USGS

WATER RESOURCES RESEARCH GRANT PROPOSAL

Title: Development of Novel Dual-Function Media Matrix for Protecting Water Resources from Noxious Organic Wastes

Focus Categories: GW, FL, HYDROL, ST, MOD, WQL

Keywords: Water Resources, Contaminant Transport, Infiltration, Landfill Materials, Waste Disposal, Wastewater Treatment

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Congressional District: N/A

Critical Regional Water Problem

Industrial growth in the Southeastern sun-belt coastal region of the United States including the Islands during the last three decades has adversely affected underground and surface water resources. Industrial effluents, especially injectable wastes such as sludge and other semi-solid wastes which end-up in landfills, caves and wells/aquifers interact in many ways with water resources. This has been identified as a serious problem in aquifers on the mainland U.S. (Dorgarten and Tsang) and also wells in Puerto Rico. Some injection sites are not too deep and are close to the water table. The wastes, especially leachates easily pollute water resources if the water table is close to the surface. For example, injected sludge at sites in the Barceloneta area of Puerto Rico is already a source of pollution. The injected wastes interact with groundwater through flooding, rainfall infiltration and run-off, landfill saturation and the rising of the water table. Some landfills and injection sites in Puerto Rico have subsequently been closed, and as a result, untreated wastewater is ending up in bays and flooded rivers.

In general, protection of water resources from contamination is an expensive process whereas decontamination of a contaminated aquifer/well is several-fold more expensive since there are no “Miracle Mathematical Formulas” for decontamination. Hence, it is better to contain the noxious organic wastes and its end products before they interact with water resources. The result will be of great economic benefit in the long run. In this investigation it is proposed to develop effective dual-function media for handling wastewater and noxious oil and grease wastes from tuna and related industries. The waste composed of sludge is currently injected in landfills/wells/caves in Lajas (PR) through a very expensive procedure. The long-range goal is to reduce the volume of sludge being generated.

Statement of Results or Benefits

The motivation for this research is derived from the fact that the efficient utilization of underground *reservoirs* requires controlled containment of contaminants within the porous structures (National Research Council, 1990). Thus, data on chemical species transport especially immobilization, biodegradation and biofiltration in these structures should be available. In this research novel dual-function media matrix will be developed for protecting water resources from injectable noxious wastes. This research addresses the handling problems associated with wastewater and sludge containing oils, grease and odorous biodegradable solids. This research will lead to the first step to design solid-liquid separators used in wastewater treatment that are not affected by the presence of fat, oils & grease and fine particles in wastewater mixtures. The media should retain wastes and allow degradation to take place in finite time without posing any hazards to water resources. This study will help in the development of novel dual-function media and will illuminate on the transport mechanisms of injectable wastes in porous media and how waste interacts with water resources. The outcome of this project will lead to an economical method for injectable-waste disposal technology and for landfill cleanup operations.

The results of this study can readily be applied to problems involving the separations of tars from toxic wastewater. This is a real problem for a number of industries in the mainland US and Barceloneta area of Puerto Rico. This research will further provide a pedagogical methodology for the efficient education of undergraduates and graduate students new to the field.

Nature, Scope, and Objectives of the Research

Various combinations of soils, sand, gravel, adsorbents and biosorbents, naturally act as dual-function media. Wastes are immobilized and degraded through indigenous microbial activity and biofiltration. On the other hand, soil acts as an adsorbent for various components in the wastes. This has been validated in numerous studies (including Abriola, 1984; Arocha et al., 1996,1997 & 1999; Liu et al., 1991; Hinchee and Reisinger, 1987). Many undesirable components of injectable wastes especially sludge consisting of mainly oils & grease are not easily biodegraded as fast compared to other constituent components. Thus, in order to preserve the quantity and quality of water resources,

transport mechanisms of wastes through dual-function media should be studied and, dual functionality should be improved depending on properties of naturally occurring materials. The current viable technologies for wastewater treatment are not cost-effective especially for Puerto Rico, which has resulted in forced curtailing of industrial operations and entire closure of production lines. Other re-alignments in manufacturing businesses due to anticipated or mandated environmental regulations have led in unison to loss of jobs. Development of novel cost-effective dual-function filter media to prevent contamination caused by injectable noxious and organic waste leachates should help both the southeastern regions of the U.S. and the islands including Puerto Rico.

The objective of this work is to develop and to determine the effectiveness of novel dual-function media matrix for protecting water resources from injectable noxious organic wastes. This research will focus on wastewater and injectable wastes from the tuna industry. These wastes pose unique challenges since they contain oils, grease and odorous biodegradable solids. The specific research objectives include: (i) filtration and washing tests of (dual-function) media matrix with immobilized oily wastes; (ii) in-situ biodegradation and biofiltration tests on media matrix; (iii) washing and biofiltration tests on injection site material with injected wastes and optimization of dual-functionality properties. The central focus is to develop effective and economical novel dual-function media to immobilize wastes and increase in-situ biodegradation rates through inoculation and biofiltration.

Work Schedule:

March 1, 2000 – February 28, 2001

It is estimated that all the specific objectives of this research will be accomplished within the first year. The PI has already initiated some studies related to this project. In one year, enough data will have been collected to enable the PIs to optimize dual-functionality. It will then be possible to estimate the cost of this technology as compared to alternative technologies.

Time Schedule

- Procurement of supplies: *March to April.*
- Experimental setups:
    - Dual-function depth filter experimental setup (PI): *March to May.*
    - In-situ Biodegradation biofilter experimental setup (co-PI): *April to June.*
- Conduct experiments using the test bed setups:
    - Dr. Bogere (PI) - will conduct solid-liquid separation tests in dual-function media and immobilization studies. The experiments will include wet chemistry analysis, odor control tests and multiphase separation tests: *from April (2000) to January (2001).*
    - Dr. Mehta (co-PI) - will conduct in-situ biodegradation and biofiltration tests to determine the extent of biodegradation and the amount of oil-eating microbes that are required. He will assist on wet chemistry analysis on all samples and in-situ.
    - Continuous sampling of wastewater and sludge from tuna plant and, injection site material samples will take place simultaneously

throughout the year. Most of the samples of injectable organic wastes will be obtained from a US Filter Corporation facility (operating at the tuna industries).

- Characterization of the properties of the enhanced dual-function media matrix and optimization studies.

Results from Previous Research

The PI has initiated studies in this field. Preliminary data has shown that high efficiency depth filters are capable of separating oils/grease, odorous biodegradable solids and other solids from tuna wastewater. The CID center at the University of Puerto funds the current project. Another study conducted by the PI and related to this project involves the separation of semi-solid tars from toxic wastewater (containing cyanide and dimethyl sulfonate). It has been established that any conventional separation method usually fails in these circumstances (due to rapid fouling of the media). Preliminary results have also shown that dual-functionality of the media once optimized is capable of immobilizing and biodegrading oily wastes/sludge. The key to fast and in-situ biodegradation is to embed a priori oil eating microbes and nutrients into the matrix. Generally this procedure should reduce the amount of sludge that is generated at the wastewater treatment site.

Methods, Procedures and Facilities

The work to be performed in this research is divided into three major parts: solid-liquid separation using dual-function filters, immobilization and washing, biodegradation and biofiltration tests. The methodology and procedures are discussed below.

Methods and Procedures

Solid-liquid separation using dual-function filters: The separation of oil from wastewater is accomplished by oil flotation equipment such as skimmers. However, other membrane-based methods are gaining ground. On the other hand, the separation of solids from wastewater containing oils/tars and odorous compounds is very challenging. At present there is no cheap and single-step process for accomplishing this goal. The oils & grease or tars in wastewater readily foul the filter septum or membrane. The oils in wastewater also diminish the effectiveness of wastewater treatment methods that are solely based on biofiltration techniques (Gonzalez, 1996). With a little modification, the high efficiency depth filters have been found to be very effective for the separation of oils and particulates from wastewater.

The mixtures to be handled consist of combinations of wastewater, oily phase and odorous organic particulates. The objective is to separate the dispersed oily phase and particulates from the multicomponent wastewater mixture. This part of the investigation will yield data on the application of dual-function depth filters for complex solid-liquid separations and odor control. The study will focus on development of enhanced dual-function media matrix. The enhanced media will consist of transport layers (membrane-like septum for high-pressure filtration) and a mass transfer zone (dual-function media matrix). The filtration characteristics and mass transfer rates of the enhanced media combination will be studied.

The study will focus on understanding the complex fluid-solid interactions within the transport layers zone and in the media matrix (mass transfer) zone. The penetration depth of oily phase and its effects on septum clogging characteristics, two-phase flow, and particulates and oily phase retention rates, immobilization of wastes and the effect of particle size in the depth (mass transfer) zone are to be established.
The experimental setups will consist of the components shown in Figure 1. The setup consists of a multiphase-multicomponent mixture feed tank, dual function filter, filtrate tank, incinerator, air heater and blower. The separation step consists of the feed tank, separator (shown in Figures 2 and 3) and filtrate tank while; the regeneration step consists of a blower, air heater, incinerator and vent. *The regeneration part of the experimentation is not part of this proposal*. In addition to the bag (Figure 2) and cartridge filters (Figure 3) to be used in this study, a deep bed filter shown in Figure 4 will be set-up to conduct washing tests. The solid-liquid separator will be constructed such that the filter septum will also serve as an air distributor during the regeneration step. The main focus of the experimentation after setting up the separator is to study its separation efficiency using the high efficiency filter (with dual-function media). Figure 4 shows the major components and instrumentation of the solid-liquid separator. The separator will be constructed from Plexiglass to be procured through this project. During normal (separation step) operation only valves 1 and 2 are open. In the regeneration step (*not part of this proposal*) valves 3 and 4 are open while 1 and 2 are closed. Pressure probes will be inserted into the bed to measure local pressure. The pressure profile will be correlated later to bed performance and saturation studies.
This part of the study will include the following itemized tasks:
1. *Sample preparation.* This will involve the preparation of laboratory samples of multiphase mixture samples composed of organic solid, oil, water, clay, polymer and sand. Candidate samples from industry will be stored in sealed drums. The samples will be added to the feed tank only when they are needed (*the samples need special handling and disposal*).
2. Dual-function filter media preparation and loading. This will involve

- Particle size analysis of media material (a combination of clay, soil, sand, gravel, anthracite, a mixture of polymeric adsorbent and combinations of biosorbents: coffee husks, molasses and walnut). Only the polymeric adsorbent and specialty clays are currently used in the generation of sludge.
- Immobilization studies will deal with selection of adsorbent and biosorbents based on oil/tar removal efficiency. The exact combination of biosorbents required to immobilize wastes will be established experimentally. Separate tests in batch mode will be conducted to determine the most suitable combination adsorbent for a given oil concentration in water. Saturation tests will be conducted on several media combinations in batch mode. Additional tests will be conducted using a combination of activated carbon and natural zeolites. The amount of adsorbent to be added into the bed will depend on the amount of oils/tars in the mixture.

3. *Solid-liquid separation experiments.* These tests will be carried out on the two filter types: (1) high-efficiency dual function bag filter; and (2) cartridge filter. The oil/tar and

solids recovery efficiency will be determined for various dual-function filter media. The penetration depth of oils and its effects on septum/membrane clogging characteristics, two-phase flow and oil retention rates of enhanced dual-function media and the effect of particle size of material in mass transfer zone are to be established. The optimum pressure across the septum/membrane, and septum/membrane diffusion characteristics will be determined. Some exploratory tests will be conducted to determine the possibility of coagulating the oil phase in-situ using a sonochemical sensor.

The separator is a high efficiency (batch mode) filter shell into which the filter bags or cartridge filters are inserted. The filter bag type is constructed of polyethylene materials with different micron size selection. The bags include additional transport layers attached to the bag. The media to trap the oils and odorous substances will be inserted into the bag. The filter cartridge type on the other hand, does not present a lot of opportunities in terms of dual functionality. The solids and oils retained in the bags will be collected for further washing and biofiltration tests. The sludge and media from the bags will be mixed and additional material will be added to control the properties such as waste retention rates and biofiltration characteristics.

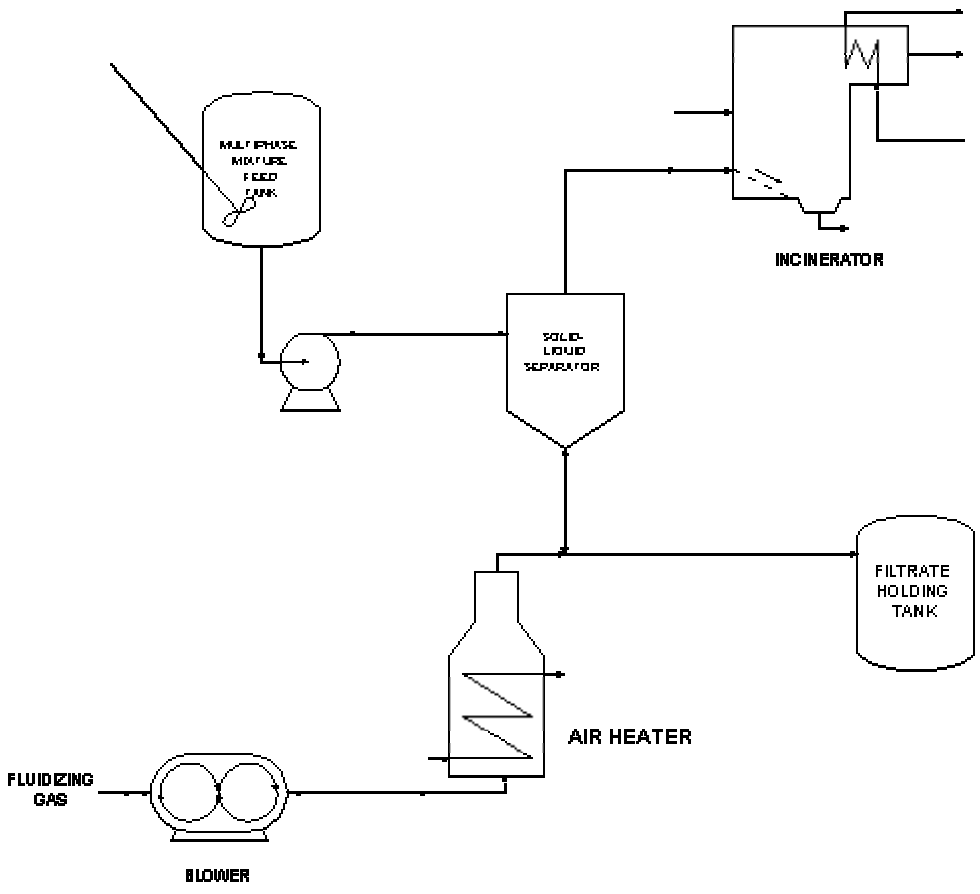

Figure 1: Major components of the experimental setup

Immobilization, washing, biodegradation and biofiltration tests: The retained solids, sludge and dual-function media in the filter bags will be conditioned for further tests. Additional material will be added to simulate injection site conditions. The resulting material (solid matrix plus waste) will be added to the depth bed (as shown in Figure 4) and washing tests will be conducted. The objective of these tests is to determine the ability of the solid matrix to retain and immobilize oily wastes in light of extenuating conditions. The solid matrix will be optimized to maximize waste retention in a finite time. Other filter bag material will be used in biofiltration tests.

In some tests, the whole bag will be inserted into a bioreactor and degradation will be allowed to take place. Washing tests will be conducted to determine leachability and biofiltration characteristics of the media. The appropriate bioreactor to be used in the experimentation is available. Only oil-eating microbes, the Biotech 2000 Formula IV, will be used in this investigation. These microbes have proven to be very effective in cleanup operations. Further tests will be conducted to determine the characteristics of injection site material (with the waste): its waste retention rates during washing and biodegradation rates (also during washing)

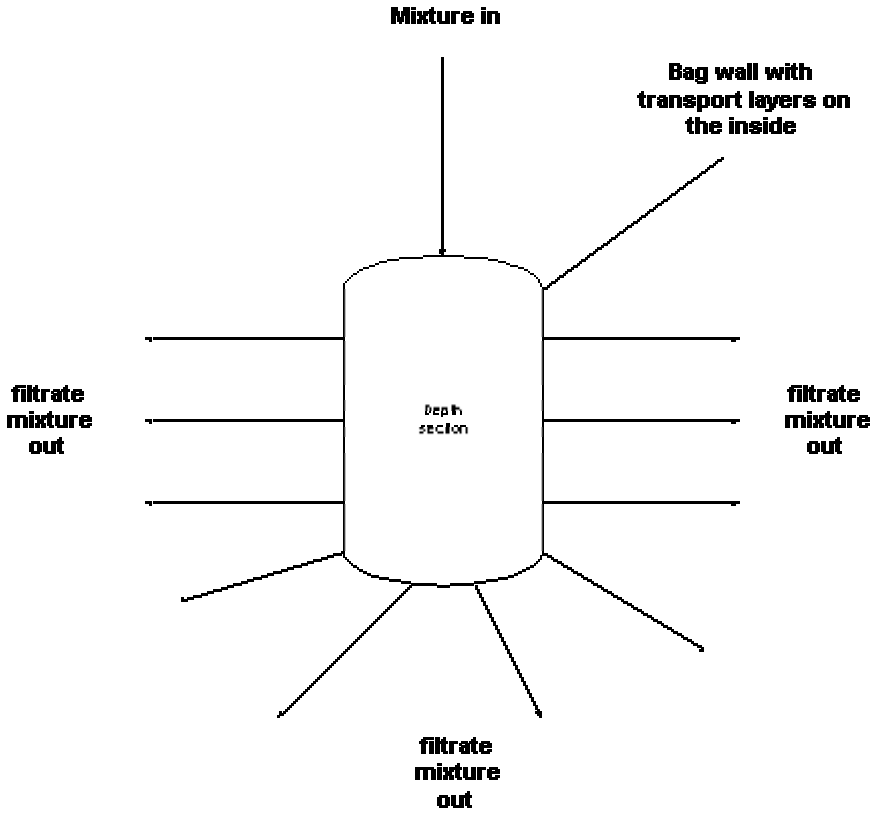

Figure: 2 Filter bag

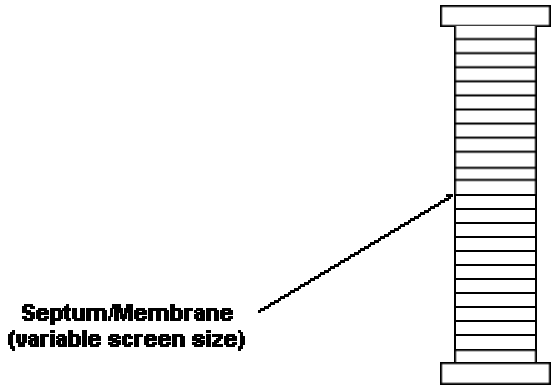

Figure 3: Filter cartridge

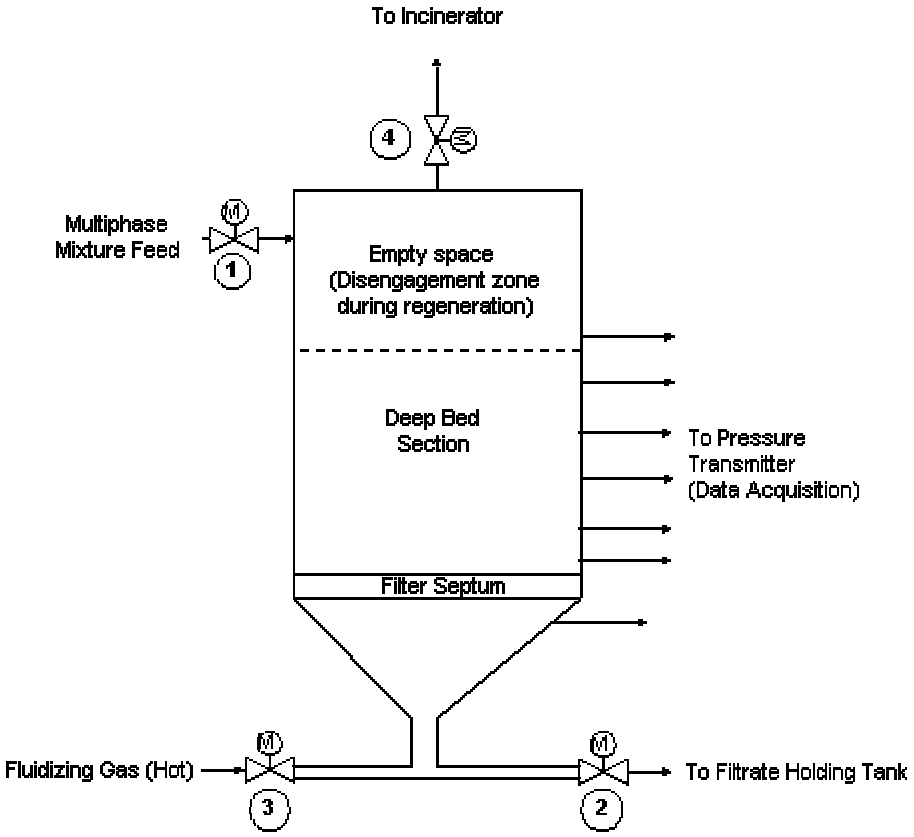

Figure 4: Major components and instrumentation of the solid-liquid separator

Facilities

The investigators in the Department of Chemical Engineering have adequate laboratory facilities necessary to carry out this research. In addition, they will collaborate informally with the personnel at the tuna factory (US Filter Corp.) facility who are generating and handling sludge. Approximately two millions gallons of wastewater are processed/treated daily at this facility to generate 40,000 gallons of sludge. In addition to the available high-efficiency depth filter and associated equipment (worth $15,000), PIs will utilize analytical instrumentation (worth $50,000). Dr. Mehta manages most of the instruments and, analytical work is crucial to the success of this project. The Unit Operations laboratory and Machine Shop are up to-date. In addition the department has access to instrumentation laboratories in the Chemistry Department. Porous media test cells (in Figure 4) will be constructed in the shop from Plexiglas.

Two high-efficiency depth filters will be used in this research. One complete high-efficiency depth filtration experiment is available. It is being used to conduct feasibility studies into separation of oils and odorous organic solids from tuna wastewater. In order to use this setup for conducting experiments in this project, additional equipment must be bought such as a high capacity pump (to handle dual-function media) and large tanks to handle sludge.

Utilization of the results

The results of this study will lead to designs of solid-liquid separators used in wastewater treatment that are not affected by the presence of fat, oils, grease and fine particles in wastewater mixtures. Primarily it will lead to development of cheap and effective dual-function media for use at injection sites.

Related Research

This proposal focuses on development of novel dual-function media matrix. The PI's expertise is in the field of multiphase transport phenomena applied to complex solid-liquid separations, washing, multiphase-multicomponent mixtures, mass transport through porous media and fluidization. The equations of change for dispersed multiphase systems were previous developed and there is an abundant literature on this subject (including Bogere, 1993; Bogere and Willis, 1992a & b, 1993; Choo, 1988; Hassanizadeh, 1986; Hassanizadeh and Gray, 1990; Willis *et al.*, 1991). The PI has initiated studies of complex solid-liquid separations from wastewater containing oils/grease/tars and odorous solids. The research is an extension of previous studies and the goal here is to determine experimentally the cost-effective methods for industrial waste disposal and wastewater handling. The PI (Mehta) has performed extensive studies in bioremediation and this expertise will be utilized in biodegradation and biofiltration tests.

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