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High Volume, High BOD Wastes: The Magnetic Separations

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Contribution from: Center for Energy and Environment Research
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Introduction:

Implementation of EPA "zero discharge" regulations may present problems for industries discharging unusually high volumes of aqueous wastes containing high BOD levels. Processes from which aqueous wastes contain a TSS load which does not settle readily in lagoons are also question marks with respect to new regulations. Non-point source pollution such as septic tank drainage field failure[1] during heavy rains has just begun to receive some attention by the authorities and the potential of non-point sources for fresh water pollution is probably quite a bit higher than that of any industrial discharge.

The options usually considered viable for waste water treatment are given in Table 1, along with some remarks which characterize some of the weaknesses in each. It should be clearly noted, that in spite of drawbacks cited, each method is capable of coping with one or more than one type of waste in what is considered to be a cost effective (or at least: cost competitive) manner.

Very recently, a new and general adaptation of an older treatment method used for very specific wastes has emerged as a candidate for problematic effluents. Reference is made in this paper to the technique of seeded high gradient magnetic separation or magnetic filtration. There are now some reasons to believe that it is an important new arm in the arsenal of methodology that the waste water treatment engineer can deploy.

TABLE 1

Treatment Technologies as Currently Practiced

Treatment Technology	Comments
Anaerobic Contact	Re-aeration of discharge required; large investment for high BOD removal.
Aerobic Contact	Odor problem. May not treat chlorinated pesticide residues.
Aerobic Lagooning	Large land areas may be required. Surface aerators (can) - Large operation costs.
Anaerobic/Aerobic Tank	May involve large land areas, high capital expenditures and require highly trained operators.
Direct Land Application	Monitoring of disposal area necessary. Not feasible if long sewerage lines are needed. Large, managed crop land area required.
Evaporation	Sludge transport and disposal management more urgent. Can be energy intensive. Can necessitate long hold up times.

Description of the Technique:

New ideas, materials and concepts have permitted the development of high gradient magnetic fields which are confined to a conduit through which a fairly rapidly moving stream of suspended magnetic particles passes. These high gradient magnetic separators are designed to maximize the force felt by magnetic materials in the stream. They are capable of efficient separation or filtration of even weakly magnetic suspended solids or precipitates for which conventional magnetic separation techniques are ineffective. This capability is the result of the development of a filamentary ferromagnetic matrix and a large volume, high-field magnet. The combination of an efficient magnet and high gradient matrix permits the economical generation of strong magnetic forces over a large surface area in the magnetic filter bed (Figure I). Filtration may be carried out economically, and at process rates of up to several hundred gallons per minute per square foot of fluid stream cross section (gpm/ft^2).

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

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

Municipal and industrial waste water treatment by high gradient magnetic filtration with iron powder seeding is under active development in several countries. Applications include treating combined storm and sewer overflow, raw sewage and waste waters from paper, petrochemical and other industries. A summary of applications, their respective states of development and country of development is given in Table 2.

FIGURE I

High Gradient Magnetic Separation Filter Showing Section of Matrix Wire

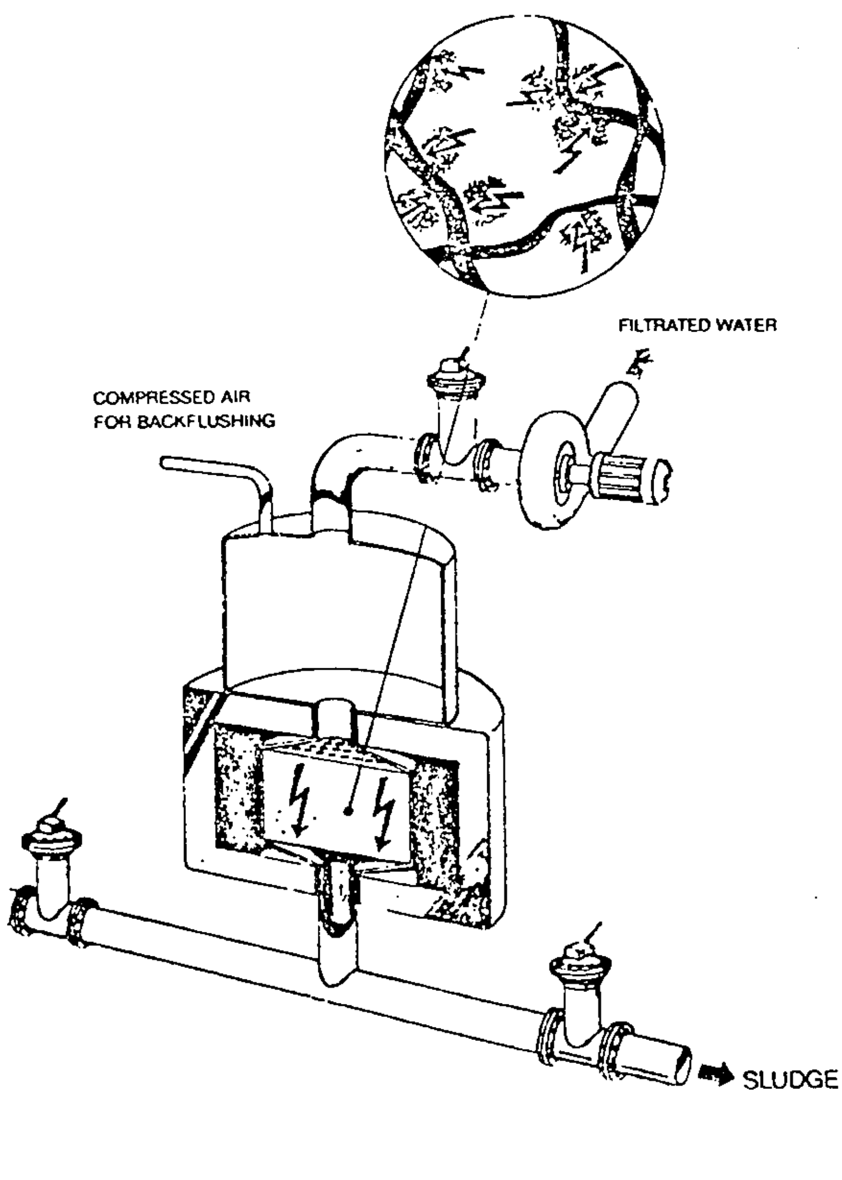

TABLE 2

High Gradient Magnetic Separation and Filtration Applications

Application \ State of Development	Full scale Application Operating	Full scale Planned	Development	Research	Country
Boiler Water treatment	X	X	X	X	USA, Japan, USSR
Clay	X	X	X	X	USA, UK, CZ
Resource Recovery	X	X	X	X	USA
Steel Mill Wastewater	X	X	X	X	Japan, USA, UK, Sweden
Mining		X	X	X	USA, S. Africa Sweden, Canada Japan
Nuclear		X	X	X	USA, UK, Japan
Brewery*			X	X	UK
Sewage*			X	X	USA, Sweden, Japan
Storm Water* Overflow			X	X	USA
Water Reclamation (Purification)			X	X	USA, Sweden
Coal Desulfurization				X	USA
Medical Applications				X	UK
Virus Removal*				X	USA

* Process in which magnetite seeding is used.

Economics of Magnetic Filtration

The costs of installed high gradient magnetic filters will obviously vary from plant to plant, and be dependent upon, among other factors, the relative concentration of the waste to be treated, the flow rate of waste, and other site-specific conditions. The most thorough economic analysis of the process published in the literature is for a 25 million gallon per day (mgd) plant for treatment of combined sewer overflow and sewage (CSO). The cost accounting was based on the results of detailed pilot plant tests (2).

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

It is interesting and instructive to compare the cost per 1000 gallons of water treated in the fore-mentioned design with the operating cost estimated for compliance with EPA regulations by aerobic lagooning (using surface aerators) of a 300,000 gal per day effluent having a BOD of 30,000 mg/liter, a description typical of stillage from an alchoholic spirits producing industry. Such an effluent (200 gal./min.) would require a transfer of 37 tons of oxygen per day. A total of 1,540 horsepower of continuously functioning surface aerators rated at 2 lbs of oxygen transfer per hour per horsepower would suffice. At an electric power cost of $0.03/kwhr it would cost in the neighborhood of $2.70/1000 gallons treated in electricity alone. This is certainly an exorbitant expenditure and one which few companies could absorb and yet remain competitive.

Results of Applications Carried Out to Date:

The range of throughput capability for typical HGMF systems is given in Table 3. It is impressive to note that about 1 million gallons per

TABLE 3

SPECIFICATIONS OF TYPICAL HGMF SYSTEMS

DIMENSIONS WIDTH	LENGTH (inches)	HEIGHT*	APPROX. SYSTEM WEIGHT (lbs)	MATRIX AREA (ft^2)	FEED THROUGHPUT RANGE (gpm)	COOLING WATER VOLUME (gpm)	COOLING WATER PRESSUE DROP (psi)	POWER INPUT (ACkVA)
162	206	126	170,000	77	5,900-19,650	9.2	54	75
120	147	112	70,000	37.8	2,900- 9,670	6.8	56	55.5
92	113	88	45,000	19.2	1,540- 5,130	8.0	26	42.5
71	91	69	18,000	9.3	720- 2,400	4.3	22	35.5
56	75	65	9,000	4.7	360- 1,200	3.5	36	28
44	63	60	5,900	2	200- 670	2.6	22	20
33	52	72	2,800	0.83	190- 300	2.3	34	18
27	37	38	750	0.06	5- 18	1.2	40	9.4

*Height measured flange to flange

Notes: The separators have a 15 cm axial matrix length and a maximum applied magnetic field strength of 5 kilogauss.

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

day throughput uses a matrix area of only about 2 ft^2.

Tests carried out by Sala Magnetics, Inc. of Cambridge, MA. indicate that typical removal factors for several well known waste types are sufficient to bring waste streams into compliance with EPA regulations (Table 4).

Wastes examined by CEER using Sala Magnetics and Salford University (UK) equipment have included raw sewage, rum slops and spent beer from pharmaceutical processing. Results for all 3 wastes are summarized in Table 5. The runs were experimental in nature and, at least in the case of rum slops, very much better separations have been achieved since the original experiments.

TABLE 5

Waste Type	Alum Conc.	Magnetite Conc.	Quantity & Type of Floc	Removal of TSS
Raw Sewage	140 mg/l	200 mg/l	Hercoflox 831 0.5 mg/l	92%
Rum Slops	0	5000 mg/l	Betz 1120 100 mg/l	72%
Spent Beer	200 mg/l	20 g/l	Hercoflox 831 50 mg/l	89%

The CEER Survey and Program

Since magnetic filtration is a developing technology and on-site demonstration of its potential for pollution control of many effluent streams has not yet been carried out, CEER is actively seeking collaboration of local industries for evaluation of the technique. To bridge the information gap from bench test to full demonstration plants CEER is planning the use of a small capacity (10gpm) mobile magnetic filtration laboratory to be leased from Sala Magnetics. The primary objective of this 12 month project is the on-site testing of various effluent streams. To accomplish this, the trailer will be stationed at selected sites of discharges in Puerto Rico for short periods. During the testing period various parameters such as quantity of seed,

TABLE 4

RESULTS OF HGMF LABORATORY TESTS PERFORMED AT SALA MAGNETICS INC., CAMBRIDGE, MASS.			
Water Type	% Removal		
	Suspended Solids	Turbidity or color	BOD or COD
Sewage	91	88 (turbidity)	60-75 (COD)
Combined storm and sewage	95	93 (turbidity)	90-98 (COD)
Paper Mill (Aeration Stabilization Basin)	93	95 (turbidity)	81 (COD)
Spent Beer	89	87 (turbidity)	--
Surface Water	99	99	--

polyelectrolyte concentration, matrix loading, residence times, magnetic field and flow rates will be changed to assign effectiveness of filtration parameters to each type of waste selected by participating industries. Influent and effluent will be analyzed continuously with respect to suspended solids, pH, apparent color, turbidity, settleable solids, BOD, CO_2, 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.

Proposals for use of the trailer in pre-treatment tests of effluents from any industry will be discretely and cheerfully considered.

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and

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