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SEDIMENT TREATMENT-ON THE THRESHOLD OF COMMERCIALIZATION?

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ABSTRACT

As the agency with responsibility for dredging the nation's navigation channels, the Corps of Engineers is keenly interested in the potential for treatment of contaminated sediments that would otherwise require confined disposal of some type. The concept of contaminated sediment treatment is not new, and a significant amount of bench and pilot scale testing has been conducted over the last 20 years. The path to commercialization, however, has not been straightforward. Contaminated sediment presents unique challenges for treatment, due to the character and complexity of the matrix, and the logistics and economics involved in coupling the process with a dredging operation. Further, there is considerable variability in the way treatment demonstrations are monitored and the data evaluated, resulting in some uncertainty with respect to their general applicability and potential for success.

The U.S. Army Engineer Research and Development Center (ERDC), together with Environ Corporation, undertook an effort to assess the present "state of the art" in sediment treatment technology. The evaluation was focused on four treatment technologies that seem to be nearest to commercialization, having been demonstrated at pilot or greater scale in one or more technology development programs. The available data for these technologies were investigated in order to re-evaluate the processes within a consistent framework. The findings have been revealing with respect to where contaminant removal and losses occur, what sampling and analysis is necessary to fully document and understand the performance of a process, and the various ways in which efficiency can be defined, each with entirely different implications with respect to the overall effectiveness and economics of a process. These findings are currently being consolidated into a summary report, which is hoped to form the basis for a uniform technology evaluation template, providing greater transparency to the processes, the treatment mechanisms, and the technology applications and limitations. The findings are summarized here with a focus on "lessons learned" from the evaluation process.

Keywords: contaminated sediment, technology evaluation, mass balance, efficiency, cost

INTRODUCTION

The concept of contaminated sediment treatment producing a useful product has emerged in recent years, motivated by the cost of sediment disposal and by recognition of sediment as a resource rather than a waste. Contaminated sediment presents unique challenges for treatment, however, due to the character and complexity of the matrix, and the logistics and economics involved in coupling the process with a dredging operation. Despite periodically intensive testing and development efforts over the last 20 years, under multiple programs, only a handful of sediment technologies are sufficiently mature to be near commercialization. In a cooperative effort jointly funded under the U.S. Army Corps of Engineers (USACE) Dredging Operations and Environmental Research Program (DOER) and EPA Technology Innovation Program, ERDC and Environ Corporation conducted an intensive evaluation of four ex-situ treatment technologies that appear to be commercially viable. Objectives of the effort were to better understand the mechanisms of treatment, potential applications, effectiveness, and full scale implementation cost. One outcome of the effort was a template that can be employed for transparent mass balance documentation and equivalent technology comparisons. Results of the evaluation will be published as a tool for individuals and agencies with responsibility for contaminated sediment management in both government and private sectors.

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Although the concept of treatment is almost universally appealing, cost and logistical issues have prevented the full scale implementation that would further mature these developing technologies. Treatment per se is therefore regarded as a niche application, and one that is subject to a relatively high level of uncertainty. However, as disposal options for contaminated materials become more limited and more expensive, the potential for broader applicability and economic support increases. There are other obstacles, however, notably the disparity between dredge production and treatment capacity. Further, sediments present a difficult medium to work with, generally characterized by high water content, debris, and complex mixtures of contaminants. Some level of pre-treatment is generally required in order to condition the materials for the core treatment process. Depending upon the efficiency of the treatment, some level of post-treatment residuals management is also required. Often these processes are not reflected in treatment cost estimates.

Because a treatment technology effective with one group of contaminants may not be effective with another, treatment must be tailored to the particular suite of contaminants present. Multiple technologies might need to be considered where complex mixtures are present (organics and metals for example). Overall effectiveness, however, is in part a matter of definition. An effective treatment is one that meets project objectives, including regulatory requirements. An efficient treatment is one that maximizes contaminant destruction or immobilization while minimizing residuals and cost. Clearly, effectiveness and efficiency is not necessarily the same thing, and the most efficient process is not always the most desirable one, depending upon the treatment objectives. These are all considerations that the project manager needs to understand in order to fairly consider sediment treatment and to compare technologies on the basis of suitability and cost.

APPROACH

A detailed process review was performed on four ex-situ sediment treatment technologies having the potential for producing a beneficial use product in conjunction with treatment. The technologies/beneficial use products were:

- Rotary kiln thermal treatment/construction-grade light-weight aggregate (LWA)
- Cement-lock™ (thermal) technology/construction-grade cement
- Minergy® glass furnace technology/glass aggregate
- BioGenesis™ sediment washing technology/manufactured soil

All four technologies met the following criteria:

- applied to contaminated sediments
- demonstrated at pilot scale or greater in a technology verification program
- potential for commercialization or near commercialization
- treating or immobilizing contaminants (metals and organics)
- generating a product suitable for beneficial use
- potential for scalability and mobility.

The goal of the first phase of this effort was to capture process demonstration histories and available performance data for these technologies from information available in the public domain. Technology briefs were prepared to highlight the major processes and considerations. Detailed technology evaluations included:

- Process flow diagrams (PFD), developed to reflect pre- and post-treatment processes required for integration with a dredging operation, and to evaluate material and contaminant pathways throughout the treatment train.
- Materials and contaminant mass balances, reconstructed on the basis of data obtained from published reports.
- Performance evaluation, based on the reconstructed mass balances.

Strictly physical technologies, such as solids separation were not included since they address only volume reduction, not contaminant destruction or immobilization. Also, the operations utilized in cement-based solidification and stabilization are so commonly practiced that it is unlikely that the technology could be considered proprietary, although at one time a number of proprietary binding agents were being marketed. The Harbour Resource technology, which combines chemical oxidation with stabilization, was initially considered for this effort. However, process data was not readily available, and results of the demonstration conducted under the New Jersey Department of Transportation (NJDOT) Sediment Decontamination Demonstration Project (http://www.nj.gov/transportation/airwater/maritime/dresediment.shtm) did not demonstrate consistent effectiveness, so this technology was not carried through the evaluation.

TECHNOLOGY EVALUATION MEASURES

The selected technologies were compared based on a set of qualitative and semi-quantitative parameters adapted from criteria developed by EPA Region IX for evaluation of remedial technologies (personal communication, Kelly Madalinski (formerly with USEPA, Technology Innovation Office (TIO)), September 12, 2006). The parameter list developed for this effort includes:

- Developmental status
- Target contaminants/concentration ranges
- Byproduct formation
- Pre- and post-treatment requirements
- Engineering considerations
    - Continuous or batch operation
    - Footprint
    - Problems encountered
    - System disruption
    - Capacity
- Performance
    - Contaminant and material mass balance
    - Contaminant fate
        - Phase transfer
        - Immobilization
        - Destruction
    - Effectiveness/efficiency
    - Nature and magnitude of process residuals
- Beneficial use products
- Cost/economics

The following are some insights on the importance of these criteria.

Applicability to the contaminants present at a site is an obvious selection factor. While there may be applications for contaminant specific technology types, most contaminated sediments contain a mixture of compounds, requiring a treatment technology capable of treating both organics and metals. In addition, some technologies are more effective on sediments with low to moderate contaminant levels, while others are equally effective for sediments with high contaminant concentrations. The level of efficiency needed versus the cost to achieve that level of efficiency is generally a consideration. Treating to a level suitable for beneficial use requires a higher level of performance than treating to a level that will allow less restrictive and less costly disposal, for example.

The potential for formation of toxic treatment byproducts is certainly of concern to the communities where these technologies will be utilized, as well as to regulators who will permit the process, and to the project manager, who may have to manage these as residuals or protect against releases. Staging area requirements vary and may influence cost as well as applicability. Having ample room to provide necessary surge capacity or equipment for slurry thickening, for example, can have a significant effect on the plant throughput; this in turn impacts dredge operating efficiency. Significant incompatibility of scale anywhere in the system (from dredge to product) potentially translates to increased cost.

Reliability of the processes considered here is a difficult factor to assess at this stage of development. Most of the demonstrations encountered various problems, as would be expected, in growing the technologies from bench to pilot or larger scale. Long-term performance data is simply not available yet. Documenting conditions that were particularly problematic, however, is expected to be helpful to the remediation project manager in considering suitability for a particular site or material. The two questions that are typically the first to be posed are, “How efficient is the technology?” and “How much does it cost?” These are unfortunately not simple questions to answer, but we have endeavored to evaluate the efficiency of the technologies on an equivalent basis, from the perspective that would be important to a consumer of the technology, and to extrapolate the cost data provided to facilitate unit cost comparisons. The results of those efforts will be detailed in the final report.

PERFORMANCE EVALUATION

Technology performance was evaluated by reconstructing the mass balance for each of the processes using data provided in the technology demonstration reports.

A conceptual pre-treatment process was developed (Figure 1) and representative process flow diagrams were prepared for the core unit operations of the treatment train, similar to that shown here for the rotary kiln technology (Figure 2). Data were organized into process streams for each technology, as illustrated in Table 1 for the rotary kiln process. Material and contaminant mass balances were then prepared in order to estimate magnitude of associated residual process streams and to evaluate treatment effectiveness. Table 2 is the materials balance prepared for the rotary kiln process, and Figure 3 is the graphical representation of those process streams. Figure 4 illustrates the materials balance for Biogenesis, reflecting the higher water inputs and resulting aqueous waste stream to be considered with this technology.

Figure 5 illustrates the relative fate of arsenic in the rotary kiln system, based on the reconstructed mass balance. Figure 5 illustrates that only a portion of the arsenic coming into the system is accounted for in the light weight aggregate matrix. A slightly higher amount of the arsenic reported with the particulates lost to the off-gas streams from kiln and dryer. The overall efficiency of the process, which takes into account all process inputs and outputs, will therefore be lower than the decontamination efficiency, which takes into account only the portion of contaminant immobilized in the product or destroyed, relative to the total contaminant coming into the process. These are important distinctions not consistently addressed in the data evaluation accompanying the process demonstration reports. Complete mass balance calculations and summaries will be published in the final report (currently in preparation) for each of the four technologies evaluated.

Each of the technology development vendors provided some level of economic analysis for their process. However, there were major inconsistencies in the baseline assumptions. In some cases it was not clear what specific assumptions had been made, and whether such elements as system startup, mobilization and demobilization costs, overhead, profit, or product revenues had been included in the reported unit costs. An integrated approach was needed, taking into account not only the costs of treatment, but also of pre-treatment and management of residuals. From the various cost estimates provided, a comprehensive list of cost components was developed. Where a value was provided by one vendor but not by another, an estimate was derived based on the available vendor estimate and other information. In this way, cost data gaps were filled and comprehensive unit treatment costs developed for each technology. Sensitivity of the estimated unit costs to variation in major cost elements was evaluated and the results are qualitatively illustrated here in Table 3. Table 3 illustrates, for example, the relative importance of energy costs on thermal technologies, and the potential impact of wastewater treatment to cost of soil washing processes.

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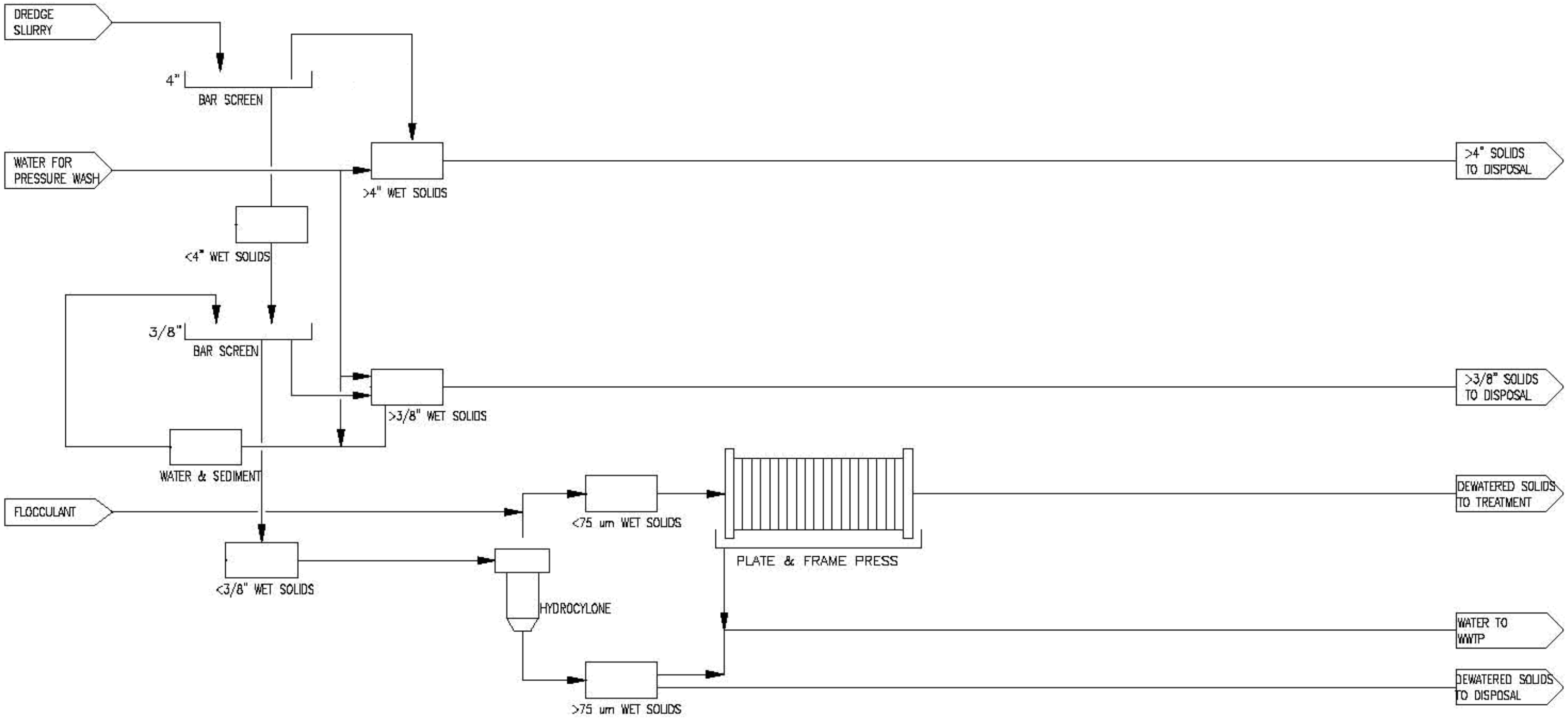

Figure 1. Conceptual pre-treatment process.

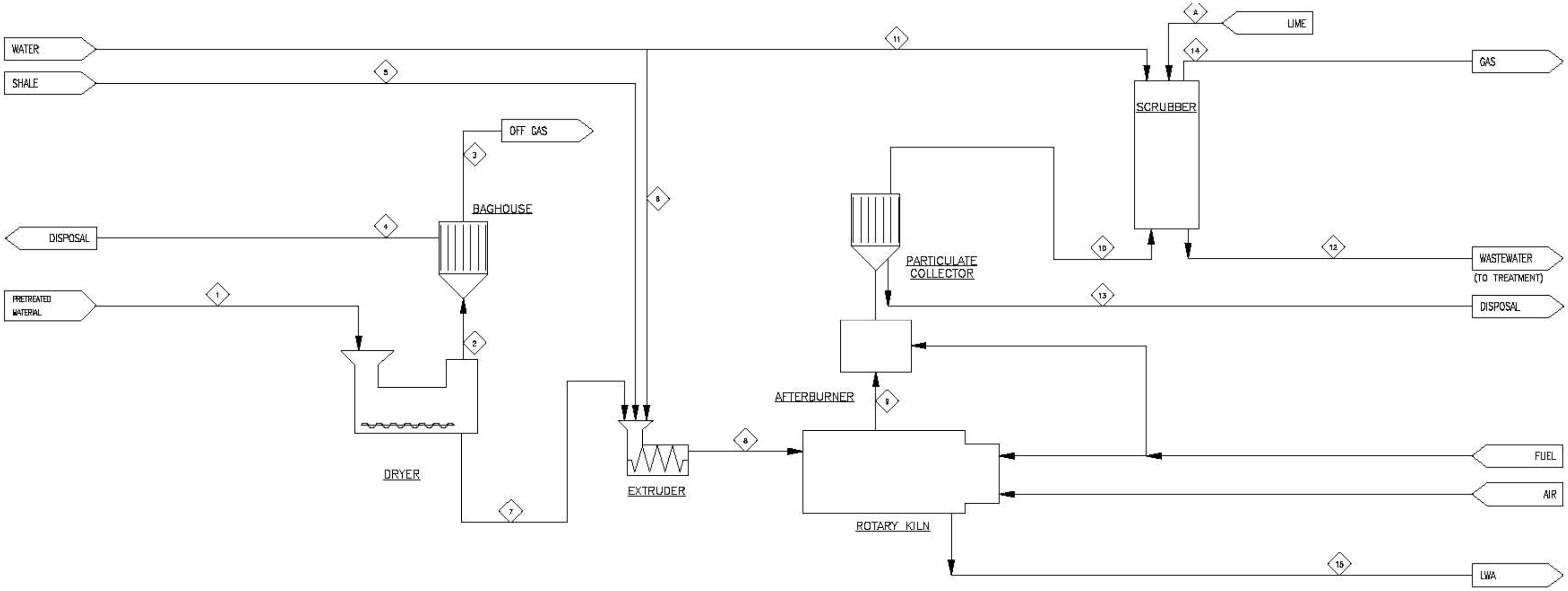

Figure 2. Rotary kiln process flow diagram.

Table 1. Data summary for rotary kiln technology.

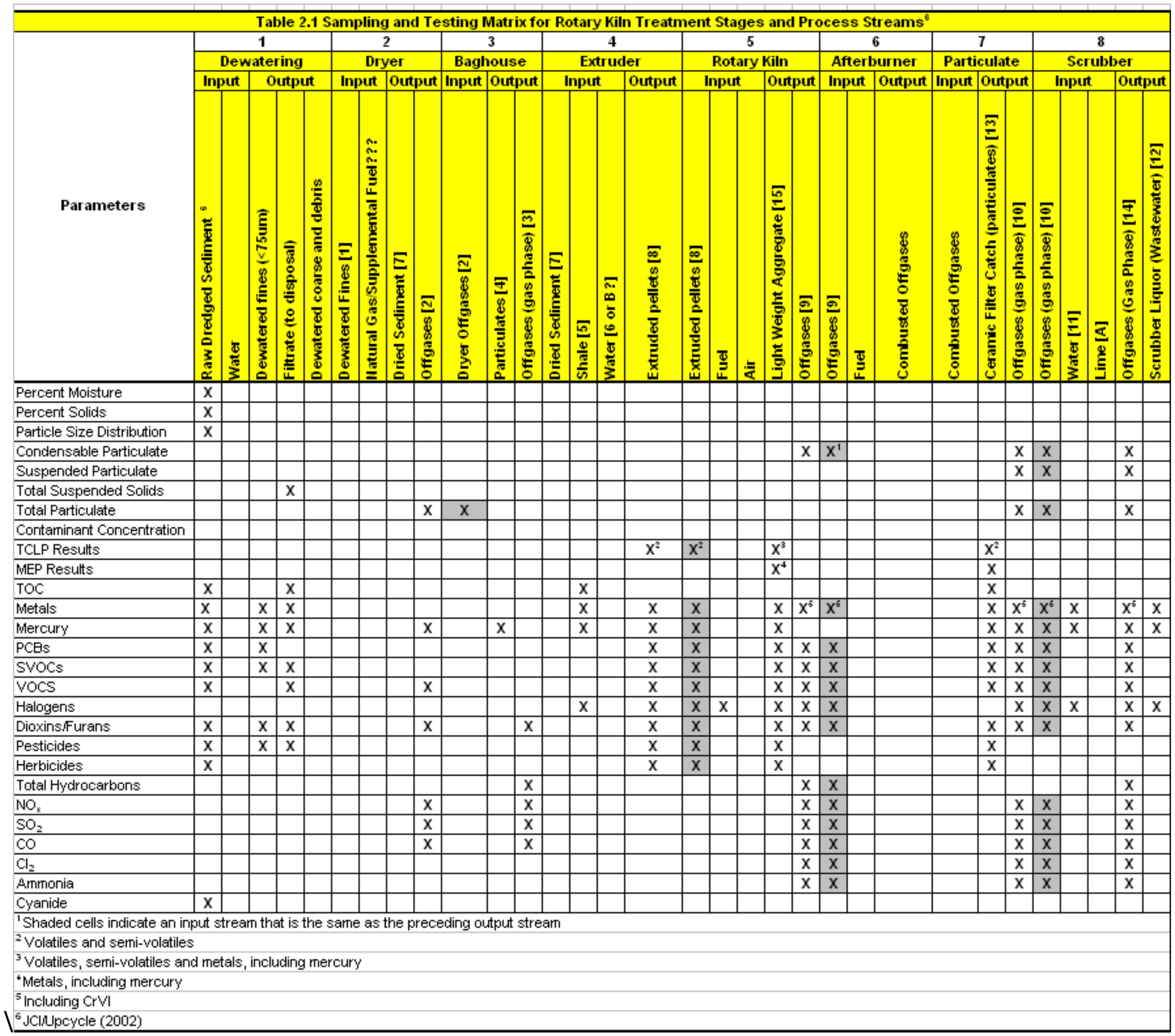

Table 2.1 Sampling and Testing Matrix for Rotary Kiln Treatment Stages and Process Streams[6]

	1					2				3			4				5					6			7			8				
	Dewatering					Dryer				Baghouse			Extruder				Rotary Kiln					Afterburner			Particulate			Scrubber				
	Input		Output			Input		Output		Input	Output		Input			Output	Input			Output		Input		Output	Input	Output		Input			Output	
Parameters	Raw Dredged Sediment [6]	Water	Dewatered fines (<75um)	Filtrate (to disposal)	Dewatered coarse and debris	Dewatered Fines [1]	Natural Gas/Supplemental Fuel???	Dried Sediment [7]	Offgases [2]	Dryer Offgases [2]	Particulates [4]	Offgases (gas phase) [3]	Dried Sediment [7]	Shale [5]	Water [6 or B?]	Extruded pellets [8]	Extruded pellets [8]	Fuel	Air	Light Weight Aggregate [15]	Offgases [9]	Offgases [9]	Fuel	Combusted Offgases	Combusted Offgases	Ceramic Filter Catch (particulates) [13]	Offgases (gas phase) [10]	Offgases (gas phase) [10]	Water [11]	Lime [A]	Offgases (Gas Phase) [14]	Scrubber Liquor (Wastewater) [12]
Percent Moisture	X																															
Percent Solids	X																															
Particle Size Distribution	X																															
Condensable Particulate																					X	X^1					X	X			X	
Suspended Particulate																											X	X			X	
Total Suspended Solids				X																												
Total Particulate									X	X																	X	X			X	
Contaminant Concentration																																
TCLP Results																X^2	X^2			X^3						X^2						
MEP Results																				X^4						X						
TOC	X			X										X												X						
Metals	X		X	X										X		X	X			X	X^5	X^5				X	X^5	X^5	X		X^5	X
Mercury	X		X	X					X		X			X		X	X			X						X	X	X	X		X	X
PCBs	X		X													X	X			X	X	X				X	X	X			X	
SVOCs	X		X	X												X	X			X	X	X				X	X	X			X	
VOCS	X			X					X							X	X			X	X	X				X	X	X			X	
Halogens														X		X	X	X		X	X	X					X	X	X		X	X
Dioxins/Furans	X		X	X					X			X				X	X			X	X	X				X	X	X			X	
Pesticides	X		X	X												X	X			X						X						
Herbicides	X															X	X			X						X						
Total Hydrocarbons												X									X	X									X	
NO_x									X			X									X	X					X	X			X	
SO_2									X			X									X	X					X	X			X	
CO									X			X									X	X					X	X			X	
Cl_2																					X	X					X	X			X	
Ammonia																					X	X					X	X			X	
Cyanide	X																															

[1] Shaded cells indicate an input stream that is the same as the preceding output stream

[2] Volatiles and semi-volatiles

[3] Volatiles, semi-volatiles and metals, including mercury

[4] Metals, including mercury

[5] Including CrVI

[6] JCI/Upcycle (2002)

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Table 2. Rotary kiln materials balance calculations. Columns in A,E,F, and L are inputs to the process, columns B,G,H,I,J, and K) reflect movement of materials within the process and columns C,D,M,N,O, and P reflect process outputs (from data contained in JCI/Upcycle 2002 and JCI/Upcycle Associates, LLC, 2004).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
Process Stream	**Filter Cake Into Hammermill Dryer**	**Hammermill Dryer To Baghouse**	**Offgas Beyond Baghouse**	**Baghouse Solids**	**Shale Added to Extruder**	**Water Added to Extruder**	**Filter Cake To Extruder**	**Extrudite Pellets To Kiln**	**Fuel Oil to Hammermill/ Rotary Kiln/ Afterburner**	**Total Kiln Offgas**	**Offgas To Scrubber From Particle Collection**	**Water to Scrubber**	**Alkali Wastewater From Scrubber**	**Particles from Ceramic Collector to Disposal**	**Scrubbed Gas**	**LWA measured**
Stream Number	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**		**9.0**	**10.0**	**11.0**	**12.0**	**13.0**	**14.0**	**15.0**
Units	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**	**kg**
Total Solid Input	2950	1818	0	186	485	0	1133	1868	0	469	0	0	0	166	0	1399
Water Content	57.0%	89.8%			0.5%		4.4%	16.2%						0.0%		0.0%
Dry Weight Solids	1269	186	0	0	483	0	1082	1565	0	0	0	0	0	166	0	1399
Water	1682	1631	1631	0	2.5	250	50	303	0	0	303	0	303	0	0	0

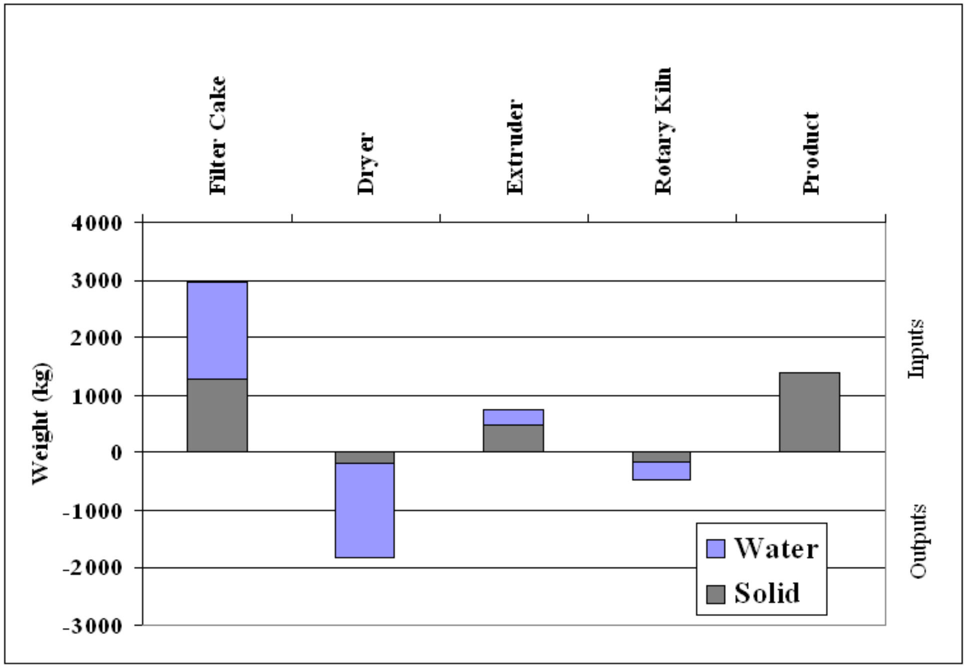

Figure 3. Rotary kiln system materials balance.

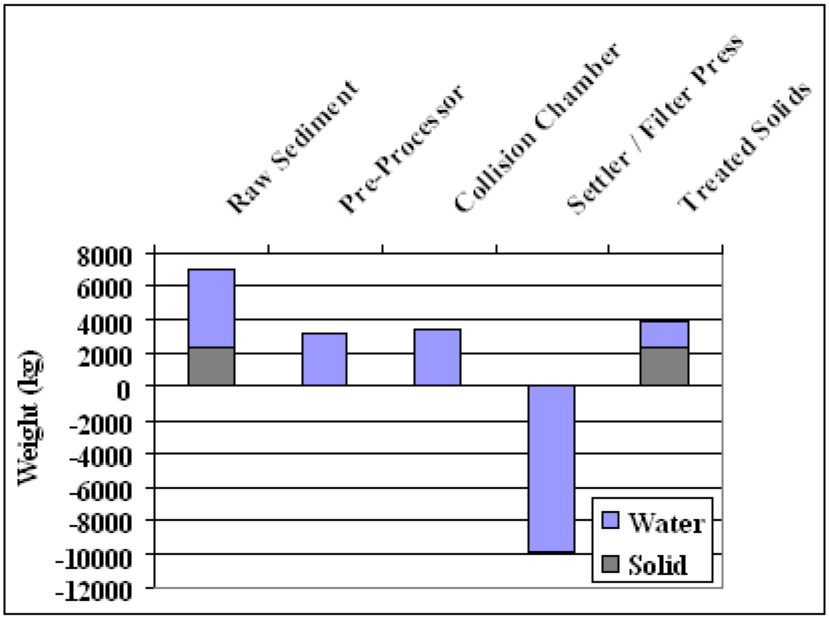

Figure 4. Biogenesis material mass balance. Mass balance figures generated from data contained in Biogenesis and Weston (1999).

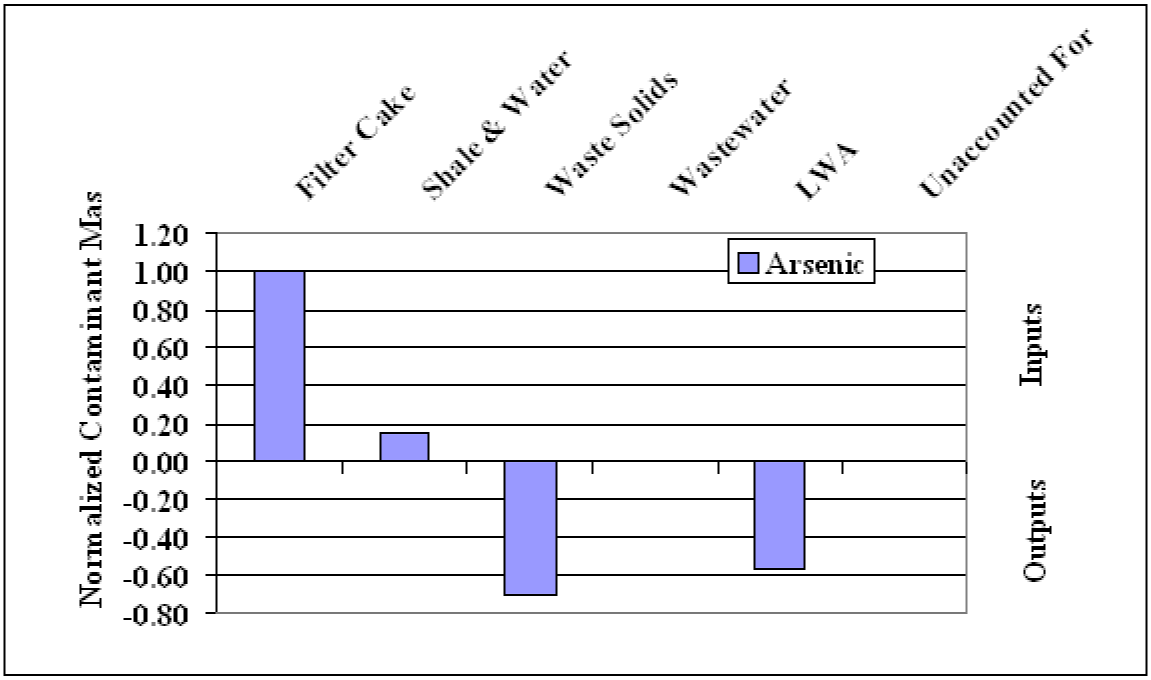

Figure 5. Arsenic mass reporting to respective process streams for rotary kiln technology. Mass balance figures generated from data contained in JCI/Upcycle (2002) and JCI/Upcycle Associates, LLC. (2004).

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Table 3. Qualitative cost sensitivity analysis.

	Plant Capacity	Energy Costs	Residuals Treatment Cost	Labor Costs	Capital Costs	Operating Costs	BUP
Rotary Kiln		**Moderate**	**Low**	**Low**	**Moderate**	**Moderate**	**Moderate**
Cement Lock	**Moderate**	**High**	**Low**	**Low**	**High**	**Moderate**	**Moderate**
Minergy		**Moderate**	**Low**	**Low**	**Moderate**	**Moderate**	**High**
Biogenesis	**High**	**Low**	**High**	**High**	**Moderate**	**High**	**High**

GENERAL CONSIDERATIONS FOR TECHNOLOGY SELECTION

Pre-treatment Requirements

Technologies differ with respect to pre-treatment requirements for the feed. All technologies will require removal of large scale debris and sediment solids that are too large to pass through system pumps or that are too abrasive for certain pieces of equipment. Thermal technologies typically also require the moisture content of the feed to be reduced in a drying step. The complexity of pre-treatment requirements has the potential to significantly influence the cost of treatment, and should always be considered in any alternatives analysis where sediment treatment is being considered.

Decontamination or Treatment Efficiency

Some technologies may effectively treat the sediment without actually removing or destroying the contaminants. Through a variety of chemical reactions, contaminants can be immobilized in the treated sediment matrix such that they do not readily leach or volatilize, are not bioavailable, and therefore do not represent a significant environmental or human health risk. In other cases, the sediment is treated by transferring contaminants from the solid (sediment) phase to an aqueous phase, as in soil washing, or to the gas phase, as in thermal desorption. In all cases, there may be some incidental contaminant losses in addition to contaminant reduction due to “treatment”.

Treatment efficiency (or percent removal) and decontamination are terms often used interchangeably as a measure of the contaminant reduction in the solids within the system. You may infer from the preceding paragraph, however, that a process may be highly efficient in terms of removing contaminant from the sediment without being efficient in terms of contaminant destruction. It is important to distinguish between overall process efficiency (total output vs. total input), stage efficiency (stage output vs. stage input, or “*where in the process*” the treatment is occurring), and decontamination efficiency (final sediment concentration vs. initial sediment concentration). Each has different implications with respect to overall environmental impact, utility of additional treatment stages, magnitude of residuals, and contaminant levels in the final sediment product. It is also important to distinguish between contaminant immobilization, contaminant destruction, and simple phase transfer of contaminants, the latter process resulting in residuals that must be managed.

Residuals Treatment Requirements

Processes that generate secondary process streams such as wastewater or spent sorbent are said to generate residuals. All treatment technologies produce some residuals, and these process streams may also require treatment and/or some type of controlled disposal. Processes that destroy or immobilize contaminants produce less residuals than those that transfer contaminants from the sediment phase to another phase. Cost to manage residuals should be considered in feasibility evaluations.

Mass Balance – Challenges and Limitations

To completely describe the fate of contaminants in a treatment process, the movement of solid and liquid materials through the system must be considered in conjunction with the changes in contaminant mass or concentration. Contaminant reduction that might otherwise be ascribed to treatment may be found to be due to loss of a particular size fraction of the solids, to transfer from the solid phase to the aqueous phase, or even to analytical limitations. Accounting for these different loss mechanisms is integral to understanding the manner in which treatment is achieved and the actual efficiency of the process. Obtaining data that fully accounts for all material and contaminant coming into, passing through, and leaving the system can be challenging. Contaminants may be present at concentrations too low to detect, but if the process stream is large enough (such as thermal off-gases, for example), this may still represent a significant mass loss. Because one cannot follow a single sample through a treatment process, monitoring the actual effect of the process is hampered by the difficulty in discriminating between treatment effects and simple variability of the feed. For continuous processes, comparison of average sample properties for multiple samples taken over an extended period of time may provide the best indication of process performance. Representative sampling is integral to obtaining the best data possible and is always difficult, but especially so when dealing with slurries that have a tendency to settle in process vessels, or even while flowing through pipes. Sampling points and method of capture should take material behavior into consideration.

Capacity and Scale Up

Navigation dredging is typically conducted over a few weeks or months each year, often at different locations from year to year, at a production rate that far exceeds the capacity of any treatment technology developed to date. These conditions require a treatment technology to have high capacity while being either relatively mobile or a centrally located plant convenient to multiple projects and perhaps capable of processing multiple types of materials. Large capacity plants are not typically mobile; however, nor are they economic without a sustained and continuous feed supply, factors which have impeded the establishment of sediment treatment as a viable commercial operation to date.

Environmental dredging operations that are coupled with separation and dewatering circuits illustrate the issue of process scale. While typical navigation dredge production rates may range from 3,000 yd^3/day to 10,000 yd^3/day, an environmental dredge may produce only 200 to 500 yd^3/day. Even at this reduced production rate, however, the environmental dredge may be limited to operating at 40 to 50 percent of capacity in order to keep the scale of land based operations reasonable in terms of size and cost. Significant surge capacity and/or storage areas are typically required to address this disparity.

Economics

While all of the technologies demonstrated under the validation programs were required to provide cost estimates for operation at full scale, direct comparisons are difficult. Baseline assumptions differ considerably from one technology to another. The period of capital cost recovery, annual production, and assumptions regarding revenues produced from the sale of beneficial use product vary greatly. Further, what has often been missing from cost projections are costs associated with pre-treatment, cost impacts of reduced dredge production, impact of intermittent or short-term feed supply and cost to treat and dispose of residuals. These are not insignificant issues. An estimate of the "integrated" cost of the treatment process, inclusive of these factors and derived from the same baseline is needed for each of these technologies. Establishing a template for equivalent and realistic cost comparison is one of the objectives.

Safety and Public Acceptability

Concerns regarding public health, safety and comfort are common to all treatment technologies. Depending upon the type and degree of contamination, accidental inhalation, ingestion and skin contact with the raw sediments prior to or during processing can be a cause of concern for workers on site. Potential for contaminant transport off-site is usually of concern to the general public, as well as aesthetics, and impacts on property values and local traffic. Public acceptance of a treatment plant may therefore be difficult to achieve in many locations. The public will require reassurance of the safety of the process through analysis, testing, real-time monitoring and adequate resolution of other issues.

Risks associated with all technologies include potential for contaminant losses through fugitive dust, volatile emissions, wastewater releases, incidental system failures and long term leaching or volatilization from products. Sediments may produce toxic gases, such as hydrogen sulfide, during processing. Appropriate gas monitoring devices, alarms and ventilation systems may be required, particularly in enclosures, to ensure worker and community safety. Increased traffic in the vicinity of the treatment plant may pose a hazard, and certainly a nuisance, in some locations.

Hazards specific to thermal treatment technologies include high temperature zones within the plant, potential for release of combustible gas mixtures from fuel supply lines, kilns and afterburners, and spills of molten material. The normal equipment cool down period may be lengthy (as much as a week), which could be problematic to emergency operations in the staging area. Redundant system safety shutoffs, gas monitoring devices, alarms, ventilation systems, containment to restrict flow of fluid releases, or of the melt in the event of catastrophic failure, elevated work platforms, emergency quench water and explosion proof equipment may all be necessary to address these hazards.

The soil washing process evaluated here utilizes extremely high pressures (10,000 psi) in conjunction with strong oxidants. Structural failure of pressurized lines and vessels is a potential risk. There is potential for chemical exposure for all of these processes during normal handling or as a result of equipment failure. Oxidants and lime are examples of chemicals used. Both solid and liquid forms may present contact, inhalation and ingestion hazards. Under certain circumstances, solids in powdered form (such as activated carbon) pose the additional risk of asphyxiation due to oxygen depletion in the air. Forced ventilation, specialized storage and handling procedures, containment, spill kits, shower stations, personal protective equipment and emergency response plans may be required to address these risks adequately.

Approval and Permitting Requirements

USEPA (1994) provides a partial list of federal environmental laws and regulations potentially applicable to a sediment remediation project. Permits may be required for specific remedial activities or for discharges that may result from these activities. For some regulations, the permitting and enforcement authority has been transferred to the state. Many states have additional laws and regulations that may be applicable to sediment remediation activities and to beneficial use of treated sediments. The Great Lakes Commission (Great Lakes Commission 2004) developed a regional framework for upland beneficial uses of dredged material, which includes a compilation of applicable regulations from the Great Lakes states.

CONCLUSIONS

Based on the available documentation, only two of the technologies evaluated here have been fielded for treatment of contaminated sediments more than once (Cement Lock and Biogenesis) and even these have been operated at a fairly limited scale. Minergy, however, is being used on a commercial basis for treatment of sewage sludge, and the aggregate produced by the process utilized by municipalities as trench fill. In addition, an extended duration test was completed for Cement Lock last year and the data from that demonstration is being evaluated for incorporation into the final report.

The entire treatment train, including pre- and post-treatment processes, must be considered in evaluating comparative logistics and cost of different treatment technologies. Reported value of beneficial use product requires locale specific verification. Generally, these values are based on market value of competing materials that do not suffer from the stigma of contaminants. Some performance history will have to be established before the full value of the beneficial use products can be realized.

Sometimes one or more contaminants will be recalcitrant (either not destroyed or still leachable) even after aggressive treatment. The reasons for this were not fully understood, but may be related to the phase of the sediment with which the contaminant was associated and the relative mobility, initial concentration, or other factors yet to be identified. These issues underscore the importance of complete and comprehensive sampling and data gathering, so that such trends can be better understood, and mechanisms of treatment and contaminant loss can be distinguished and accounted for. Even comprehensive data is subject to limitations, however, due to the difficulties in monitoring continuous processes, heterogeneity of feed, and difficulty in obtaining representative samples.

Unit costs reported in the literature vary widely with respect to basis and cost elements included and, given the uniqueness of the technologies, traditional cost estimating resources are of limited utility.

The issues encountered in this effort speak to the need for a more uniform and transparent monitoring and documentation process. This will enable technology consumers to make reasonably informed decisions regarding the suitability of treatment. Ultimately this will benefit the technology developers themselves, as some of the uncertainty associated with these processes may then be resolved.

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