Title: MAGNETITE SEEDED HIGH GRADIENT MAGNETIC FILTRATION TREATMENT OF INDUSTRIAL AND DOMESTIC WASTES - FINAL REPORT FY-80

Date: November 15, 1980

Department: CENTER FOR ENERGY AND ENVIRONMENT RESEARCH, UNIVERSITY OF PUERTO RICO, U.S. DEPARTMENT OF ENERGY

Report Number: CEER- c-088

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INTRODUCTION:

The economic electrical generation of intense high-density magnetic fields confined within a cylindrical volume of large cross-sectional area has led to a rapid development of high gradient magnetic separation (HGMS) over the past 10-15 years. Several reviews of HGMS and its applications have appeared recently. In spite of its relatively short period of existence, HGMS has enjoyed a good deal of enthusiasm and acceptance.

In applications involving the removal of magnetic materials from liquid and gas streams, the theory of optimization of separations from liquid and gas streams has come under study and is likely to be expanded as combustion engineers begin to apply High Gradient Magnetic Separation (HGMS) to the desulfurization of coal slurries.

2. Description of HGMS Treatment:

High gradient magnetic separators or filters have been designed to maximize magnetic forces on fine magnetic particulate material suspended in fluid media. This is achieved using a filamentary matrix in a cylindrical pipe cavity situated inside the coil of a large electromagnet of 2000-5000 Gauss intensity. The combination of an efficient magnet and a fine wire matrix permits the economical generation of a very dense magnetic field at the wire surfaces of the matrix and a high gradient of the field near the matrix wire. This results in strong forces over a large surface area in the magnetic filter bed.

Since the magnetic field interaction accounts for the filtering hold-up forces and the filamentary matrix typically only occupies 3-7% of the cross-sectional area in the cylindrical pipe conducting the flow, there is only a small pumping pressure or head loss during the processing. Indeed, filtration at rates of 7000-10000 liters of liquid per minute per square meter of fluid stream cross-section can be carried out economically.

The entire HGMS process is cyclical in nature. Magnetic particles in the material flowing through the magnetic separator accumulate on the matrix. The separator matrix packs up with separated material from the side where flowing material first meets it. This is the feed part of the cycle which ends before the breakthrough of particles on the other side of the matrix occurs. At that point, the field is switched off and the captured particles can be removed from the matrix system by flushing the canister containing the matrix with air, an air-water mixture, a solvent, or with water alone. The length of the feed part of the cycle can be determined roughly.

Assuming that the wires of the matrix can capture three to four times their own volume of material. This means that a loaded filter canister will contain about 20% by volume of captured particles. The processing rate of the magnetic separation, P, is given by $P = VQ$, where V is the slurry velocity, Q is the cross-sectional area of the separator, and D is the duty factor. The duty factor is given by $D =$ Feed Time / (Feed Time + Dead Time). The dead time is part of the cycle when the feed is not flowing and consists of time to switch the magnet on/off and the time to flush out the magnetically trapped material. For efficient operation, the feed time must be much greater than the dead time.

The extension of the process to the filtration of non-magnetic particles and even dissolved materials may be attained by precipitation, aggregation, and flocculation of these species with magnetic "seed" particles. This process makes high gradient magnetic filtration applicable to a wide variety of fluid effluent filtration problems.

The magnetic seed material which has been most generally applicable is magnetite, Fe_3O_4, magnetic (black) iron oxide. While other ferromagnetic 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% of that of pure iron. Second, the type of magnetite required is relatively inexpensive (about $80 per ton). Third, it is quite inert in most systems of interest. Finally, the surface of magnetite appears to be a good adsorbent material. Viruses and algae, for instance, have an excellent affinity for the surface and in general the particles are easily incorporated into flocs formed by inorganic flocculants. Other possible seed materials include other less oxidized forms of iron, iron ore, cobalt, and nickel as well as oxides of these and other well-known, relatively strong magnetic substances. Another possible alternative which has received some attention recently

This is based upon the use of an electric superconductor magnet to generate ultra-high fields and field gradients in the canister containing the matrix. This system has the advantage that ferromagnetic seed material would not be necessary because potentially cheaper paramagnetic material such as metal oxides would be sufficiently attracted to the matrix wires and could carry out the same or superior adsorption as that demonstrated for magnetite. After seeding, magnetite or other magnetic particles in wastewater are bound to non-magnetic component solids and solutes normally present by means of adsorption, coagulation, flocculation and co-precipitation. The process of adsorption includes non-magnetic and ferro components adhering to the surface of the seed particle, or the seed particles adhering to larger non-magnetic aggregations. The adsorptive forces may include one or more than one component in an interfacial double layer and, to enhance adsorption, pH adjustment may be required.

Inorganic and organic compounds can also be added to the candidate waste stream to aid coagulation (slime, ferric chloride) and flocculant (anionic, cationic or neutral surfactants such as Hercofloc, Nalcofloc, Percol, etc.). The organic polymer surfactants generally tend to bridge the gaps between large particles, creating massive flocs which are more resistant to disruption by hydrodynamic shear forces upon passage through and during holdup in the magnetic matrix. Co-precipitation of dissolved organic compounds and weakly magnetic or non-magnetic inorganic ions and compounds is a third factor in HGMS treatment. 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 thin layer of hydroxide existing on the surface of naturally occurring iron oxides in boiler water can adsorb or occlude calcium and magnesium ions sufficiently well that single pass HMS treatment can

Significantly reduce the bottled water hardness. Bottled feed water can also be treated for removal of copper ions and copper oxides, though in many applications, the quantity of naturally occurring iron oxide and metallic iron is large enough that, again, no seed material is necessary. An obvious extension of these processes to remove dissolved material is precipitation followed by flocculation of the resulting suspension with magnetic seed. For specific applications, several natural flocculant/seed combinations have been developed, such as the formulation of aluminum sulfate containing fine particles of magnetite, or a magnetite suspension in which the magnetite particles have received a fine coating of an organic polymer flocculant.

2.1 Design of the HOMS Plant

The high gradient magnetic separation runs were carried out using a mobile pilot plant designed and built by Sala Magnetics, Inc. of Boston, Massachusetts. The pilot plant is a self-contained HGMS plant requiring 120/240 V electrical power. It includes pumps, mixers and ancillary equipment to screen influent, dose the influent with alum and magnetite in a slowly agitated polyethylene chamber, subsequently to dose with organic flocculant, magnetically filter, flush the magnetic matrix with a compressed air/water mixture and thicken sludge in a circular settler. The maximum filtration flow rate obtainable using the pilot plant was 38 l/min, with maximum sludge production of 0.5 kg/hr. The actual flow rates used during the experiments varied between 9 and 18 liters per minute. All operations could be accomplished automatically by setting the appropriate on-board computer/timer. The pilot plant was designed to fit in a large truck trailer chassis which could be transported using a 2 1/2 ton pickup truck. A conceptual diagram of the pilot plant operation is shown in Figure 1 with major operational steps numbered: 1. Screening, 2. Alum and magnetite addition with pH adjustment, 3. Polyelectrolyte Flocculant addition.

4. WMS processing.
5. Compressed air/water flushing of the matrix.
6. Outflush to a surge tank.
7. Sludge settling/thickening.

In the experiments on municipal sewage, no attempt was made to recover magnetite, though there are several possible methods for post-treatment of the sludge for such recovery.

1. During the passing week, numerous experiments were conducted.

3. Municipal Sewage Treatment

Over the past year, studies of HGHS applied to industrial and municipal wastewater in Puerto Rico by the Center for Energy and Environment Research of the University of Puerto Rico have yielded process and cost information relevant to the application of HGMS as a large scale sewage treatment. The purpose of this section is to present performance data for HGMS applied in situ to municipal sewage treatment and to provide approximate cost comparisons for equivalent performance between a secondary aerobic treatment plant and an HGMS treatment system.

The El Conquistador secondary aerobic activated sludge treatment plant is located in Trujillo Alto, Puerto Rico. Its design capacity is 2x10^6 liters per day but the actual volume of sewage treated by the plant rarely exceeded 400,000 liters per day during this study.

The Guaynabo Treatment Plant design uses primary treatment and settling followed by trickling filtration through a rock bed. One of the Guaynabo trickling filters along with the mobile HGMS laboratory is shown in Figure II. This plant has a handling capacity of 10^6 liters per day of raw sewage.

3.1 Operation Parameters of the HGHS Plant for Sewage Treatment

Optimum feed concentrations of magnetite, alum, and polyelectrolyte flocculant were determined using jar tests on 200 ml. samples of wastewater. For alum dosing, the optimum concentration was taken as the lowest concentration providing a maximum decline in turbidity of the wastewater after 4 minutes of stirring and up to 1 minute of settling; for magnetite dosing,

The optimum initial experimental concentration was taken to be that which conferred sufficient magnetism on the settled floc. A bar magnet subsequently introduced into the test jar attracted the floc sufficiently well that the clear water could be poured off, leaving the bar magnet and the magnetic hydrous aluminum.

Magnetic Filtration Figure: High Gradient Magnetic Separation Pilot Plant parked in front of a Trickling Filter Unit of the Guaynabo Sewage Treatment Plant.

For polyelectrolyte dosing, the optimum concentration was taken to be the minimum concentration necessary for binding and settling of the gelatinous precipitate produced by the 4-minute agitation of the alum-dosed solution. Optimum concentrations from the jar tests were then used to calculate the concentrations of the stock solutions to be added to the wastewater stream using typical pumping rates. For example, in the case of alum, the appropriate alum stock solution concentration was approximately determined by assuming a delivery rate of the pump used to dose the alum and applying the following equation (3):

$$USC = FW \times OC$$

Where:
USC = Unknown alum stock solution concentration
FW = Flowrate of wastewater influent (present)
OC = Optimized concentration of alum
DR = Delivery rate of USC (Assumed)

Stock concentrations of magnetite suspension and polyelectrolyte solution are determined in an analogous fashion. In practice, precise rates of delivery were adjusted during a run to maintain maximum removal of turbidity from the effluent processed using the minimum amount of each additive. The pH adjustment usually involved dropwise addition of 5N sodium hydroxide to the first mixing tank into which the magnetite and alum were being added. The rate of addition of sodium hydroxide was adjusted using a direct reading pH meter during processing.

3.2 Water Quality Parameters

The water quality parameter of greatest importance in...

Monitoring the HoMS pilot plant performance was the turbidity, generally measured at 550 mm using a 10m path length with a Zefss M™M3-0L single beam spectrophotometer or a portable Hach single beam spectrophotometer having a path length of approximately 2.5 cm. Total suspended solids (TSS) were measured by methods 208 D in "Standard Methods"™8; biochemical oxygen demand (BOD), and total phosphorous (TP) were determined according to procedures 507 and 425 C,D respectively in "Standard Methods""®. The measurements of total Kjeldahl nitrogen (TKN) were performed on 100 ml. of suitably diluted sample digested with 1.5 gms of potassium sulfate, 0.1 gms. of copper sulfate, 5 ml. of concentrated sulfuric acid nominally 36N and 4 selenized Hengar granules after which the procedure generally described in method 421 was employed with the Nesslerization modification 418 D 4c from "Standard Methods"!®. During extended runs of 1 1/2 to 3 hours, samples were taken at the start, halfway through the separation and just before the end of the run. At each sampling point, quantities of both the influent and the effluent after HoMS treatment were collected for comparison.

3.3 Description of the Experiments

The WGMS filtration of influent to the secondary activated sludge plant (The El Conquistador Plant, Trujillo Alto, Puerto Rico) was done batch-wise with a maximum of 346 liters per run of the shredded fresh influent. In the latter application, the maximum filtering flow rate tested was 11 liters/minute with filter cycles lasting 1 minute. A magnetic field intensity of 2.5 kilogauss was maintained during all runs. Granular alum and Hercofloc 831 were utilized in all the filtrations. Optimum concentrations of alum, magnetite, and polyelectrolyte were of the order of 50 mg/l, 400 mg/l, and 3 mg/l, respectively for all runs. No attempt was made to vary these concentrations during an actual extended filtration run. The on-site filtrations were carried out at the trickling filter Plant (The Guaynabo.

The Municipal Plant was observed over a period of 7 weeks. During that time, approximately 26 filtration runs of fresh sewage were made with filter flow rates ranging from 11-18 liters per minute and a magnet delay, or dead time, of 4-6 seconds. The longest continuous filtering operation lasted around 3 1/2 hours, and a 2.5-kilogauss magnetic field was used for all tests.

Two forms of alum, granular and liquid, were utilized. Various polyelectrolytes, ranging from anionic to nonionic and cationic, were jar-tested to determine their effectiveness. The high molecular weight synthetic polymers used during actual filtrations included Betz 1110, 1120, 1130, and 1140, Hercfloc 818, 627, and 831, and Percol 720, 726, 728, and 776.

Testing of these polymers was conducted after the pilot plant system was standardized in terms of the optimum concentrations of alum, magnetite, and Hercfloc 831. Once testing of a specific polymer was completed, the system was reverted back to its conventional operational configuration using Hercfloc 831. This step was taken to reassess the system and ensure that the concentration requirements for the waste had not changed during the testing period. Each testing period lasted about 30 to 45 minutes.

Results and discussion for sewage treatment, specifically for the aerobic activated sludge plant, are as follows: Results of HGMS batch-wise pilot plant treatment of shredded and screened effluent from the aerobic activated sludge plant are depicted in Table 1. Two typical runs and one superior run were selected as representatives. The average percent reduction in absorbance, TSS, BOD, and TP of 96%, 92%, 72%, and 87% respectively can probably be reproduced at any given time, provided that operating parameters such as the quantity of alum, Hercfloc 831, etc. can be adjusted to reflect changes in the incoming sewage. Our experience with the Guaynabo trickling filter plant influent was that very small changes in operating parameters are required to continuously meet pre-specified treatment objectives.

Criteria: The quantity of alum, approximately 550 mg/1, does seem excessive. As will be discussed below, the concentration of alum necessary for optimum treatment of influent to the Guaynabo Municipal Treatment Plant was considerably less.

3.4.2 Plant No. 2 (Guaynabo Plant)

In Table 11, performance results for HGMS applied to shredded screened influent to the Guaynabo Plant are displayed. These runs represent widely varying influent composition and the HGMS treatment appears to be at least adequate in every case, particularly with respect to phosphorous removal.

The average treatment for all runs shows removal of absorbance, TSS, BOD, and TP to be 88%, 72%, and 90% respectively. Three runs were made on effluent from the primary clarifier of the Guaynabo Plant and the results of HGMS treatment of this waste are shown in Table III. There is a substantial improvement in the wastewater quality although HGMS treatment seems to be more suitable for freshly shredded and screened influent.

The average treatment for the three runs shows removal of absorbance, BOD, TP, and TN to be about 85%, 56%, 52%, and 97% respectively. The continued high performance of HGMS with respect to phosphorous removal may be related to the fact that most of the phosphorous in the effluent was in the form.

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Please note that the unreadable text should be replaced with the correct information for accurate comprehension.

Orthophosphate, which precipitates very well as a complex 'aluminum hydroxyphosphate', should be removed very efficiently in the HOMS process. Visual observations of the sewage entering the plant on dry and sunny days were strikingly different from those made on rainy days. This change in effluence could also be noticed in a change in the requirements of alum, which were generally higher on rainy days. Alum proved to be the most critical and variable of the additives used for magnetic filtration. The quantity required to produce rapid precipitation of curdy flocs varied from as low as 90 mg/l to as high as 190 mg/l. On average, for Guaynabo, alum concentrations of 130 mg/l gave positive results. Granular versus liquid alum made no difference in the amount of alum needed for filtration. However, liquid alum was much easier to handle than the granular form. Magnetite concentrations as low as 100 mg/l and as high as 1000 mg/l were tried; but it was observed that 250 mg/l was enough for good filtration of raw sewage. Concentrations higher than 250 mg/l did not improve the filtration and did not lengthen the filter cycle as had been expected. Concentrations of 180 mg/l and lower resulted in a considerable quantity of flocculated material escaping from the magnetic matrix. This was probably due to the decreased incorporation of the magnetic particles in the flocs. Interestingly, on average, a magnetite concentration equal to 1.6 times the concentration of suspended solids present was sufficient for acceptable filtration. This is far lower than the conventional recommended dose rate which is about 3 times the concentration of TSS in many applications.

3.4.3 Tests of Polymer Flocculant Norcofloc 631, a synthetic polymer, was the polyelectrolyte utilized in all filtration experiments conducted over an extended period. A number of other polymers were also tested on raw sewage from the trickling filter plant but

Always for periods of time shorter than 1 hour. Concentration of this moderately anionic polymer ranged from as low as 1.0 mg/l to as high as 20 mg/l. It was observed that a 1.5 mg/l concentration gave as good results as higher concentrations, while at concentrations as low as 1.0 mg/l the precipitate aggregates formed were not large and yielded easily to disruptive hydrodynamic shear forces while passing through the magnetic matrix. Of the rest of the polymers tested only two produced good-sized flocs and the filtrate in each case showed a generally higher absorbance value than did the filtrate using Hercofloc 831. With the highly anionic Betz 1120, a reduction in absorbance of 97.3% was observed and a percent reduction in BOD of 77.8 was obtained. The moderately anionic Betz 1110 produced a reduction of absorbance of 73.2 and large flocs. It should be pointed out that all of these polymers were tested at pHs which did not require adjustment (i.e. between 6.3 - 6.5).

3.5 Comparison of Performance of HGMS and Activated Sludge

The HGMS treatment was superior to that observed over an 8 month period for the El Conquistador secondary aerobic activated sludge plant (operated at 20% capacity) with respect to TSS and TP. However, the El Conquistador plant was capable of removing 85-82% of the influent BOD, while the HGMS treatment rarely exceeded 80% removal. While none of the experiments was run without prior planning, fine tuning of HGMS treatment was not part of the scope of the pilot plant trials and it is believed that BOD removal in excess of 85% can be realized on a routine basis with little additional experimentation. Indeed, HGMS treatment of wastewater and combined sewage and storm overflow indicates that 90% or higher BOD removal may be reasonably expected.

3.6 Economic Analysis of HGMS

In order to place seeded HGMS in a cost/benefit perspective, cost estimates for construction, operation and maintenance were carried out for a 4x10 Liter (1 million gallon) per day (MGD) plant.

The text was operating during the 3rd quarter of 1980. The analysis was designed for comparison with the same capacity aerobic activated sludge plant with a performance equivalent to the HGHS plant (Table IV). The cost of the land on which either plant could be installed was not included, though the land area requirements for HGMS are certainly no greater than half of those for an aerobic activated sludge plant. This fact may be very important for small, densely populated islands, such as Puerto Rico where suitable available land for municipal use as a sewage treatment plant area may cost in excess of $200 per square meter. If 2000 m^2 (roughly 1/2 acre) is required for construction of an aerobic plant of the designated capacity compared with 700 m^2 for the HGHS plant, the savings in land, alone, using the HGMS plant, is considerable. Construction costs are $741,313 using estimates for a dedicated HGMS plant and adjusted for 3rd quarter 1980 at an annual increment of 9%. The cost represents design, construction, and installation of a fully automatic, self-contained 4x10^6 liter/day plant of the following description:

It incorporates pre-treatment (screening and degritting), sludge dewatering, and magnetite seed recovery subsystems in addition to the basic seeded HGMS process. The solids operation, i.e., sludge dewatering and magnetite reclamation, would function during a single shift only and chemical storage facilities would permit a 30-day uninterrupted operation period. The control systems would allow continuous operation requiring only a daily operation inspection. This plant would have a back-up system for units critical to process function. The estimated cost includes standard instrumentation and data logging equipment. Estimated construction costs for a 4x10^6 liter/day municipal aerobic activated sludge sewage treatment plant were obtained from U.S. Environmental Protection Agency (EPA) data for the years 1973-1977. The cost data was adjusted as described above to 3rd quarter 1980. The actual

The cost, $2,578,816, includes all unit process installations: shredders, screens, pumps, digesters, sludge drying beds, chlorination chamber, etc.; site preparation, instrumentation and laboratory. Operation would require 1 shift operator and 1 inspector weekly. No backups are included in the base design. The function of the plant would be uninterrupted except for maintenance of digester sections, probably comparable to the operation schedule of the HGKS system. According to these estimates, capital expenditures are 72% higher for a secondary aerobic activated sludge plant when compared with the HGMS system. Operation and maintenance costs provide a substantially different perspective. The total estimated yearly operation and maintenance cost for HHS during the 3rd quarter, 1980 in the 4x10 liter/day plant is $138,335. This cost can be broken down as shown in Table IV into the following accounting categories: additives for processing, including chemicals, reagents, magnetite etc. - 40.1%; electrical power - 22.28%; repairs and replacements - 21.9% and operator labor - 15.8%. Estimated operational and maintenance total cost for a 4x10° liter/day conventional secondary aerobic activated sludge treatment plant operating between 90 - 110% capacity during 3rd quarter 1980 is $89,482. Again, the cost is based upon EPA derived data for 1973-77 and was adjusted to 1980 using the simple dollar inflation estimate of 8.3% for 1978, 79 and 80. The investment return or crossover point in the operation/maintenance costs of HGMS versus capital expenditure costs for aerobic activated sludge digestion plants depend strongly on how the capital expenditure of the latter is financed. A small municipality might reasonably expect to sell a bond issue paying 10% interest annually with monthly compounding and a 2 year maturation rate. In such a case, the difference in cost between the aerobic activated sludge plant and the HGMS is given by the following equation (4) D = (0.00965) (240) (cA-cH) in which D is the difference.

The text appears to be about a cost comparison between a High Gradient Magnetic Separation (HGMS) plant and an aerobic activated sludge plant. Here is the corrected version of the text:

The capital expenditure for an HGMS plant in CA is spread over 240 monthly compounded periods. The factor 0.00965 represents the monthly payment necessary to pay off a $1.00 loan over 20 years at a 0% annual rate, compounded monthly. The undiscouted difference in total costs between the two plants becomes substantial when considering financing, amounting to $4,255,656.90. If we assume that the operation and maintenance costs will increase at a reasonable inflation rate of 9% per year, the difference in costs between the HGMS and the aerobic activated sludge plant over a 20-year period can be calculated using the following series (5): TOoM ~ 1oow (141.097 = ..., +

1.0819) -20.

Table IV. Cost Comparison of 1 MGD HGMS Plant with an Aerobic Activated Sludge Secondary Treatment Plant, 3rd Quarter, 1980.

Cost	HGMS Treatment	Aerobic Treatment
Construction:	$741,313	$ 2,578,816
Operation and Maintenance:		
Processing Additives:	$55,472	
Electrical Power:	$30,710	
Repairs:	$30,298	
Labor:	$21,058	
Total:	$138,335	$89,482

In which TOOM is the total difference in operation and maintenance costs over a 20-year period at a 9% annual inflation rate, and IDOM is the initial (1 year) difference in operation and maintenance costs between an HGMS plant and a secondary aerobic activated sludge plant. Calculating IDOM from Table IV and substituting into the series results in TOOM = $2,697,950.50.

Assuming a 20-year plant life, the HGMS plant seems an attractive alternative with a net saving of $1,577,706.40. However, the crossover point for the costs of the two processes occurs soon after the 20-year assumed lifetime, namely at 24.5 years.

The financial analysis is summarized in Table V.

3.7 Summary and Conclusions

The performance of seeded HGMS treatment of municipal wastes is comparable to aerobic activated sludge treatment. The HGMS treatment produces a dense, easily dewaterable waste sludge which can be reclaimed for seed material. From the standpoint of capital expenditure and land use, an HGMS plant is a more viable option.

The aerobic activated sludge plant of $4x10^6$ liter/day capacity is an attractive alternative. However, the operation and maintenance costs of the HGMS plant may make the aerobic plant competitive in the long term. The economic analysis might have favored the HGMS plant more if the cost-benefit of magnetite seed recovery and reuse had been included and if a reasonable statewide index for average municipal land costs could have been derived. Another aspect which favors HGMS is its electrical power requirements which, despite the use of high field electromagnets, is believed to be substantially lower than those necessary for 100% capacity operation of the aerobic activated sludge plant.

Table V. Economic Analysis of Differences in Total Capital Expenditure and Operation/Maintenance Costs for Aerobic Activated Sludge Plant and HGMS Plant.

Cost AASP- Cost HGMS

Capital Expenditure 20-year, 10% annual financing rate $4,255,656.90

Total Operation/Maintenance cost for 20 years operation $ 2,697,950.50

Total Operation/Maintenance cost for 22 years operation $ 3,321,676.50

Total Operation/Maintenance cost for 28 years operation $ 4,062,725.40

Crossover point for capital expenditure and operation/maintenance expenditure 24.5 years

In December 1979, a project was begun with SKAF Lab. Co., Guayama, Puerto Rico to determine if wastes from its process units could be treated using HHS. Results of tests made for purposes of gauging feasibility are contained in quarterly reports 1 and 2. Basically, it was concluded that HGMS was only applicable if a substantial part of the waste had been acted upon by microbes in the aerated lagoon. On those occasions when biological activity was inhibited or suspended in the lagoon through high pH or ionic strength load shocks, HGMS treatment was successful at a treatment level of about 10% - 20% COD removal, nowhere near sufficient to approach compliance.

On the one hand, COD removal of 30-40% was routinely possible using HGMS when the aerobic lagoon treatment was sufficient to lower the COD to 1000 mg/l or less. Thus, a preliminary step of converting organic loads to biological (i.e., cellular) colloidal material appeared to be necessary in order to effectively treat the lagoon wastes via HGMS. Parameters of lagoon function were partially mapped during effluent characterization and our recommendation of segregation and separate disposal of blending and dilution from the caustic scrubber blowdown seems to have been adopted by SKAF Lab. Co. This is a very useful first step.

4.1 Effluent Characterization and Testing

Effluent from manufacturing and production processes at SKAF Lab. Co., Cidra, P.R. and Millipore Corp., Cidra, P.R. were characterized with respect to the suitability of treatment using aerobic activated sludge, aerobic lagooning, and magnetic filtration. Rum slops from Bacardi Corp. and from Puerto Rico Distillers were treated to a level of 50-70% reduction in absorbance, but only after mixture with raw sewage at a ratio of 1 part stillage to 5-10 parts raw sewage. This again indicates that HGMS is not very effective for loadings which are primarily soluble organics and which do not have colloidal cellular material present.

5 Publications and Conferences

Articles have been forwarded to journals: Revista Colegio de Quimicos de Puerto Rico and Journal of the Water Pollution Control Federation. The former is entitled: "Pilot Plant Studies of High Gradient Magnetic Filtration at the Guaynabo Treatment Plant" by A.NcB. Block, U. Ortabasi, H.B. Riesco, E.N. Laboy, L. de Andino, A. Mirabal, M.L. Fuentes, H. Miranda, I Garcia and J. Villamil. The latter is entitled: "Sewage Treatment in Puerto Rico Using High Gradient Magnetic Separation" by A.McB. Block, M.B. Riesco and U. Ortabasi. A conference entitled: “Economic Analysis of

Wastewater Treatment Using High Gradient Magnetic Filtration" was presented at the Association of...

Chemists of Puerto Rico Annual Meeting, October 23, 1980. 6 Technical Details of Investigative Projects Technical details of projects undertaken in HGMS during 1980 are described in HGMS quarterly reports No. 1-3. Copies are available on request.

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