrUog/eTDK> oauT eDInUs= y PUL { UsoRIeq paID?TTOD

SeTaES

1/8 9-2 :*3u09 92ktoaa>9TeKT0a

era

vrs of 1/30 Oot $3003 EMTY

ee rue 34/0 95 2427907 MOTE

ye 02% +2409 sapaaUtEK a 9°T HpTota 9y30u8eK

?SROTITONOD ISar

HEEM16< 1B8°66-£9"66 196 "66-99°66 ?_?2596-Z°S6ZL"E6-B°15 ZT"66-0°86 suey

be 28°66 1258°66 26°96 9°26 86 asexony

aoe z

OLS OT * Z-2-04"0 OTe uss v6-1y 230g

o @ 6 ov ® (s28a4_ 30 4)

O98 oR TT yor es 8 or ?eaexony

(uny_snonuy3u09)

SHIGE CSLVRRL

HB-SLe JOT X OL-T'S JOT X O°S-U'Z OZ - 00Z 008 - 009 Ors - OOy atuey

@ @ o © © © (s2801 30 9)

(étwo ardues 1)

fle wrx e9 tx oe ocz os 099 ?woviaAY Gal

Oor/stt99) (T= oor/s1199) (oa) «ya

?4031109, waa 109 (away 30109 sarios superse

WuoL "wou KITGTeIn. = INWVaaY aaONaasOS No aaLD3TI00 059

Now G¥ZIRIL40 :4AVId LOTTA snooNTINOD "STE

2352

---Page Break---

Results of HGH of mostos by Sala Magnetics

as affected by test conaitions

Test Conditions: malts

pa] atu Por E Deseription ?Suspended

(os/). Solids Reduction

3.8] 1000 | mete 1120 - 100 m/1| no ftoce not measured

7.2] $000 | Bets 1160 - 2500mg/1| anal flocs ?not measured

7.0 | 5000 | Hexcoftoc #18

250m9/1 no flocs not measured

4.0 | S000 | Hercofiec 249

2500/1 large flocs mm

Betz 1120 - 100ng/1

---Page Break---

concentrations are clearly not optimized but the reduction of suspended solids

{in one trial gives a good indication of the feasibiTity of the approach. The

tests at Sala are supported by the earlier tests carried out at the Univer~

sity of Salford,

376

---Page Break---

Section VIIT

CER EFFORTS IN THE FIELD OF HGMF

Work Objectives and Scope of the HGHF Program

High Gradient Magnetic Filtration 1s 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 systen, the water quality of most of then appears to benefit from ?the magnetic fiTtration 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 enphasis on the needs
of the people of Puerto Rico, the Puerto Rican Govern
ment and industry in general.
To help to provide specific HGMF system designs for
denonstration plant applications.

+ To test and help monitor the demonstration plants.

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

= To make specific recomendations to government and in-
dustry.

HGMF Program Outline

?The HGMF program at the CER 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

---Page Break---

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 stabiTity.

= pi 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 sludges.

- Thickening and dehydration methods.

= Seed recovery.

= Ultimate disposal.

4) Demonstration or Testing

= System automation advantages testing.

= System design.

= Systen 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 tine schedule and

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

wiTl require substantial economfe support from the local and federal govern

nent 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 run slops containing 0.09% mercuric

chloride as a preservative were received. The surface chemistry of the sus~

pended particles was examined. It was found that at the mostos pli = 4.6 the

particles were close to the zero point of charge. With addition of HCT the

DH was adjusted to 4 and the particles became s1ightly positive. With @

further adjustment to pli = 3, the mobility of the particles wes measured as

5 um/sec/volt which is @ Tow value, indicating @ small positive surface charge. Using potassium hydroxide, the pt was increased to 7 where the parti-les have a weak negative surface charge. The seed having a strong positive charge would therefore be effective at piH= 7, Since the particle surface charge 1s not a strong function of pit it was concluded that the systen 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 pl = 4.6, it must be added to the mostos with a cationic Flocculant in Tow concentration. Another possibility is to pre-coat the seed with a suspected Took-alike polymer, before magnetic separation.

?An 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

---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 89.08,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 Tower 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 KjeldahI nitrogen on untreated and treated samples of pharmaceutical waste showed @ reduction of 62.3%, When analysing the data given above, it should be kept in mind that these nunbers 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 pro-

blens of Puerto Rico.

atl

---Page Break---

Figure 3

Comparative Graph of Light Absorbance in Untreated Mosto

(M) ond Magnetically Filtered Mosto (MMF)

a

700

"| 650

ry 00

550

3 500

450

2 400

ing dition

\ factor E16

Sept 28, 1978

400 500 600 700

Wove Leno [WM]

ze

---Page Break---

TABLE 7

HMGF Results on Raw Sewage fron Puerto Rico obtained by

Sala Magnetics, Inc., Cambridge, Mass.

CONDITIONS

Alun + 140 mg/1

Magnetite 200 mg/t

Polyelectrolyte Hercofloc 831, 0.5 mg/1

Magnetic Field + 2KG

Flow Velocity 82 gpm/ee?

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/t

Magnetically filtered POAT mg/t

Reduction in Concentration

of Suspended Solids 91S

Analysis of Suspended Solids in run #2 in:

Feed : 166 mg/t

Magnetically filtered 2 12.7mg/1

Reduction in Concentration

of Suspended Solids 92.38

---Page Break---

TABLE 8

HQE Results on mostos from Puerto Rico obtained

by Sala Magnetics Inc., Cambridge, Mass.

CONDITIONS

Alun bo

Magnetite 5 s/t

Polyelectrolyte + Hercofloc 849; 250 mg/1

Betz 1120, 100 mg/1

Magnetic Fied] 2S 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 in:

Feed 7415 mg/t

Magnetically Filtered + 2050 mg/t

Reduction in Concentration

of Suspended Solids 2 728

---Page Break---

TABLE 9

HQ Results on Spent Beer from Puerto Rico obtained by

Sala Magnetics, Inc., Cambridge, Mass.

conprT¥0

Alun 2 200 mg/1

Magnetite 20 8/1

Polyelectrolyte : Hercofloc 831; 50 mg/t

Magnetic Field 2 KG

82 gpn/#t2 (initial)

4 minutes

Flow Velocity

Residence mixing

Matrix : expanded metal with 45 mil

spacers

Sample volume 250 mi

RESULTS

Analysis of Suspended Solids in

Feed 29.3 g/t

Magnetically Filtered 2 3.1 8/1

Reduction in Concentration

of Suspended Solids 2 898

=A5=

---Page Break---

Absorbonce

Comparative Graph of Ligth Absorbance in Untreated

Pharmaceutical Waste (UPW) and Magnetically Filtered

Pharmaceutical Waste (MTPW)

Aurew

1.208

leer

ese

isa

isn

sor

ier

acted Using

12-1979

Wove Length [NM]

62

---Page Break---

Mobile Magnetic Filtration Tratler

Magnetic filtration is @ 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 informatiori gap from bench test to full demonstration plants CER 1s planning the use of a small capacity (10gpm) 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 statfoned at selected sites of discharges in Puerto Rico for a perfod of fone week. During the testing period varfous parameters each, including seed, polyelectrolyte concentration, matrix loading, residence times, magnetic field

and flow rates will be changed to assign effectiveness of filtration par

meters to each type of waste. Influent and effluent will be analyzed continuously with respect to suspended solids, pl, apparent color, turbidity, settleable solids, 80D, CO coliform bacteria and heavy metals. The data obtained from this trailer will then be utilized to develop the criteria for the applicability of HGMF to treat industrial waste streams surveyed, to form the basis for pilot plant design studies and to chart future research and development directions.

---Page Break---

Section 1X

CoNcLUSTONS.

?The High Gradient Magnetic Filtration is a new technology to treat industrial, domestic and commercial waste effluents. Data from presently operating and full scale HSMF 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 sone of the conventional methods.

Im particular this Panel concludes that HGNF is potentially a cost effective and practical nethod to treat mostos. It should be stated however, that a rigorous research development and denonstrat ion program must be assenbled to implonent this method successfully.

The Center for Eneray and Environment Research has already initiated the First phase of this program and has denonstrated the feasibility of nostos treatment on a bench scale. For a full scale development: of the progran other resources from the goverment and industry will have to be allocated.

HOME can be developed into a powerful new method that will permit a

Targe fraction of the industries {n Puerto Rico to comply with the zero dis~

charge EPA regulations by 1985.

---Page Break---

5.

10,

un.

1,

REFERENCES

Environmental Quality Board; Environnental Reports 1971 ~ 753

(Several Reports).

Environmental Quality Board; final report (draft October 1978)

Project 208 Island-wide; October 1978,

Environmental Quality Board; Industrial Sources and Municipal or Privately Owned Sewage Treatment, Decenber 1977.

Environmental Quality Board; preliminary report (unpublished)

Project 208 metro, December 197

U. S. Environmental Protection Agency, 1978. Design Seminar Handout: Sludge Treatment and Disposal. U. S. EPA Technology Transfer Document. U. S. EPA Research Lab. Cincinnati, Ohio.

U, S. Environmental Protection Agency, 1978. Design Seminar Handout: Small Wastewater Treatment Facilities. U.S. EPA Technology Transfer Document. U.S. EPA Environmental Research Information Center, Cincinnati, Ohio.

R. Pérez-Escolar "Reclamation of a Saline-Sodic Soil by Use of Molasses and Distillery Stops". J. Agr. Univ. Puerto Rico 50, 209 (1966).

"Study of Magnetic Filtration Applicatfons of the primary and secondary systems? of P. R." EPRI NP-514 TPS-76-665, Final Report, May 1978

J. He P. Watson *?

jagnetic Filtration", J. Appl. Phys. 4444209 (1973)

J. H. P. Watson "Capture of Particles in Magnetic Separation? IEEE.
Trans. Magns MAG - 11,1597 (1975).

J. He P. Watson "Approximate solutions of the Magnetic separated
equit ions" IEEE Trans. Magns MAG - 14,240 (1978)

Treatment of Combined Sewer Overflow by High Gradient Magnetic Separa-
tion, EPA - 600 12-77-015, March 1977.

2492

---Page Break---

13. Water Resource Research Institute, School of Engineering
University of Puerto Rico Industrial Pollution Control
Substudy, North Metro 208; November 197.

---Page Break---

[APPENDIX A

The data generated in this and previous of seeded water treatment.

have provided considerable information useful in the formulation of design and size presented the estimated capital, operation and maintenance-related costs for @ 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 out-Vined 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 NGD conbined wet and dry weether flow treatment plant are summarized by sub-syston in Table VII-1, The total es-timated capital cost for this seeded water treatment systen is just under 5.2 milTion dollars. Not included in the capital cost estimates are systens for seed recycling and alum recovery. These systems are contemplated for a fullscale facttity, but at this time too Tittle process information is avail able for a detemination 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 vartous 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 es-

timated because of its site-specific nature.

---Page Break---

TABLE VII-1 CAPITAL COST ESTIMATES FOR A HIGH GRADIENT MAGNETIC FILTER BASED

25 MCD CSO/SERAGE TREATMENT FACILITY.

ea

Estimated Installed Cost

De-gritting and Pre-screening $ 394,900

Feed Pumping 297,600

Flocculation Train ¥ Chesfcal Feed 510,500

High Gradient Magnetic Filters 990,000

Back#lusing 441,300

Filter Piping and Valving 327,600

Thickening and Dewatering 265,600

Disinfection 86,900

Flectrical 337,100

?Automatic Process Control & Monitoring 258,700

Physical Plant Construction 490,000

Subtotal: $4,100,000

Construction Contingency 10% 410,000

Subtotal: $4,500,000

Engineering and Adainistration 15% 677,000

TOTAL ESTIMATED CosTs: $5,187,000

Pert 2

A breakdow of the subsysten conponents on which the above cost

nates were made is given below.

Dexgritting and Provscreening System

+ influent flow meter (Parshall fl0me)

rotary wedge wire screens (6)

entry pipe to plant

bypass piping and valving;

1 concrete troughs and pits;

1 influent flow distributors

+ conveyor systen; and

{grit hopper.

---Page Break---

TABLE VII-1 CAPITAL COST ESTIMATES FOR A HIGH GRADIENT MAGNETIC FILTER BASED

25 MCD ?S0/SEKAGE TREATMENT FACILITY,

Pare 1

Subsysten Hatinated Installed coat

Devgritting and Pre-screening $394,900

Feed Pumping 297,600

Floceulation Train ¥ Cheaical Food 310,500

igh Gradient Magnetic Filters 990,000

Backflusing 141,300

Filter Piping and Valving 327,400

?Thickening and De-vatering 265,600

Disinfection 86,900

Blectrical 337,100

Automatic Process Control & Monitoring 258,700

Physical Plant Construction 490,000

Subeotal: $4,100,000

Construction Contingency 10% 410,000

Subtotal: $4,500,000

Engineering and Administration 15% 677,000,

?TOTAL ESTDUTED costs

$5,187,000

ee 2

A breakdown of the subsysten components on which the above cost

?estinates were made is given below.

Decgritting and Pre-screening Systes

influent flow meter (Parshall flume);

coarse bar screens

rotary wedge wire screens (6)3

entry pipe to plant;

bypass piping and valving;

concrete troughs and pit

influent flow distributors;

conveyor system; and

grit hopper. 520

---Page Break---

2 (continued)

Food Funping Systen

variable speed pumps;

Single speed pumps;

Piping for feed flow; and

2 support. Franes;

2 sump well.

+ Hoceulators (3)5

I fash mixers (6)

static mixer (3);

lun storage and delivery system;

polyelectrolyte make-up and delivery system;

2 magnetite slurry and delivery system; and

{support structures.

Magnetic Fil:

+ High gradient magnetic filters (5)¢

1 Power? supplies

2 Indizece! cooling

2 instrumentation; and

2 support structures.

Blackflush Hquipnent

+ screw compressors (2);

+ piping:

D valves (5);

1 air receivers (5);

2 stands and concrete pad:

Instrumentation.

ens:

Filter Piping and Valying

+ filter piping and valves:

Thickening and De-vatering Systens

+ thickener and rakes

+ sludge pumps (2);

2 surge tanks

?vacuum belt filters (2)

?conveyor

sludge hoppers

piping for sludges

sump punp for thickener overflow; and

overflow piping. ose

---Page Break---

TABLE VIT-1, Part 2 (continued)

Disinfection Syeten

hypochlorite storage tanks

chlorine diffusers;

netering pun

residual chlorine analyzer;

chlorine piping:

2 contact chanbers (3); and

1 outfall piping.

Electrical system

motor control center

wiring and conduit;

transformer and accessorie:

electrical boxes, etc.

Automatic Process Control and Monitoring Systems

micro-processor controller, including:

~ flow metering;

= alarms;

= differential recording; and

= interface capability;

monitoring systen.

Physical Plant Construction

Building of approximately 16,500 ft, including

+ piping;

1 electrical system;

1 Lightings

1 office facilities;

?control rooms

S laundrys

Dee.

---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 re-

moved from the waste water.

OPERATION AND MAINTENANCE COSTS

Operation and maintenance costs for the 25 MAD 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 MSD over the course of a year.

The chemical and electrical costs shown are approximate, current Jocal prices for the Cambridge, Massachusetts area. Operator labor is based fon 24 hours/day monitoring of the facility plus an @ 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.

No costs have been included for final disposal of sludge and grit, or for sludge treatment chemical conditioning (should the latter prove neces-sary). The chemical denand and net operation costs could change significantly if seed recycling or alum recovery are incorporated into the flowsheet.

Power consumption for a systen running at § GD and at 25 MGD is

shown in Table VII~3. The magnetic filters specified for this system are

---Page Break---

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 streans for waste

water purification, although there will be one flow as they enter the factlity

(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/ft?

are available to handle the 25 MGD peak storm flow. When all five filters

are activated, the maximum capacity of the system will be 32 NGD, and average

annual through put is assumed to be 5.7 MGD. Figure VIT-1 is a system design

schenatic.

---Page Break---

---Page Break---

REY TO FIGURE vrI-1

?Alun Delivery Pump (2 pare)

?Alum Storage Tank

Air Receiver

Bar Screen

Control Gate

Caustic Rinse Pump

Chlorination Systes

Caustic Storage Tank

Conveyor

Feed Pump (2 spare)

Flocculator Tank Systes

rit Hopper

Magnetic Filter

Magnetic Delivery Pump

6

5

3

a

5

3

3

Magnetive Screw Feeder

Magnetite Sturry Tank

overflow Pump

Polyelectrolyte Make-up System

Polyeelectrolyte Delivery Pump (2 spare)

Rotary Strainer

Serev Compressor

Sludge Hopper

Static Miner

Sludge Pusp (1 spare)

Surge Tank

Swap Welt

58"

Rages esa g ges eas aanee ge aalk

---Page Break---

KEY TO FIGURE VII-1 (continued)

1 ? ?Thickener

2 ? Vacuum Filter

TABLE VII~2 OPERATION AND MATNTENANCE COST ESTIMATES FOR A HIGH GRADIENT

MAGNETIC FILTER BASED 25 MCD CSO/SEVAGE TREATMENT FACILITY.

Costs in § per 1000 gallons

Iten 5.7 vp 25 map

Chemicals

+ Alva (liquid, 502) 100 mg/1 042 1042

$100/dry ?ton

§.110/kg

$.27/gat.

S071

Magnetite (comercial grade, ~325 mesh) .030 030

200 me/1

$35/t0n

§.018/1

5.039/eg

Polyelectrolyte (Hercofloce 831, oun 011

?anionie) T ae/h

$1.36/%b

33. 00/eg

Chlorine (15% Sodium Hypochlorite,

Witthior 2) Lmg/i

§.30/gat

s.o79/t

$.529/kg availabie Cl,

(delivered price)

Total Chemical Coste: 087 087

Ghenicel Freight Cost:

?Alun for 50 mi or 80 kx 007 007

§.05/eal

s.013/1

+ Magnetite for 200 mi or 322 km 008 +008,

?Sieleon

sOL1/kg (estimated)

Total Freight costa: as as

59,

---Page Break---

TABLE VII-2 (continued) £1000 gatone

Item 5.7 McD. 25 woo

Blectrical Power $.055/kimh 032 026

+ Magnetic Filter (5) 15 i ea,

Other Bquipment

125 5 McD

404 ww 25 MoD

operator Labor:

32 man-hours/day $15/hr +039 039

Maintenance Costs:

Mechanical Equipment and 042 008

Physical Plant (3% of equipment cost)

Electrical Equipment, Instr on 002

mentation, and Piping (2% of equip

ent cost)

otal Labor and Maintenance Costs? 082 049

TOTAL OPERATION AND MATNTENANCE

(cost PER 1000 GALLONS: "is Ts

TABLE VIT-3 POWER CONSUMPTION FOR A 25 MGD FACTLTIY

td ?oergy Consumed in iit

510 25 ven

De-gritting and Pre-screening 82 18.7

Feed Pumping 45 £. head 40.0 200.0

Chensea! Makeup and Delivery 2d 6s

Floceulator chain Mixing 9.0 38.0

Magnetic Filters 15.0 60.9

Compressors 12.0 45.0

Dewatering System no 42.0

Control Instrusentation and Bldg. Service 32.0 23.0

Miscellaneous 10.0 30.0

?ToraL: 608 140.0 464.0

---Page Break---

TABLE VII-4 ASSUMED PARAMETER VALUES FOR A 25 MoD SYSTEY

Magnetic Fie

+ Bore

2 Length

1 Magnetic Field Strength

2 Maximum Flow Rate through Matrix

Waste Water Characterieti.

+ Maxinun Storm Flow

{Nominal Dry Weather Flow

1 Average Flow over 1 Year

Backélush

rameter

+ Backflush Flow Flux Rate through

Matrix

+ Backflush Duration

{ Backflush Volume

{Maximum Pressure Drop before Backfush

+ Caustic Rinse Flow Rate through Matrix

Mixing and Residence Times

© Factor for Flash Mixer

+ G Factor for Floceulator

+ Reynolds Number for Static Mixer (21 in)

{Total Mixing Residence Time

Chemical Dosages

?Alum Concentration

2 Magnetite Concentration

+ Polyelectrolyte Concentration

{ Ghiorine Concentration

Chemical Storage

Other Parameter:

+ Pusping Head for Feed Pumps

+ Pre-sereening size

612

25 wap (1,1 3/sec)

5.MGD (22 msec)

3.7 MoD (.25 m/sec)

100 mg/1.

500 gpa/#e? (73 =°/nin)

(29,300 gpm)

B sce

2600 gal (20 n°)

10 psi 3

20 gpm/tt? (2.9 m/min)

300/sec

100/sec

7.5.x 10°

S'nin

100 we/1

200 mg/

1.0 mg/

2'ng/t

6 days at peak flow; 30 days

at dry weather flow

45 ft. (33 psi)

20 mesh (.84 mm)

---Page Break---

FIGURE VII-2 TOP AND SIDE VIEWS OF ALUM RESIDENCE/FLASH MIX/

FLOCCULATOR RESIDENCE TANK CHAIN FOR THE 25 MCD

SEEDED WATER TREATIONT SYSTEM

---Page Break---

Table VIII-8 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 conbined wet and dry weather flow treatment plant has an inherently Jarge reserve capacity with remains unused for a major portion of the year.

For the 25 MGD peak flow systen in question, it was arbitrarily assumed that in 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 ?through put 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 anount of equipment must be regularly maintained for only sporadic use. AS @ conse~ quence, operation and maintenance costs are relatively high in proportion to the nunber of gallons treated.

The systen shown in Figure VII-1 is similar to the seeded water treatment flowsheets presented in the past (1.e., the Mobile Pilot Plant Trailer design and the 25 MGD 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 alun 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

---Page Break---

system.

Another change is with the magnetic filter design which affects the backflush system; each magnetic filter now has its own hydrotank for blackflushing incorporated as an integral part of the magnetic filter canister (forward flow) plumbing. In this way, much extra plumbing and valving have been eliminated, as well as the extra control provisions for fi11ing 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 sys-ttem 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.

---Page Break---