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Document Availability

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Table of Contents

Attachments

Introduction

DTSC's Office of Pollution Prevention and Technology Development (OPPTD) has long been involved with encouraging and promoting source reduction within California's petroleum refineries. In May 2003, OPPTD and Western States Petroleum Association (WSPA) co-sponsored a pollution prevention technical forum attended by DTSC, WSPA, and environmental staff from all of California's major petroleum refiners. Approximately 40 people from northern and southern California, Washington and Texas attended this one-day event to share ideas about pollution prevention and learn something new.

The overall response to the May 2003 technical forum was very positive, a testimonial to the productive relationship developed between DTSC and the petroleum industry over the last several years. Steven Arita of WSPA stated "Members of WSPA appreciated very much working with DTSC on this technical forum. The success of the forum helped build bridges with DTSC staff and we look forward to working with DTSC in future pollution prevention seminars." Surveys indicated that most of the attendees from industry envisioned applying at least one of the technical forum topics at their facilities, and all surveyed indicated that they would attend a similar venue if it were offered next year. Some attendees expressed interest in planning next year's forum. According to DTSC Director Ed Lowry, "Creating a successful pollution prevention program relies on DTSC developing partnerships with the private sector. The real success of these efforts is the voluntary adoption of pollution prevention measures by large corporations, individuals, and small businesses. Even more impressive are benefits realized by participating business and the environment."

Background

Petroleum refineries, one of the largest industries in California, are California's largest hazardous waste generators. Since 1990, they have planned for source reduction pursuant to the requirements of the Hazardous Waste Source Reduction and Management Review Act of 1989 (SB 14). SB 14 requires hazardous waste generators to document source reduction planning efforts as well as source reduction achievements every four years. In 1993 and 1997, OPPTD compiled information from petroleum industry SB 14 documents into industry assessments and shared these assessments among the industry. A third assessment will be published and distributed in late 2003. Environmental staff at petroleum refineries have stated that these assessments provide them with useful information and ideas for source reduction.

As a result of implementing source reduction, this industry reduced their hazardous waste generation by 32% from 1990 to 1994, by 18.6% from 1994 to 1998, and by 31%[1] from 1998 to 2002 for non-waste water sources. Source reduction measures implemented on hazardous waste water streams have resulted in industry-wide reductions of 7.3% from 1994 to 1998, and 19%[2] from 1998 to 2002.

[1] The percentages for hazardous waste source reduction from 1998 to 2002 are preliminary, were calculated based on available data, and represent most but not all of California's refineries. These percentages are subject to change once additional data becomes available and the data is evaluated in greater detail.
[2] Ibid.

Since 2000, representatives from the petroleum refining industry have been involved in the Pollution Prevention Advisory Committee convened in accordance with the provisions of SB 1916 (1998). This committee has been working with DTSC by providing input on direction for DTSC's pollution prevention program. Petroleum industry representatives were also involved at the inception of a voluntary refinery pollution prevention project, which was cancelled for security reasons due to the events of September 11, 2001. Building on the relationships and momentum developed during the first refinery project, the Advisory Committee supported the idea of a pollution prevention technical forum involving petroleum refiners.

A small planning team convened in fall 2002 to design and plan the technical form. The seven member planning team included representatives from OPPTD, WSPA, BP refinery in Carson, and the Tesoro Golden Eagle and Shell refineries in Martinez. The team met on five occasions to identify problematic refinery waste streams, identify technical topics and speakers, and plan a technical forum to match the needs and interests of the industry.

The 2003 Technical Forum

The 2003 WSPA/DTSC Joint Pollution Prevention Technical Forum featured representatives from industry and government who spoke on the following topics:

- Biologically activated carbon and bioreactivation of granular activated carbon, Behzad Mirzayi, Sub Surface Waste Management.
- Spent abrasives recycling, Greg Weyl, Kleen Industrial Services.
- Industrial ecology – applying the principals of ecology to industrial development and regional economic development, Gil Friend, Natural Logic.
- The new Summary Progress Report form required by SB 14, Leslie Goodbody, OPPTD.
- Universal Waste Rule, Mike Horner, State Regulatory Programs Division.
- Drum-top Fluorescent Lamp Crushers, Suzanne Davis, OPPTD.

The above presentations are summarized in proceedings included in the following sections. Question and answer sessions, which occurred at the end of each presentation, are documented at the end of each proceeding. Correspondence and supporting materials provided by each presenter are included as Attachments to these proceedings.

Future Activities

Pursuant to suggestions provided by forum attendees, a larger technical forum planning team has convened to consider ideas for a 2004 technical forum. The planning team is considering topics such as:

- A multimedia discussion on soils management;
- Policies and procedures for a pollution prevention program;
- Results from the 2003 forum – which technologies were applied, what worked, what didn't; and
- Opportunities and obstacles to source reduction and improved waste management practices.

Bio-recycling of Spent Granular and Powdered Activated Carbon Filtration Media

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Chief Engineer Sub Surface Waste Management, Inc.

Abstract

Over 360 million pounds of spent granular activated carbon are recycled off-site at thermal treatment facilities in the U.S., and unknown quantities are landfill disposed. ***BAC***Ô and ***Bio-GAC***Ô bio-recycling has been perfected within the guidelines developed by California Environmental Protection Agency (Cal EPA), California Department of Toxic Substances Control (DTSC), USEPA, and South Coast Air Quality Management District (AQMD) for on-site recycling of spent activated carbon filtration media.

BACÔ and ***Bio-GAC***Ô have been developed using proprietary microbe blends to "metabolize and degrade" the adsorbed contaminants in the Granular Activated Carbon (GAC) media. The byproducts of this process include carbon dioxide, water, and non-hazardous biomass. Extensive active process test results have indicated that the chemical and physical properties of the bio-recycled activated carbon (***BAC™***) are equal or better than those of thermally regenerated carbon, and are actually comparable to some grades of virgin carbon. The ***Bio-GAC™*** system consists of traditional granular activated carbon units typically used for adsorption of hydrocarbons that are enhanced with a bioreactor upgrade modification. The ***Bio-GAC™*** system utilizes the activated carbon as the adsorber, and a bio-bed similar to activated bio-bed bioreactors used in a wastewater treatment plant. The advantage of this system over traditional GAC is that the system is very effective in the treatment of methl-tert-butyl ether (MtBE) and its byproducts such as tertbutyl alcohol (TBA), resulting in typical cost savings of up to 50 percent relative to traditional GAC systems. This technology has been evaluated by DTSC with the determination that on-site bio-recycling of spent carbon filtration media is exempt from permitting under California's recycling law.[3] AQMD has also evaluated this technology and its status on air permitting requirements is pending.

Introduction

Activated carbon (AC) is the generic term used to describe a family of carbonaceous adsorbents having a highly crystalline form and extensively developed internal pore structure. A wide variety of activated carbon products is available exhibiting markedly different characteristics depending upon the raw material and activation technique used in their production. Activated carbon can be produced from a variety of naturally occurring substances including: bituminous, lignite coal, nutshells (coconut), wood and peat. Once the carbon containing material is processed and impurities are removed, the carbon needs to be activated. The activation process removes other organic residues and changes the structure of carbon to an amorphous form. During this process, the porosity of the carbon increases

[3] California Health and Safety Code Section 25143.2; see specific discussion in *Question and Answers* located at the end of this paper.

exponentially resulting in large surface area to mass ratio. After activation, one ounce of AC has an estimated 30,000 square yards of surface area.

The chemical nature of amorphous carbon, combined with its high surface area and porosity, makes it an ideal medium for the adsorption of organic chemicals. AC is currently used in various processes to remove taste, odor and impurities from gases and liquids through the adsorption of contaminants onto the AC media. Typical uses of AC include, but are not limited to, the following operations:

- Air purification
- Tank Venting
- Industrial air emission control
- Catalyst support
- Decolorization
- Deoderization
- Gold/metal recovery
- Liquid purification
- Environmental remediation
- Emergency poison treatment
- Solvent recovery
- Sugar refining
- Whiskey manufacturing

The typical chemical constituents, which can be effectively removed from vapor and/or liquid phase waste streams, include:

- Chlorinated solvents
- Volatile organic compounds (VOCs) & semi VOCs (SVOCs)
- Alcohols, Ketones, amines, esters
- Organic acids
- Radio-nuclides
- Hydrocarbon solvents
- Petroleum hydrocarbons
- Hydrogen Sulfide
- MtBE (marginal)
- Pesticides
- Herbicides

As contaminants are adsorbed, the carbon's adsorption capacity is gradually exhausted. When the carbon's adsorption capacity is reached, "breakthrough" condition occurs, and the effluent from the AC will contain some concentrations of the influent chemical contaminants. For waste streams containing multi-chemical contaminants, a breakthrough condition may occur at different times during the service. Once initial breakthrough occurs, the carbon is considered "spent" and it must be regenerated or replaced with new carbon. Traditionally, "spent" carbon is either transported off-site for high temperature (<500? F) thermal regeneration, or is disposed in a waste management unit.

Although AC is very effective and widely used in industrial and environmental waste management practices, the following shortcomings are typical:

- Low adsorption of smaller molecules
- Low adsorption of polar molecules
- Non-soluble or slightly soluble molecules adsorb better than highly soluble molecules
- Low sorption coefficient of MtBE
- Relatively no sorption of TBA
- Potential for non-optimum adsorption uses in multi-constituent waste streams
- Requires frequent exchange with fresh or reactivated carbon

- Unscheduled or early breakthrough
- Cost, regulatory, health and safety concerns associated with removal and transportation of "spent" carbon
- Liability concerns associated with disposal in waste management units

To further extend the useful life and performance of the AC, and to allow for on-site reactivation of "spent" AC, Subsurface Waste Management Inc. (SSWM) has developed two proprietary processes: ***Bio-GAC™*** System and Bio-Reactivation of Spent Activated Carbon (***BAC™***). The bio-augmentation process and each of these innovative approaches are described following sections.

Bio-Augmentation

Bio-augmentation is a process whereby naturally occurring, performance-selected bacteria cultures are introduced to the waste stream after having been individually grown in high concentrations in a laboratory. Impacted soil/groundwater contains hundreds of bacteria strains. Some strains are tolerant of contamination but will not degrade or consume the contaminants. Other bacteria strains may be capable of degrading the contaminants, but are not present in high enough populations to affect a degradation process. It is also possible that bacterial strains capable of degrading contaminants are present in small quantities but are competing for nutrients with other bacterial strains that are simply tolerant of the site conditions and not degrading contaminants. Bio-augmentation is the process by which desirable degrative strains of bacteria are cultured off site and then applied to the soil or waste stream to treat the contaminants. In this manner, contaminant-specific bacteria are applied in sufficient numbers to degrade contaminants when essential nutrients are present.

The scientific community has long recognized that many microbes and microbial consortia are capable of transforming or degrading a wide range of environmental pollutants including crude oil and refined petroleum hydrocarbons, solvents, and even some metals. However, in the past some people have avoided this technology because these treatment processes can take a long time. The rate of degradation for each contaminant is a function of a variety of physical, chemical, and biological constraints of the waste stream. In recent years, much of the work has been directed toward addressing these limitations resulting in accelerated biodegradation and biotransformation rates that are viable to provide successful remediation of large impacted sites and waste streams.

Biotransformation rates can be accelerated in several ways including:

- Bio-stimulation through the addition of chemical amendments to increase the number of microorganisms in the contaminated soil
- Bio-augmentation (active introduction of microorganisms to the soil)
- Increasing the availability of contaminant compounds to organisms

SSWM and US Microbics (USM) have investigated each of these approaches at both bench and pilot scale. Some of these approaches have been implemented at full scale. For example, adding various nutrients and electron donors/acceptors (required for the growth or activity of indigenous micro biota and plants) has been tested at various sites. Chemical additives such as surfactants have been recently site tested to increase the bioavailability of pollutants to

native or introduced degradative organisms with great success. To a very limited extent, bio-engineered microbial isolates and plants have been introduced to accelerate treatment.

SSWM and USM have 40 years of experience in scientific and engineering research, development and field application associated with accelerating bioremediation rates. Building on our knowledge of microbial community dynamics, biotransformation and biodegradation processes, bio-molecular engineering, and phyto-remediation, we have developed a proprietary approach that utilizes a combination of bio-stimulation, bio-augmentation, and bio-surfactant enhancement. By implementing this approach, we have been able to successfully accelerate bioremediation rates and achieve bio-degradation of both light and heavy hydrocarbons.

USM has developed various microbial blends for treatment of petroleum hydrocarbons, MTBE, and chlorinated solvents. USM's natural, non-genetically engineered specialty microorganisms received approval from the U.S. Department of Agriculture in 1979 and have received its highest safety designation as "relatively safe".

Bio-GAC™ System

The ***Bio-GAC™*** system is very simple and can typically be employed using readily available components. In this system the exiting and/or new GAC containers are augmented with a bio-application system that delivers microorganisms and nutrients directly into the waste stream and GAC units. The microorganisms introduced to the system colonize and develop a bio-film over the large surfaces and within the pore space of the AC. As contaminants are adsorbed and immobilized by the AC, the immobilized pollutants are bio-degraded. The waste stream-specific microbial blend produced by US Microbics degrades the chemical contaminants present in the waste stream via the following biological processes:

1. **Growth**
    a. As a growth substrate – the microbial population grows using contaminants as a food source with the incorporation of carbon or nitrogen molecules into their bio-cell structure.
    b. As an electron acceptor
2. **Cometabolism**
    Cometabolism is the transformation of a substance without nutritional benefit in the presence of a growth substrate. This is the basis of biotransformation used in biotechnology to convert a substance to a chemically modified form. The prerequisites of cometabolic transformation are the enzymes of the growing cells and the synthesis of cofactors necessary for an enzymatic reaction.

The first process step in the ***Bio-GAC™*** system is the bioreactor/surge tank. The conditioned process water enters the bioreactor where nutrients and microbes are added and the dissolved oxygen levels are increased. The bioreactor contains a bio-support matrix (i.e. bio-balls) to maintain a healthy microbial population. A portion of the microbes in the bioreactor are carried through to the ***Bio-GAC™*** vessels to help seed the ***Bio-GAC™*** vessels and ensure that microbial populations are maintained in the event of systems upset conditions. Dissolved oxygen is added by bubbling ambient air into the bioreactor through fine-bubble aeration

devices or by adding hydrogen peroxide, oxidizers such as U.S. Microbics Bio-Miracle™, or other commercially available oxidizers.

The second process step is the ***Bio-GAC™*** vessels. The process water containing nutrients, microbes, and dissolved oxygen enters the ***Bio-GAC™*** vessels where a carbon matrix adsorbs and concentrates the organic compounds. The carbon matrix can consist of GAC or any number of carbon based products including pellets, mats, fabrics, or a combination of carbon materials. The carbon material acts as an adsorption media for the organic compounds and as a support matrix for the microbes. An example of a typical ***Bio-GAC™*** system is shown in Figure 1.

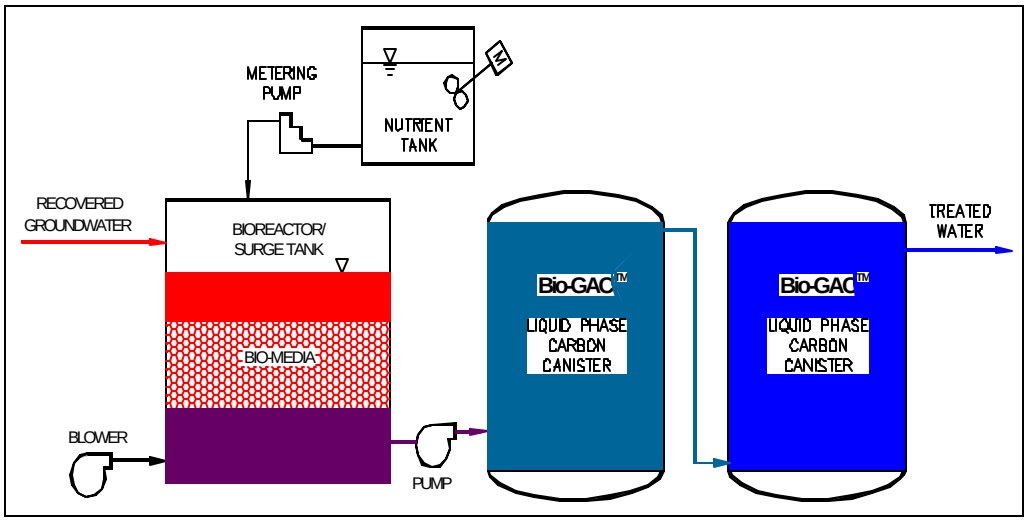


Figure 1 ***Typical Bio-GAC™ System***

The ***Bio-GAC™*** process has the following advantages when compared to conventional AC treatment processes:

- Extends the life of AC units (approximately four to five rotations at a minimum)
- Can be used for both liquid phase and vapor phase carbon applications
- Generates no hazardous waste and/or byproducts
- There are no hazardous air emissions from the process
- Reduces energy costs associated with high temperature thermal treatment
- Effective in treating benzene, toluene, ethylbenzene, xylenes (BTEX) and VOC compounds
- Effective in treating MtBE
- Effective in treating TBA
- Reduces potential for unscheduled or early breakthrough
- Reduces health and safety concerns during removal, transportation and off-site treatment
- Reduces high costs associated with AC change outs
- Eliminates potential long term liability associated with spent carbon land disposal

Sample *Bio-GAC™* Projects

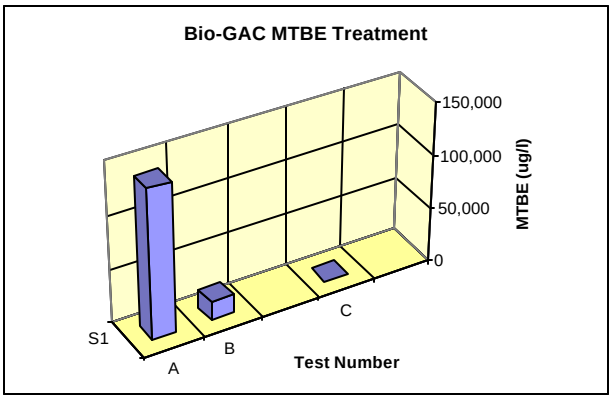
Sample Project No. 1 – MtBE Pilot Study

The ***Bio-GAC™*** system was tested in the laboratory using two 55-gallon drums of *spent* carbon in series. Figure 2 presents the pilot test system configuration. Tap water spiked with MtBE was processed throughout the system at a rate of approximately 1 gpm. Nutrients and **MTBEctomy™**, a specially formulated bio-blend was introduced into each GAC unit using a metering pump. The result of this pilot study is presented in Table 1 and displayed graphically in Figure 3.

Figure 2 ***Typical Bio-GAC™ System***

Table 1 ***MtBE Continuous Flow Test Result***

Sample No.	Sample Description	MTBE (mg/l)	Reduction (%)	TBA (mg/l)	Reduction (%)
A	Feed water	140,000		5,000	
B	Sample A, Reactor 1	17,000	88	200	96
C	Sample B, Reactor 2 Effluent	190	99.86	0	100



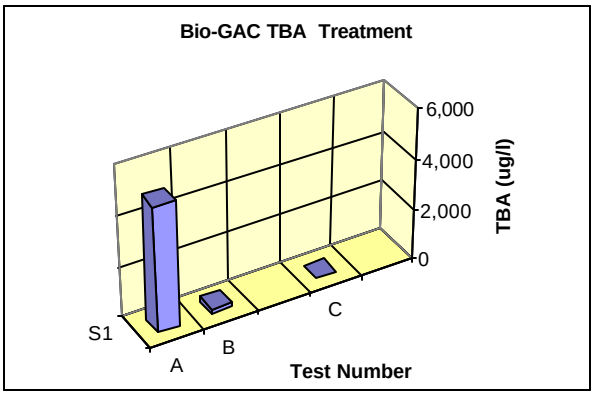
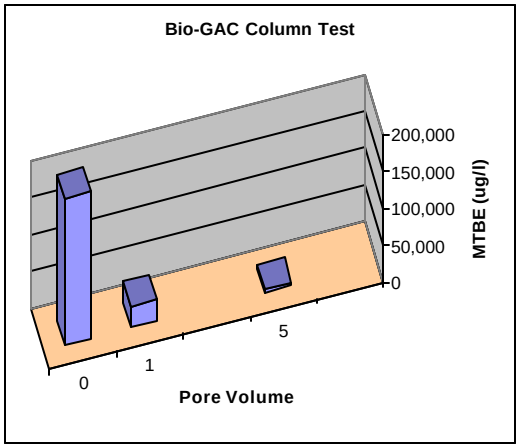


Figure 3 ***MtBE Continuous Flow Test Results***

Column tests were also performed to evaluate the effectiveness of the ***Bio-GAC™*** and to prepare design paramaters for a series of MtBE column tests. The results of the column tests are tabulated in Table 2 and graphically presented in Figure 4.

Table 2 ***MtBE Column Test Results***

Sample No.	Sample Description	MTBE (ug/l)	Reduction (%)	TBA (ug/l)	Reduction (%)
0	Feed water	200,000		8,000	
1	1 pore volume	30,000	85	500	93.75
5	5 pore volume	6,000	97	0	100



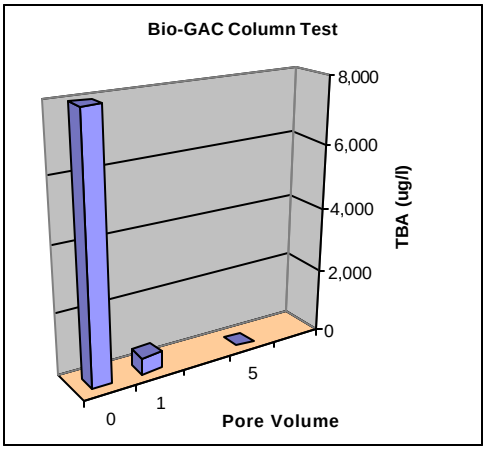


Figure 4 ***MtBE Column Test Results***

Based on the continuous flow and column ***Bio-GAC™*** tests conducted on MtBE-impacted water, the following observations and conclusions can be drawn:

- The ***Bio-GAC™*** system is very effective in treating MtBE and TBA in both continuous flow and batch process conditions.
- The bio-blend **MTBEctomy™** exhibited optimal ability to degrade MtBE and its by-products with a very short hydraulic retention time.
- The ***Bio-GAC™*** system supported high microorganism populations in excess of $1x10^8$ cfu/gm.
- No bio-fouling or pressure build-up (i.e., flow resistance) was observed in the GAC units during the test.
- No measurable biomass resulted at the end of the test period (approximately 4 weeks). Based on observations made during the test, it appears that the biomass is further utilized in the system as a nutrient source by selected strains of microorganisms contained in the **MTBEctomy™** blend.
- The spent carbon units used for this pilot study were not only capable of additional service, but they continued to function as "virgin" carbon during the course of the pilot program. Based on the test results, we can estimate that the carbon life cycle can be extended a minimum of 4 to 5 rotation cycles beyond that possible using traditional GAC.
- The process is very simple and there was no need for complex mechanical and/or electrical equipment.

Sample Project No. 2 – Refinery Wastewater

The ***Bio-GAC™*** system was utilized for treatment of a wastewater stream in a southern California refinery. The raw water from the on-site wastewater treatment plant was passed through 3-500 lb GAC units at an estimated rate of approximately 2 to 3 gpm for a period of 4 weeks. The exact chemical composition of the wastewater was not known, and for testing purposes, the raw and treated water were tested for various petroleum hydrocarbon chains. The result of this water treatment project is graphically presented in Figure 5.

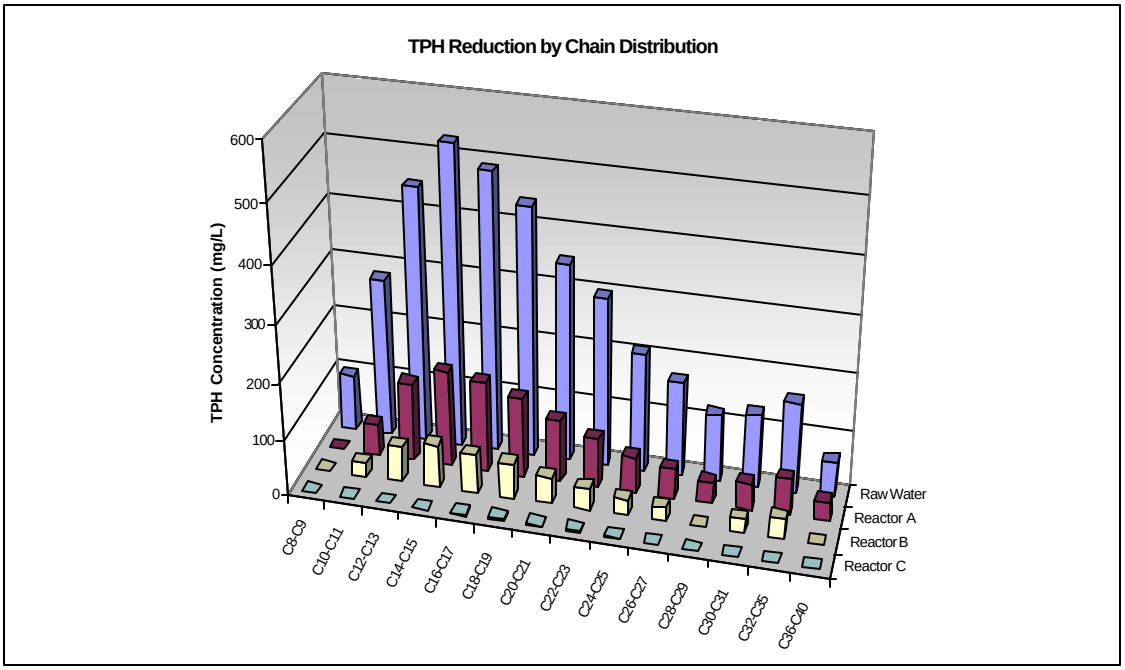


Figure 5 ***Refinery Wastewater Treatment Results***

These test results revealed the following:

- The ***Bio-GAC™*** system is very effective in treating petroleum hydrocarbon compounds.
- The ***Bio-GAC™*** system supported high microorganism populations in excess of $1x10^8$ cfu/gm. No adverse or bio-toxic conditions were observed during the process.
- No bio-fouling or flow resistance was observed in the GAC units during the test.
- During the treatment train, microorganisms cometabolically transform the longer chain compounds into shorter chain compounds; the shorter chain compounds can then be utilized as a source of carbon to enhance microbial population growth.

Sample Project No. 3 – Chlorinated Solvent Treatment

The ***Bio-GAC™*** system was utilized for pilot treatment of impacted groundwater waste streams at two industrial facilities in Europe. Raw water from on-site recovery wells was passed through two 200 lb GAC units at an estimated rate of approximately 1 gpm for a period of approximately 6 weeks. The results of the water treatment tests at each project site are presented in Tables 3 and 4.

Table 3 ***Chlorinated Solvent Test Results; Site #1***

	Units	Initial Concentration	After Treatment
Methylene chloride	µg/l	13	ND
1,1,1-Trichloroethane	µg/l	1400	ND
Trichloroethene	µg/l	13	ND
Toluene-d8 (S)	µg/l	ND	ND
Note: ND Not detected (<5 µg/l)			

Table 4 ***Chlorinated Solvent Test Result; Site #2***

	Units	Initial Concentration	After Treatment
Dichlorodifluoromethane	µg/l	ND	ND
1,1-Dichloroethane	µg/l	73	ND
1,1-Dichloroethene	µg/l	160	ND
Methylene chloride	µg/l	18	ND
1,1,1-Trichloroethane	µg/l	920	ND
1,1,2-Trichloroethane	µg/l	ND	ND
Note: ND Not detected (<5 µg/l)			

The results of the ***Bio-GAC™*** treatment test for chlorinated solvents indicate that:

- The ***Bio-GAC*** system can effectively treat chlorinated solvents to very low concentrations (below detection limits).
- Aerobic and anaerobic conditions were noted in the treatment train. Due to the facultative nature of the U.S. Microbics bio-blend, both aerobic and anaerobic degradation processes could be attained within the treatment train.
- The ***Bio-GAC*** system supported high microorganism populations in excess of $1x10^7$ cfu/gm. No adverse or bio-toxic conditions were observed during the process.
- No bio-fouling or flow resistance was observed in the GAC units was observed during the test.

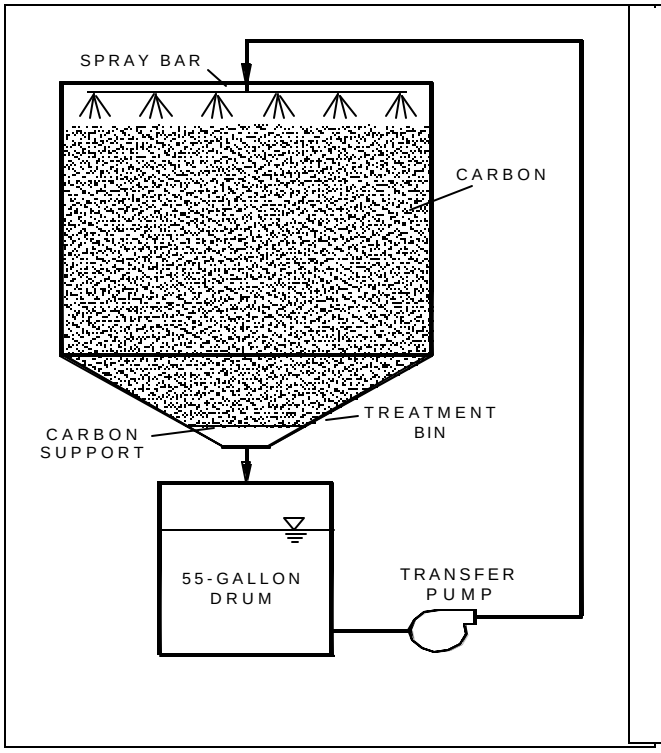
Bio-Reactivation of Spent Activated Carbon (BAC)

SSWM has developed two methods for bio-regenerating carbon. The wet method involves submerging the spent carbon in water inoculated with microbes and nutrients, and delivering oxygen (air) into the bottom of the tank to maintain acceptable dissolved oxygen levels and carbon mixing. The spray method involves spraying a mixture of water, microbes, and nutrients over the top of the spent carbon in a non-submerged condition. Both methods have proven to be successful in achieving the regeneration specifications at comparable costs.

The best regeneration method for a given site depends largely on the layout of the existing treatment system, condition of the treatment vessels, characteristics of the carbon, and other site-specific variables. The spent carbon can either be regenerated in the existing treatment vessel, eliminating the need to transfer the carbon from vessel to vessel, or transferred to a system specifically design to regenerate carbon. The regeneration typically requires 4 to 14 days, depending on the type of contamination and extent of regeneration required.

After the regeneration is complete, vapor phase carbon must be dried prior to placing the unit back online. This can be accomplished several ways, the simplest of which involves blowing air through the vessel until the desired moisture content is achieved. If faster drying times are required or the local humidity is high, a dehumidifier or heating unit may be required to speed this process. SSWM uses a small GAC unit to capture any fugitive emissions from this vented air stream.

An example of a spray regeneration system is shown in Figure 6A. The spent carbon is loaded into a treatment bin with a cone-shaped bottom. A carbon support screen at the bottom of the bin holds the carbon in place, allowing water and air to pass through it. The regeneration solution containing microbes, nutrients, and surfactants is held in a tank located below the treatment bin.



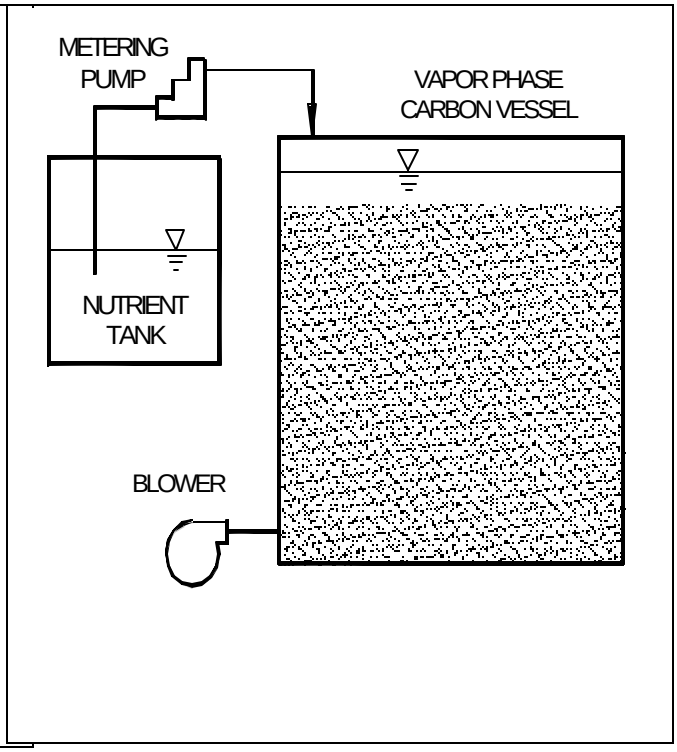


Figure 6A ***Spray Bio-reactivation Process*** **Figure 6B** ***Submerged Bio-reactivation Process***

A transfer pump passes the regeneration solution to the top of the treatment bin where a spray bar distributes the solution over the spent carbon. The regeneration solution trickles down through the carbon, delivering nutrients and microbes to the carbon. As the process continues, the microbes attach and grow on the carbon, consuming the contaminants adsorbed by the carbon. Oxygen required for the metabolic process is derived from air passing through the treatment bin.

An example of a wet or submerged regeneration system is shown in Figure 6B. In this system, the spent carbon is submerged in the regeneration solution. Dissolved oxygen is added by bubbling air through the tank and/or adding hydrogen peroxide to the water. A separate nutrient tank provides a constant supply of nutrients to the regeneration vessel in order to optimally support the microbial population. Microbes are added at the beginning of the cycle once the pH, dissolved oxygen, and nutrient levels are established and stabilized.

To compare the adsorption capacity and other properties of bio-activated carbon with that of virgin AC and thermally re-activated carbon, representative samples of bio-activated carbon, spent carbon and thermally activated carbon were submitted to a third party laboratory for analysis. The virgin carbon properties were obtained from published specification provided by the carbon supplier. Table 5 summarizes the results of carbon testing conducted by PACS Laboratories in Coraopolis, Pennsylvania.

Based on the results, it can be confirmed that bio-reactivation is very effective in restoring spent carbon to a near virgin condition. For the bio-activated carbon, the Iodine Number, which is an indicator of the adsorption capacity of carbon, was within the "virgin carbon" range and was higher than the Iodine Number for the thermally reactivated carbon. Other parameters, such as density and residual compounds, fell within acceptable ranges.

Table 5 ***Carbon Characteristic Test Results***

Sample ID	Iodine No. (mg/g)	Apparent Density (g/cc)	Residual MTBE (mg/kg)	Residual BTEX (mg/kg)	Residual TPH-G (mg/kg)
Virgin Carbon	930 - 1,100	0.45 - 0.54	ND	ND	ND
Spent Carbon	< 100	NA	~10,000 (1)	NA	NA
Reactivated Carbon (thermal)	835	0.650	<2	<2	<2
Bio-Activated (wet)	940	0.640	2.6	ND	ND
Bio-Activated (spray)	975	0.614	11.0	ND	ND

ND - non-detect (0.5mg/kg)
NA - not analyzed
(1) Estimated based on adsorption efficiencies

The BAC™ system offers the following benefits:

- The spent carbon can be regenerated on site so there is no need to remove spent GAC from the site for regeneration or disposal, and no need for or costly thermal treatment.
- The risks associated with transportation and/or disposal are low compared to the traditional handling and thermal regeneration approach.
- The bio-reactivation process is less expensive than thermal regeneration and requires significantly less energy.
- Saves landfill space and natural resources.
- Eliminates potential liability associated with off-site treatment and disposal.

Sample *BAC*™ Projects

Sample Project No. 1 – Industrial Wastewater Treatment Off-gases

Spent GAC units from an industrial operation were bio-reactivated on site using the spray ***BAC***™ system. SSWM modified the existing GAC unit to allow ***BAC***™ processing. Forty-five units were bio-activated over a six-month period. Prior to on-site bio-reactivation, typical breakthrough occurred within seven days after each change-out. After bio-reactivation, the units not only performed within the normal GAC operational ranges, the average change out cycle increased by approximately 30 days (4 times longer than a typical carbon replacement regime). This additional longevity was attributed to the presence of residual microorganisms within the carbon pore spaces after completion of the bio-degradation process. The result of this project is graphically presented in Figure 7.

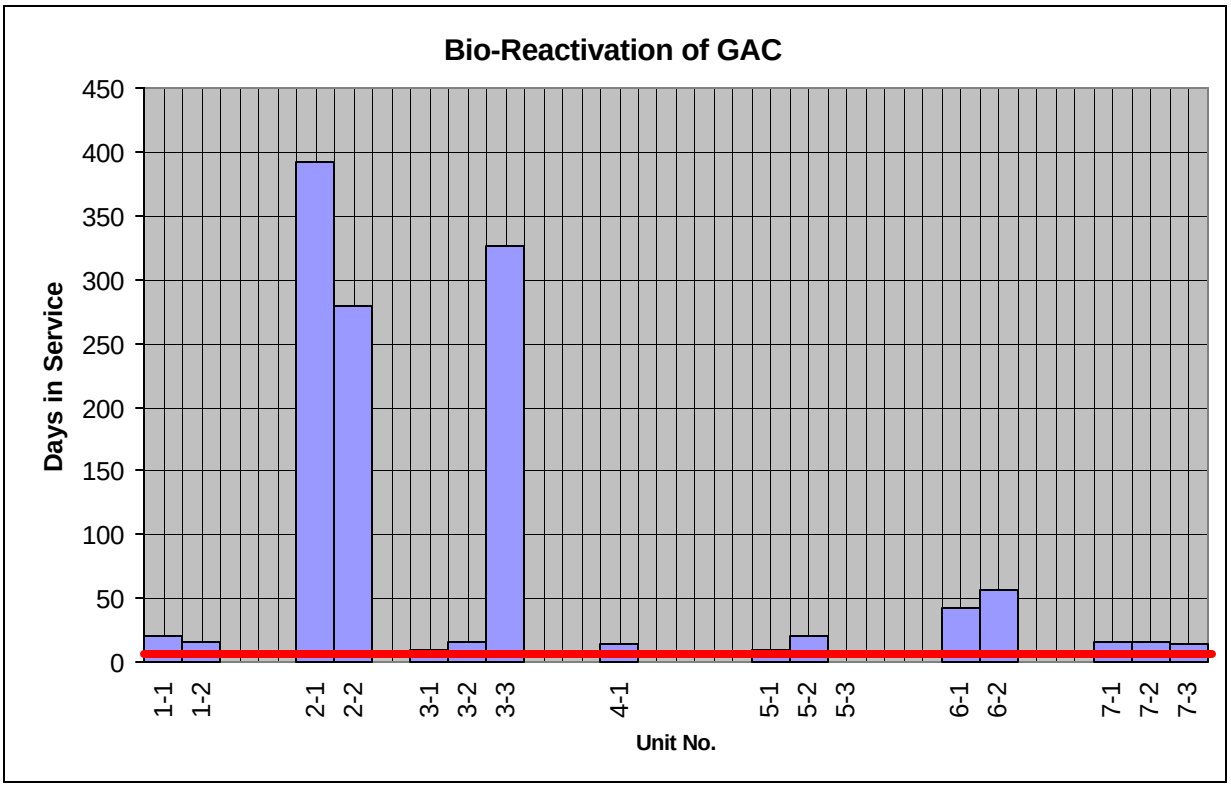


Figure 7 ***Industrial Wastewater Treatment Off-gases***

Sample Project No. 2 – Industrial Off-gas Treatment

A spent carbon unit used at an industrial manufacturing facility was bio-reactivated using the BAC™ system. The facility used GAC to control VOC emissions from indoor manufacturing activities. Prior to initiating bio-reactivation, the facility was replacing their spent GAC with a mixture of thermally treated carbon on the average of every 9 to 10 days. After the BAC™ system was implemented at the site, the average life cycle of each unit in service was extended to 40 days (4 times longer than its pre-BAC duration). Figure 8 tabulates the number of days each unit was in service prior to needing replacement.

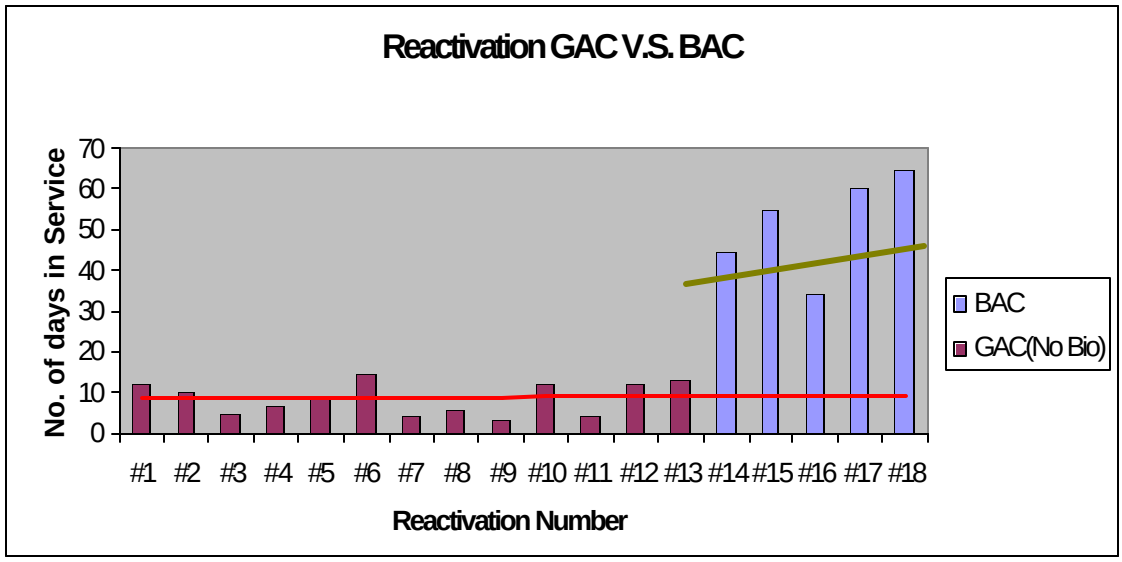


Figure 8 ***Bio-Reactivation of VOC Spent GAC***

Conclusion

Based on research and development studies as well as the results of various pilot studies and field trials conducted by SSWM and USM, it is the opinion of the author that ***Bio-GAC***™ and ***BAC***™ are technically and logistically superior and cost effective alternatives to off-site thermal reactivation of spent carbon. The ***Bio-GAC***™ and ***BAC***™ systems are recycling processes that will reduce the cost and potential human and environmental risk associated with transportation of spent carbon. Each system offers a technically sound and environmentally friendly alternative to disposal and thermal regeneration. There are no harmful or toxic by-products and/or emissions produced during the process. There is no need to waste highly valuable energy resources to thermally treat spent carbon or to dispose of it in a landfill, creating future environmental liability.

The various studies and trials conducted indicate that ***Bio-GAC***™ is capable of extending a typical GAC life cycle by a minimum of 4 times and could be designed for much longer periods depending on site conditions. The ***BAC***™ process can effectively be used for on-site bio-reactivation of spent carbon to near virgin conditions at approximately 50% the cost of other alternatives.

Question and Answer Session

At the conclusion of the technical presentation, the following questions were asked by attendees and answered by the presenter, Behzad Mirzayi.

Q: What is the source of oxygen during the bio treatment process?
A: There are a couple of systems for introducing oxygen: hydrogen peroxide injection and an air system developed by Apex that uses compressed air and a ceramic material that increases the dissolved oxygen in the water (to about 35 mg/l). This is not aeration; it is converting compressed air into dissolved oxygen with no off-gassing. If off-gassing is not an issue, they can use aeration and run the off-gas through a vapor phase bio-GAC system, making it a closed loop system.

Q: Regarding iron sulfide fouling – wouldn't introducing oxygen into the system cause iron oxidation and result in fouling? Wouldn't you rather use anaerobic digestion over aerobic digestion?
A: SSWM conducts site-specific testing to create a bio-blend of microorganisms, aerobic or anaerobic, which will best meet site needs. Some contaminants cannot degrade anaerobically, and visa versa. Treatment of VOCs occurs through in situ oxidation. For treatment of chlorinated compounds, going from PCE to TCE requires anaerobic conditions, while going from TCE to dichloro compounds is aerobic. The bugs can change from aerobic to anaerobic and back, depending on what the contaminants are.

Q: Changing carbon because of breakthrough can cause an afternoon of downtime. How long does bio-reactivation take?
A: Two to five days for wet carbon application, longer for dry. SSWM suggests using a dual system with 2 carbon canisters – use fresh or reactivated GAC to treat your waste stream while using the BAC system to treat (or reactivate) the "spent" GAC.

Q: What is the cost for bio-speciation (to determine the best site-specific bugs for the bio-blend? Is it reflected in the cost breakdown on Slide 22?
A: Yes, cost for speciation is included in the breakdown on Slide 22. Speciation is done by microbiologists at SSWM's in-house lab. Not covered in the estimate is the cost for compliance testing. We suspect that compliance testing frequency can be reduced once one proves that breakthrough is not occurring.

Q: How would one determine which application to select – bio-GAC, which is a continuous in-line system, or BAC?
A: It is a client decision – what makes best sense for their facility based on cost and how flexible their system is to in-line augmentation.

Q: What is the payback on a BAC system compared to traditional GAC applications?
A: Answer would depend upon the agreement one has with their GAC supplier or the traditional treatment/reactivation plant, and if they got a deal based on purchasing/treating large quantities. BAC is not lucrative for GAC manufacturers, GAC suppliers, or traditional regeneration facilities. Cost would also depend on the spent

carbon passing the TCLP. If it doesn't, it will cost a lot more to be shipped out of state. Bioreactivation doesn't use a lot of energy or produce a lot of off gasses. Behzad is finding that suppliers and regenerators are aware of the potential of SSWM's bio-GAC and BAC reactivation so they lower their prices.

Q: How long can you continue to reactivate carbon using BAC?
A: Carbon that is treated using BAC could be used over and over but one may eventually want to get rid of it. Behzad believes that treating carbon with BAC could extent the life of the carbon 5 to 10 times, compared to traditional treatment methods. When you are ready to dispose the carbon, Behzad suggests BAC treating it first to make it non-hazardous prior to disposal.

Q: With bio-reactivation, what happens to off gasses and the thermal scrubber?
A: There is no thermal scrubber with this system. BAC is a flow-through system with the bio-blend and there are no off gasses. DTSC and AQMD looked a both systems and exempted them from needing permits. AQMD originally exempted a 6-month bio-recycling pilot project from air permit requirements because the equipment was not being used on a production scale. AQMD requested emissions data from the pilot study – a procedural requirement – even though the process is wet, closed loop and generates no off-gasses. During the pilot, SSWM measured for fugitive emissions using an organic vapor analyzer, submitted these results to AQMD, and as of the date of this publication, is awaiting AQMD's response.

Q: What is DTSC's position on permitting requirements for the bio-reactivation process?
A: This response is from DTSC: California Health and Safety Code (HSC) Section 25143.2 contains certain exemptions for recyclable materials. With respect to spent GAC that is recycled on-site via bio-reactivation and reused as activated carbon, the following conditions apply:

- The spent GAC (as described above) is a "recyclable material" as defined in HSC 25120.5.
- If the spent GAC meets the definition of a non-RCRA hazardous waste, it is excluded from classification as a waste (i.e., becomes an excluded recyclable material).
- No tiered permit authorization is required to for on-site recycling of excluded recyclable materials.
- If the spent GAC is classified as a RCRA hazardous waste, it can be recycled on-site without a tiered permit provided the following conditions are met:
    - The material is recycled and used at the same facility at which it was generated;
    - The material is recycled within 90 days from the time the spent GAC was taken out of service; and
    - The material is managed in accordance with all applicable requirements for generators of hazardous waste.

IMPORTANT: There are conditions and restrictions related to exclusions and exemptions for recyclable materials. Please review all the terms of HSC 25143.2 for a full discussion of these conditions and restrictions.

Q: With vapor phase carbon, does the bio-reactivation have to be in water phase application?
A: Yes, because bugs thrive on a moist environment.

Q: With the bio-reactivation application, what is done with the biomass – how is it classified?
A: Biomass gets washed through the carbon into a container and around again (closed loop). For a 10 to 20 gpm system, less than 2 pounds of biomass are generated after about 6 months.

Q: Starting with traditional GAC treatment systems treating MTBE, what are the benefits of switching to a bio-GAC system?
A: bio-GAC extends treatment life because MTBE does not adsorb to the GAC (it gets consumed by bugs).

Q: How are the bio-solids from bio-regeneration classified?
A: The volume of bio-solids generated during bio-GAC and/or BAC is very small, less than 1 kg for 6 month of operation. As far as USEPA is concerned, the bio-solids are non-hazardous. The bio-regeneration process biodegrades the hazardous constituents. Constituents do not bio-accumulate. Bill Ryan (an attending DTSC branch chief) spoke on behalf of DTSC indicating that there are a variety of tests that would need to be done to determine if the bio-solids meet hazardous waste criteria (see California Code of Regulations, Title 22, Section 66261).

Q: What is the drying process?
A: Let the carbon drain then use an online low energy dryer with reverse flow that reaches 140 degrees F. A dehydrator takes the moisture out of the air stream in a closed-loop system. The goal is usually to return the carbon to 5% moisture, although some people who use vapor phase application like higher moisture content because the bugs thrive in a moist environment.

Q: Do VOCs mobilize or volatilize during drying?
A: No. VOCs are degraded during the regeneration process. Plus, the drying temperature is not hot enough – temperature needs to be at 1000 degrees F to mobilize adsorbed VOCs for drying we use temperatures of less than 150 degrees F.

Spent Abrasive Recycling

Greg Weyl
Director of Operations at Kleen Industrial Services

Thousands of tons of spent abrasives are generated every year in the State of California and much of that continues to be landfilled. Landfilling wastes potential resources, ignores waste minimization requirements, and can be costly when generator fees are included. Landfilling also exposes the generator to possible future liability, whereas a properly managed recycling program will limit exposure and liability. Most spent abrasives can be beneficially reused within California but recycling options may be limited depending on the type of abrasive used. In addition to federal requirements, California has additional specifications for abrasives and requirements for recycling that other states do not have to comply with. This paper provides information on how to develop a defensible alternate raw material program according to the U.S. EPA guidance document titled *"Criteria for Evaluating Whether a Waste is Being Recycled,"* hazardous waste regulations established in Title 22 of the California Code of Regulations (CCR), and statutory requirements for recycling set forth in the California Health and Safety Code.

Abrasive Selection

Abrasive selection involves asking the following questions:

- Is it approved for use?
- Does it meet the contract specifications?
- Does the abrasive meet the job-specific expectations for coating removal efficiency, productivity and surface profile?

In order to market their products for use in California, abrasives manufacturers need to verify that their products meet specific requirements and specifications. Abrasive blast media must satisfy California Air Resources Board (CARB) tests for friability and dust generation to be approved for use in California. The Steel Structure Painting Council (SSPC AB-1) and US Navy (MIL-A-22262 (B) SH) both have specifications that evaluate abrasives on performance, cleanliness and environmental quality. Meeting these qualifications is the first step for abrasive manufacturers to take to successfully market their product.

Abrasive Choices

There are many competitive choices for abrasives in the California marketplace and each choice may affect options for recycling or beneficial reuse. Some of the choices, which meet some or all of the requirements and specifications referenced above, are silica sand, garnet, copper slag, coal slag, steel grit, and other abrasives. Advantages and disadvantages to these abrasive choices are detailed below.

Abrasive	Advantage	Disadvantage
Silica sand		Free silica is considered a carcinogen (OSHA)
Garnet	Very hard	Very expensive
Copper slag (available on west coast)	• Readily available • Excellent productivity • Economically viable	• Some generate high dust • Dust may contain heavy metals at levels exceeding regulatory standards
Coal slag (available in Midwest and east Coast)	Good productivity	• Not economical for west coast applications
Steel grit	• Excellent production rates • Low dust production • Can be reused 20 to 40 times	• Very expensive • Labor intensive • Expensive equipment requirements
Nickel slag (available in Oregon)		• Some nickel slags exceed regulatory levels for nickel and chromium. • limited beneficial reuse options
Crushed, recycled glass (available in Washington and Ohio)	Better at polishing than cutting	• Low production rates • Dusty

If there is lead in the coating, there are a few abrasive additives that prevent the spent abrasive from being classified as RCRA hazardous wastes:

- TDJ Blastox (a calcium silicate granule blended at 15% with the abrasive);
- PreTox 2000 (a calcium phosphate liquid coating at 40 mil applied to the surface prior to blasting); and
- Lead-X (a calcium phosphate granule/powder mix blended with the abrasive at ~15%).

Some processes may not be compatible with the phosphate-based additives. Kleen Industrial Services (KIS) distributes a variety of abrasives products (under the name Kleen Blast) that are blended with Blastox, which can render the spent abrasive non-RCRA hazardous.

Spent Abrasives

As with any waste generation, proper management of wastes or production by-products is an important issue. With abrasive blasting contracts, owners and contractors must answer the following questions: What are the disposal issues? Who is responsible for the waste? What are the contract requirements? How can the spent abrasive be recycled or reused?

The first step is to conduct a waste determination. Generators use the following information in performing a thorough waste determination:

- abrasive manufacturer's knowledge;
- project knowledge or paint chip tests;
- MSDS's from coating history; and
- representative sampling and testing according to SW-846 "Test Methods for Evaluating Solid Waste", US EPA.

Unfortunately, to develop and implement a successful alternate raw materials recycling program, one must overcome both regulatory and technical obstacles. The crux of regulatory obstacles to recycling stems from whether or not a spent material is considered a hazardous waste under the Resources Conservation and Recovery Act (RCRA) and/or California regulation. There are two deciding factors to making this determination:

- Is the spent abrasive a *waste* or an *excluded recyclable material* as defined in California Health and Safety Code (HSC) Section 25143.2?
- Does the spent abrasive, whether a waste or an excluded recyclable material, meet the definition of a RCRA hazardous waste? Non-RCRA hazardous waste?

For spent abrasives, the "hazardous waste" determination is usually made based on whether or not the material satisfies the toxicity criteria. Under RCRA, toxicity is determined based on the Toxicity Characteristic Leaching Procedure (TCLP) test for soluble metals, whereas in California, toxicity is based on both total and soluble concentrations of metals. California's toxicity testing requirements are contained in Title 22 CCR Section 66261. The hazardous waste vs. excluded recyclable material determination and other project information are used to determine how a spent abrasive can legally or regulatorily be managed. In some cases, RCRA hazardous waste disposal is the only option.

California allows for recycling of RCRA and non-RCRA regulated hazardous waste without permits or manifests if the conditions in HSC 25143.2 are complied with. The chemical composition of spent Kleen Blast is ideal for the manufacture of Portland cement clinker. Beneficial reuse of spent abrasives (which meet the conditions of an excluded recyclable material under HSC 25143.2) in Portland cement is the most common recycling option for this material. Some of the recycling conditions contained in HSC 25143.2 include:

- storage requirements (preventing wind dispersal, storm water run-on and runoff);
- handling requirements, (i.e., labeling);
- reporting requirements, such as hazardous materials business plans and notifications to the lead enforcement agency;
- final product verifications of quality standards; and
- testing to demonstrate a binding of hazardous constituents in the manufacturing process (HSC 25143.2 and Title 22 CCR 66261.21).

(This is not a complete list of recycling conditions. The reader should review HSC 25143.2 and contact DTSC's Waste Identification and Recycling Section to discuss conditions specific to their recyclable material.)

Kleen Industrial Services submitted copies of documents concerning the Excluded Recyclable Materials Cement Kiln program to DTSC and California Portland Cement Company addressing these issues. Correspondence between KIS, Cal EPA, and DTSC are attached.

If the spent abrasive passes all required tests (i.e., does not exhibit any characteristic of a hazardous waste), then the generator has a non-hazardous material and the material is not restricted by HSC 25143.2 conditions. Unlike the cement manufacturing application discussed above, this allows for direct land application such as asphaltic concrete or road base. KIS gained regulatory concurrence for the use of non-hazardous spent fine aggregate in cement and asphalt products as documented in the attached letters from both DTSC and San Diego County Environmental Health Department.

Issues can also arise from end use product quality standards, such as those originating from the Federal Highway Administration (FHA), various State Department's of Transportation (DOT's), ASTM and Final Product Demonstrations. Product quality standards can limit the manufacturer's ability to use an alternate raw material. Attached with this report is documentation from Washington and Oregon State DOT's, and Oregon's Department of Environmental Quality on the acceptance of spent Kleen Blast Abrasives as a fine aggregate in the manufacture of asphaltic concrete, base and subbase materials, provided the spent abrasive does not exhibit any characteristic of a hazardous waste.

EPA Guidance Document

USEPA developed a guidance memo that discussed some of the pertinent issues for a viable and compliant recycling program. KIS has tried to address these concerns throughout its spent Kleen Blast recycling program. Some of the pertinent items are discussed below.

1) Is the secondary material similar to an analogous raw material or product?

Kleen Blast and other copper slags have many direct uses today, such as roofing granules, cement kiln raw material (primarily iron), blasting abrasives, and other uses in road building products (fine and coarse aggregate asphalt and base materials). CanAm Minerals has sold thousands of tons of copper slag from the Anyox pile and Grand Forks pile to cement kilns for use as iron-based raw material in the manufacture of cement clinker. Copper slag, blast furnace slags, steel slags and other slags are used worldwide in railroad ballast, asphalt ingredients and road building products. Eighteen million tons of iron blast furnace, basic oxygen furnace, and steel slags are generated every year in the US with 37-40% used in asphalt and concrete applications, 29-35% used in road base, and 9-15% used as fill. These uses demonstrate that the Kleen Blast spent abrasive recycling options, such as use in cement kiln and road building, constitute common product uses that are similar to analogous raw materials.

2) What degree of processing is required to produce a finished product?

All raw materials undergo some type of processing prior to mixing or feeding into the manufacturing operation. Aggregates need to be crushed, sized and screened prior to building roads. Cement kilns need ground or milled materials to mix with silica and calcium based raw materials. Spent abrasives need to undergo processing similar to what primary raw materials undergo to re-enter the market. For excluded recyclable materials regulated by HSC 25143.2, screening, sizing and sieving are considered normal processing and not treatment. Since the processing is similar to that of common raw materials, no special processing is required.

3) What is the value of the secondary material? Is there a guaranteed market for the end product?

The value of each raw material is truly market driven. An alternate raw material program may involve additional paperwork, tracking and handling, all of which increase the internal cost and diminish the value of the material if evaluated on price alone. The cement kiln and road building industries sell their products on a daily basis. They are usually limited in terms of storage space and process their materials continuously in order to meet market demand. There is a guaranteed market for their products as demonstrated in the attached letter from Al Cornibe of RMC Pacific Materials.

4) Is the secondary material handled in a manner consistent with the raw material/product it replaces?

In most cases, the only regulatory restriction at issue is for storage of a spent abrasive alternate raw material prior to use. Of paramount importance to the cement kiln application is keeping the material dry by preventing it from contact with run-on, and also preventing the material from entering runoff. Some cement kilns store both spent abrasives and virgin raw materials in a similar manner to avoid their getting wet, thereby reducing the high cost associated with drying.

Conclusion

Kleen Industrial Services has endeavored to develop a beneficial reuse program for spent abrasives that is both economical and compliant. By working with owners/generators, blasting contractors and potential recyclers, KIS has been able to implement a successful program since 1994 based on the qualities and chemistries of the Kleen Blast product. The turnkey supply and recycling program has successfully recycled over 40,000 tons since conception.

KLEEN
INDUSTRIAL SERVICES

Question and Answer Session

At the conclusion of the technical presentation was followed by a question and answer session, which inadvertently was not recorded. Any questions on this presentation or about products and services offered by Kleen Blast should be directed to:

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Keynote Presentation

Industrial Ecology: Promise and Challenges

Gil Friend, President and C.E.O.
Natural Logic

Industrial ecology – applying the principles of ecology to industrial and regional economic development – offers considerable promise for improving economic performance while reducing industry's environmental footprint. It also faces technical, economic and political challenges to realizing that promise. Overcoming these challenges is especially important given the impact of industrial inefficiency on environment, health, equity, and the productivity of society and the planet.

Industrial ecology offers a design and management framework that can address these technical, economic and political challenges, with clear directives for resource use including:

- balancing resource use with natural system regeneration;
- improving resource use efficiency; and
- finding productive uses for industrial by-products, or eliminating "waste" altogether.

The sustainability challenge for petroleum and chemical sectors stands out when looking at material stocks and flows. "What business are we really in (e.g. extracting materials or providing services)?" Answering this question yields new business insights that are being turned into profit and market advantage by leading companies such as BP and Dow.

Business model innovation driven by industrial ecology can transform EH&S sustainability initiatives into revenue producers. Making industrial ecology real requires a systematic process that moves it beyond a concept. One key aspect is an "industrial metabolism" analysis that leads cross-functional teams through a systematic approach to define Key Environmental Performance Indicators (KEPIs). Ultimately, these indicators can be used as a basis for implementing support systems that help teams make better business decisions, reduce operating costs, benchmark performance between facilities and units, and identify leverage points for change.

Industrial Ecology in Motion

The following examples from Natural Logic's website www.natlogic.com illustrate how the ideas of industrial ecology are being applied profitably in operating companies.

An article in the October issue of Pollution Engineering magazine entitled *Redefining Recycling: Everything is a Product* profiled Chaparral Steel, one of the largest electric arc furnace (EAF) steelmakers in the US. According to author Barbara Quinn, Chaparral's vision is to "push the limits of steelmaking practice to the point where everything the steel mill produces will, in synergy with adjacent enterprises, be a useful product." "It is a vision based not only on environmental concerns," Quinn observes, "but on pragmatic economic considerations. If you believe everything is a resource, then 'waste' is a sacrificed financial opportunity – and Chaparral doesn't intend to sacrifice anything."

So, in collaboration with a nearby cement plant that happened to be owned by its parent company Texas Industries Inc., Chaparral set out to find new opportunities reduce waste generation, increase efficiency and create value. The results have been noteworthy. Chaparral has reduced the volume of baghouse dust (a hazardous waste which costs $220/ton to dispose) to 28% below industry average, reduced lime content in the dust by 87% (allowing it to be used in metals recovery), reduced lime use by one-third and saved over $1 million in 1994 by using 5130 tons of recycled dust in the furnace.

In 1993 Chaparral improved magnetic separation of slag, (which it had previously sold as a road-building material for $0.55/ton), recycling iron back to the furnace and selling the resulting higher grade, low iron slag to the cement plant at $22/ton – added revenue, $6 million. Chaparral has replaced hazardous mill cleaning solvents: non-organic caustic, halogenated organic and ignitable organic with non-toxic products, and reduced solvent use overall by 160 tons/year, for an annual savings of $400,000. And closed loop processes have enabled Chaparral to cut make-up water consumption in half.

These are steps in the right direction, but Chaparral's overall goal is zero waste, with on-site, combined processing of slag, scale and dust instead. Quinn quotes Chaparral senior vice president of engineering Libor F. Rostik, "It is no longer possible for steelmakers to be concerned only with steel production. They have to accept responsibility for byproducts and waste streams. That responsibility becomes an incentive for innovation and progress."

Of course the concepts of waste exchange, of the "non-product outputs" of one process serving as the inputs for the next process, are nothing new in the petroleum and chemical industries. "Oil refineries all tend to be quite specialized," writes chemical engineer Douglas Holmes; "they take in one kind of crude oil, and they produce specific products for particular markets. But since crude oil is a mixture of literally hundreds of different kinds of molecules, what do they do with those they do not need? Sometimes they change the molecules [to create other products]. But, in many cases, recognizing the value of their by-products (they are NOT referred to as waste products), they have arranged to sell these to a neighboring company. This has evolved quite far; there are even closed recycle loops crossing the fences [between companies]."

But even those relatively advanced examples are far from the zero waste concept. Though the petroleum and chemical industries have reported substantial reductions in toxic waste production in recent years, these industries account for a major share of the hazardous waste generated in the US. But those same industries may prove among the leaders in the move toward zero waste systems: two major chemical firms – Monsanto and Dupont – are among a handful of companies that have publicly adopted a "zero waste" goal.

Is this goal realistic? As Gunter Pauli of the Zero Emissions Research Institute tells it: $40 billion revenue. Dupont's decision was based on their success in reducing pollutants 80% in five years. And when Chairman Edgar Woolard decided that this was not enough,

he found that "it was actually easier to motivate the 80 top managers to commit to zero emissions than it was five years ago to motivate them to commit to reduce 80% waste." Some decision makers listen to advisors who say "Zero emissions? Impossible." Fortunately some operate by the more interesting motto, "The difficult we do immediately. The impossible takes a little bit longer."

Question and Answer Session

The following questions were asked by technical forum attendees and were answered by the presenter:

Q: With sustainability directives coming from Shell corporate in Europe, and coming to Shell in US Shell refineries are doing things for sustainability but actions are not quite being owned – the sustainability message is not coming across as clearly as, perhaps it should. How should refineries proceed?

A: Technologies of these issues is relatively simple compared to the human factor. You can engineer a system (design, calculations, and projections). This is much easier than convincing someone to implement it, training them to do it, or selling the project to finance department on investing.

Things you can't affect:

- There may not be widespread agreement that the Europeans *do* have it right.
- There may be some resentment from the directives from Europe whether their right or wrong.
- There is a lot of habit of how we're done it this way.
- There is a political climate in US that sees these particular issues, the greenhouse issues, very different from how Europe sees them.

Things you can affect: How can you make sustainability projects your own in a way that meets your objectives? Example: you're not reducing by 20 percent because Netherlands says so – you're doing it because you can get some gain out of it like:

- traction in particular markets where it will give us the advantage,
- reductions in operating costs that will expand profit margins that will let us redirect capital to where we couldn't put it before;
- that will let us identify new processes that we could get new products out of.

As we benchmark world wide, we see a lot of very good work coming out of the US (with many exceptions), but the Europeans are about 5-10 years ahead of American industry in a host of industrial sectors. US can't sell to the European market (3-4 billion people) unless it meets their standards, and European industry is meeting their own standards better than the US is. Sony just had a whole shipload of PlayStations turned away from the Netherlands because they didn't meet European environmental standards for product components, recycleability, etc. So, Sony changed the way they made their PlayStations.

Bottom line: You can treat the directive as a bothersome requirement or as an early warning signal.

Q: Evolutionary change vs. revolutionary change: How much of our resources do we focus on improving things at status quo with existing processes and approaches at the expense of delaying or being an obstacle to new directions, new types of market structures, and new types of technologies?

A: It's a challenge both to the regulator with relation to the industry AND within the companies. When companies are in the process of setting their goals for performance improvement, there is a philosophical gap between:

a) those who say lets figure out what we can do reliably and make that our goal, and
b) those who set a goal that they know they need to get to even though they don't know how they'll get there.

Dupont story is a good example. Culturally, neither way is right or wrong. Politically, with best available control technology (BACT), performance improvement goals are locked into historic practice when they should be moving forward. If politics push beyond BACT, they get resistance from industry. In the mid 1975, Detroit was sending a lot of lobbyists to Washington DC to oppose the pending 1980 renewal of the Clean Air Act, arguing that it was technically and economically infeasible to meet the standards. But, Honda had been meeting the 1980 standards since 1973 and gaining market shares. This showed that the statement that it was infeasible was untrue.

The moral of the story: There is real value in raising the bar and in pushing. The regulatory arena can offer the basic regulatory regime – what you *have* to do, what is reasonably and politically acceptable. And offer incentives to raise the bar… reduce reporting requirements, streamline processes, faster permits, etc. The challenge is finding the incentives and how to wire them so that people are paid for the right thing. What are you measuring to help companies be smarter and make better decisions? How do you wire the incentives so that people are actually paid for the right things and not the wrong things? There are a lot of examples of paying incentives for the wrong things – in our tax policies, corporate compensation policies, and investment policies. We need find ways to unlock this.

Q: When dealing with competition in the corporate world, you deal with short term vs. long term goals. You can have very egalitarian ideas for the long term that get devoured by the short term. How do we deal with that?

A: With brutal realism. Many environmentalists feel that companies should be willing to sacrifice short term progress in return for the long term benefits that will accrue to them as well as to society. This is not realistic; you don't get the capital or the value in the market.

There is an assumption that short term and long term goals are at odds. But what we are seeing is that if you approach how you do business intelligently and systematically, you can increase the short term returns as well as the long term returns, and your competitive position (although not in every case or situation and certainly not easily).

Just as the environmentalists' position is not realistic, business' position – that businesses have to focus on short term profits and not worry about the long term – is also unrealistic. What's worse, the way we discount cash flows, we say that future money not worth as much as it is now. This warps out economic logic that doesn't allow us to invest in the future. Business people need to invent strategies that can address both short and long term needs. The logic is that we need to live today, 10 years from now, and our kids need to live 50 years from now. Why would we want to sacrifice one at the expense of the other? The only possible reason is that you think that you have to. If you are smart enough to figure out a way to do both, you don't have to sacrifice long term.

SB 14 Update

The New Summary Progress Report

Leslie Goodbody, Hazardous Substance Engineer
Department of Toxic Substances Control
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Background

Starting in September 1, 1991, and every four years thereafter, businesses that routinely generate more than 13.2 tons of hazardous waste annually are required to meet the planning and reporting provisions of the Hazardous Waste Source Reduction and Management Review Act of 1989 (SB 14) [California Health and Safety Code Section 25244.12 et seq.]. SB 14 requires generators to prepare a forward-looking Source Reduction Plan, a retrospective Performance Report, and a Summary Progress Report (SPR) every four years. The most recent SB 14 documents were due on September 1, 2003.

SB 14 also requires OPPTD to compile SB 14 documents into industry-specific assessments for at least two industries every two years. OPPTD has prepared an industry assessment for the petroleum refining industry for each reporting cycle because this industry continues to represent California's largest hazardous waste generator. The first two assessments have facilitated sharing of source reduction ideas and success stories throughout the petroleum industry. A third assessment, covering refinery source reduction efforts from 1994 to 1998, will be published later this year, and a fourth assessment based on SB 14 reports reflecting 1998 to 2002 performance, will be published in 2004.

Since the inception of SB 14 in 1989, the petroleum refining industry has shown significant reductions in the amount of hazardous waste they generate. DTSC's industry-specific assessments indicated that the petroleum refining industry reduced their hazardous waste generation by 32% from 1990 to 1994 and close to 40% from 1994 to 1998. Correspondingly, the amount of crude processed in California during these periods decreased by only 5% from 1990 to 1994 and 4% from 1994 to 1998.[4]

At the time of the May 22, 2003 technical forum, petroleum refiner's SB 14 documents for the 2002 reporting year were likely in various stages of development. These documents include the Performance Report covering accomplishments from 1998 to 2002, the Source Reduction Plan for the 2003-2006 planning period, and the SPR summarizing both 1998-2002 source reduction accomplishments and projections through 2006. It is important to note that nothing in the SB 14 legislation or supporting regulations [California Code of Regulations Title 22 Section 67100] has changed since the previous reporting cycle. Because petroleum refiners are very familiar with the reporting requirements of SB 14, the technical forum discussion focused on recent changes to the SPR.

[4] Crude processing percentages calculated using data provided by California Energy Commission.

Recent SPR Changes

OPPTD recently revised the SB 14 Guidance Manual and SPR form for the 2002 reporting year to mitigate commonly repeated mistakes identified in generator's 1998 documents. Most notable revisions include the overhauled SPR form, terminology changes, and the addition of clarifying language. OPPTD also provided generators with more choices for completing their SPR, including the option to file their SPR online.

SPR Form Design

When designing the new SPR form for the 2002 reporting year, OPPTD staff sought to make it easier to complete accurately without jeopardizing informational needs. Our goal was to eliminate the fine-print instructions on the back of the tables, which were difficult to read and, in some cases, difficult to understand.

The new and improved form includes two parts.

- Table 1 for reporting general facility-wide information and waste stream totals (to be completed only once); and
- Table 2 for reporting waste stream-specific information, requiring a separate Table 2 for each waste stream.

The new form does not include instructions – rather it describes on the form what is required for each entry. *SPR Tips* were incorporated throughout the guidance manual to help generators link reporting requirements for the Source Reduction Plan and Performance report to the SPR tables.

Terminology Changes

SB 14 only requires source reduction planning for *major waste streams* (i.e., those that are greater than 5% of the total SB 14-applicable waste at a facility). When calculating major waste streams, one must first separate waste that is treated on site in a wastewater treatment plant then discharged to a sewer (formerly called *aqueous waste*) from those waste streams that are not (formerly called *nonaqueous waste*). By separating these two types of waste streams before calculating percentages, one ensures that the larger aqueous waste is not the only waste stream greater than 5% and, therefore, evaluated for source reduction.

While most large generators who filed the 1998 SPR, including petroleum refineries, understood this approach, many smaller businesses were confused by the terminology. Why would anyone call a water-based waste that is containerized, manifested, and shipped off site *nonaqueous*? The problem stems from the fact that, for a waste to be considered *aqueous*, it must meet very specific conditions: treated on site in a waste water treatment unit that conveys the effluent to a publicly-owned treatment works or to a water body under an NPDES permit. If it does not meet these conditions, it is *nonaqueous* using the previous SB 14 guidance manual terminology.

To alleviate this confusion, the 2002 edition of the Guidance Manual used neutral terminology: aqueous is now *Category A* and nonaqueous is now *Category B*. This

terminology is also used in the new SPR along with a definition of each waste stream category.

Source Reduction Achieved

By far the largest number mistakes were found in generators estimates of *source reduction achieved*, which is the amount of hazardous waste reduced in pounds/year due to implementing source reduction measures. Compounding this problem was that fact that the reporting requirements for the Performance Report outlined in the March 1999 Guidance Manual did not specifically ask for this number.

The number reported for source reduction achieved is important to OPPTD's analysis of source reduction performance on a statewide perspective, industry-specific perspective, and waste stream-specific perspective. This information helps OPPTD assess whether the state has achieved it's 5 percent per year source reduction goal.

Source reduction achieved is the amount of hazardous waste that was not generated because source reduction measures were implemented. Generators are encouraged to determine the most appropriate way to calculate this number for each waste stream and quantify it as pounds per year. No single approach is best for quantifying this value. Page 50 of the December 2002 Guidance Manual offers suggestions on how one might quantify this value. Normalization was suggested to account for fluctuations in business or production activity. Some suggested approaches require generators develop a value (weight or volume/time) that represents the change in hazardous waste generation due to source reduction, and then complete the appropriate calculations to report this value in pounds/year.

While careful calculation of *source reduction achieved* enables OPPTD to report more accurately on statewide progress toward source reduction goals, it also helps facilities tout their success to management. Equating a source reduction measure to cost savings, better compliance, and improved worker health and safety, can help facilitate management's commitment to future source reduction activities.

SPR Filing Options

On or before September 1, 2003, generators were required to complete their SB 14 documents and send their completed SPR to OPPTD. For this reporting cycle, OPPTD provided generators with more SPR filing options, including the option to file SPRs online. OPPTD strongly encouraged generators to consider this option because of limited staff and/or funding available for data entry.

Generators who do not have internet access or who are uncomfortable using the online system could either complete the form manually, or complete an electronic version of the form, then mail or e-mail the completed from to OPPTD.

The online SPR filing system offers generators some security features. Once an individual logs on to the SPR system with their facility's USEPA Generator ID number, the system links that ID number to the individual's computer terminal. This connection

ensures that no one other than the person using this terminal modify the ID number-specific SPR. This person then has seven days in which they can log on and off to complete their SPR. After seven days, the system accepts the SPR as final and provides no further access to the database using that ID number. Generators should contact OPPTD for help with the online form or to re-access their SPR after the seven-day period.

Information Sources

Please consider the following sources for more information about SB 14, online SPR filing, OPPTD and our publications:

- http://www.dtsc.ca.gov/PollutionPrevention/index.html for information on DTSC's pollution prevention programs, resources, pollution prevention links, and publications, including SB 14 publications, go to
- http://www.dtsc.ca.gov/database/SB14/index.cfm to access the online SPR database

Or call DTSC's Source Reduction Unit, (916) 322-3670, if you have questions or need assistance with SB 14 or the SPR.

DEPARTMENT OF TOXIC SUBSTANCES CONTROL

California's Universal Waste Rule

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The Department of Toxic Substances Control (DTSC) has adopted regulations establishing California's Universal Waste Rule as the most comprehensive in the nation. Sixteen different wastestreams have been designated as universal wastes by DTSC regulations or by statute. These waste streams, which were previously identified as hazardous waste (with two exceptions), all meet the criteria established by the United States Environmental Protection Agency (U.S. EPA) for designating universal wastes.

Background

Universal wastes are hazardous wastes that are commonly generated by a large number and wide variety of generators, frequently in small quantities. The Universal Waste Rule was developed to increase the likelihood that these wastes will end up at recycling centers or hazardous waste treatment or disposal facilities, and not at solid waste landfills or illegal dump sites. The Universal Waste Rule applies performance based management standards that are protective yet much simpler than the general standards for hazardous waste. The environmental protection measures focus on the final "destination" facility that recycles or disposes the material rather than on management prior to arrival at the destination facility.

The California Universal Waste Rule can be found in Title 22 of the California Code of Regulations, beginning with section 66273.1. Further universal waste standards for non-empty aerosol cans are found in section 25201.16 of the Health and Safety Code.

Universal wastes, per unit, pose limited hazards compared to industrial hazardous wastes due to the small size and limited quantity produced by each universal waste generator. Universal wastes are regulated because of the aggregate hazard they pose when improperly disposed in large quantities.

Universal Waste Designation

California has designated wastes as "universal wastes" using the same criteria used by the U.S. EPA when establishing the base federal Universal Waste Rule (Code of Federal Regulations, Title 40, Part 273). U.S. EPA's criteria for designation as universal waste are listed below.

- The waste is a hazardous waste.
- The waste is not exclusive to a specific industry or group of industries and is commonly generated by a wide variety of types of establishments.
- The waste is generated by a large number of generators and is frequently generated in relatively small quantities by each generator.

- Regulation under the Universal Waste Rule ensures close stewardship of the waste.
- The risk posed by the waste during accumulation and transport is relatively low compared to other hazardous wastes and, in concert with applicable Department of Transportation requirements, is protective of human health and the environment during accumulation and transport.
- Regulation of the waste under the Universal Waste Rule increases the likelihood that the waste will be diverted from solid waste landfills to recycling, treatment, or disposal at hazardous waste facilities.
- Regulation of the waste under the Universal Waste Rule improves implementation of and compliance with the hazardous waste regulatory program.

California has designated sixteen waste streams as universal waste including three of the four wastestreams that are universal waste under federal law. These waste streams and the rationale for their listing are provided below in Table 1.

Table 1 California Universal Wastes

Listed California universal wastes	Rationale
1. Batteries	corrosivity and heavy metals
2. Lamps (fluorescent tubes, other mercury lamps, and other "street light" type lamps)	mercury, leaded glass, sodium metal
3. Cathode ray tube materials	large amounts of high lead glass
4. Consumer electronic devices (all small electronics that test as hazardous waste)	lead and copper
5. Non-empty aerosol cans (by statute)	reactive and often toxic
Mercury-containing wastes including:	
6. Thermostats (with mercury capsules)	mercury
7. Motor vehicle light switches (by statute)	mercury
8. Non-automotive mercury switches	mercury
9. Dental amalgam wastes	mercury
10. Mercury-containing pressure or vacuum gauges	mercury
11. Mercury-added novelties (by statute)	mercury
12. Mercury counterweights and dampers (stabilizers and recoil dampers for hunting bows and shotguns, clock pendulums)	mercury
13. Mercury thermometers	mercury
14. Mercury dilators and weighted tubing	mercury
15. Mercury-containing rubber flooring (older cured-in-place gymnasium flooring)	mercury
16. Mercury gas flow regulators (obsolete design, being removed from service)	mercury

DTSC did not designate cancelled and suspended pesticide products, which are universal waste under the federal rule, because waste pesticides in California are already eligible for streamlined collection programs under the Agricultural Commissioner and because large quantities of cancelled and suspended pesticides pose much too high a risk.

Why has California designated these wastes as universal wastes?

Application of the general hazardous waste standards to the waste streams that California has designated as universal waste would be unmanageable for several reasons:

- Effective regulation of such a large number of generators would require an impossible augmentation of DTSC resources. For instance, DTSC staff responsible for managing generator ID numbers currently manage 74,000 ID numbers. Adding the approximate 1.1 million commercial universal waste generators to the system would require a 15 fold increase in staff. DTSC's permitting, enforcement, and administrative staff would require similar augmentation – an impossible event given the State's current fiscal situation.
- Command and control regulation of the large numbers of universal waste generators and handlers would dilute DTSC's vital efforts to control the large volumes of industrial hazardous wastes that pose much more imminent and serious threats compared to universal wastes.
- Imposing expensive and complex requirements without sufficient DTSC enforcement and oversight resources in place would create an incentive for generators to illegally dispose universal wastes. Such illegal disposal to the general environment is a more serious threat than continued disposal at solid waste landfills.

How is the California Universal Waste Rule different from U.S. EPA's?

- California identifies a wider scope of wastes as hazardous wastes and universal wastes. California identifies alkaline batteries as hazardous and universal wastes, and subjects household universal wastes, and very small generator universal wastes their rule while U.S. EPA does not.
- California requires recycling to manage many of the 16 waste types as universal waste. Generally, California's recycling requirement applies to the mercury-containing wastes. U.S. EPA has no comparable recycling requirement.
- California requires a hazardous waste facility permit for recycling universal wastes. This permit and the enforcement program are the focus of the environmental protection offered by the Universal Waste Rule. Most hazardous waste recyclers do not need permits from U.S. EPA.
- California has not included cancelled and suspended pesticides in their Universal Waste Rule. California has special rules for Agricultural Commissioner-sponsored collection events to allow simple collection of waste pesticides. The massive pesticide release to the Sacramento River near Dunsmuir, California, illustrated the need for careful and specialized control and management of pesticide releases.

What benefits do regulation under the Universal Waste Rule offer to the regulated community?

- Very simple generator standards with simplified storage, packaging, labeling and training rules, and longer accumulation time limits.

- Ability to self-transport or use a common carrier, and use of a bill of lading in lieu of the hazardous waste manifest.
- No permit is required for intermediaries that collect, accumulate, and move universal wastes on to destination facilities. This allows a wide range of private and public sector solutions to managing these wastes, such as retail/wholesale takeback, commercial collection, captive accumulation sites, and household hazardous waste collection.

What will happen next to DTSC's universal waste program?

- If problems with illegal disposal or other mismanagement arise, potential changes could be made to the basic Universal Waste Rule standards such as:
    - Increased recordkeeping for all handlers
    - Notification requirement for offsite accumulation facilities
- Alternative management standards for other wastestreams and activities may be adopted, pending passage of legislation. DTSC would designate additional hazardous wastes as universal wastes and establish special "tailored" standards for other specific activities. These wastes may include:
    - Wastes managed by mobile service providers (maintenance, repair)
    - Deactivation of phostoxin (fumigant) residues
    - Treated wood wastes as universal wastes

DEPARTMENT OF TOXIC SUBSTANCES CONTROL

Question and Answer Session

The following questions were asked by technical forum attendees and were answered by the presenter:

Q: Was there a reason why car batteries were not included in California's Universal Waste Rule?

A: Most rechargeable batteries had to be UW but the cranking batteries don't have to be. The car battery rules that we have now are less burdensome that UW and it works. We have one of the highest battery recycling rates in the country. Everyone is comfortable with the existing system and it really is successful.

Q: Why did DTSC allow people to do temporary disposal with the end of disposal exemptions? What is DTSC going to do about it?

A: There is no effective infrastructure to collect those wastes at this point and they are largely going in the trash. The fear was that, by telling people that certain wastes couldn't go in the trash and telling collectors that they can't collect UW, it would result improper handling and disposal. They could get broken and hidden in a paper bag, exposing people to mercury. Or it will end up out in the country, like the used tires.

DTSC, Energy Commission, and the Integrated Waste Management Board formed an infrastructure workgroup, that is trying to come up with ways do develop a robust infrastructure. Unfortunately, it will rely on a funding source which may be in jeopardy because of the budget crisis. We are hoping that something comes of this effort because household collections are the best alternative for households and small businesses. We're trying to convince the manufacturers to form take-back programs. For e-waste, we are hoping for passage of a product stewardship bill where those who sell consumer electronics must take them back.

Comments: Convenience is the key to public recycling. The garbage man is not checking your can to see if there is a computer in there. Until we have a "bucket" for UW, it will be difficult to get compliance.

Some of the characteristics of a system that will work are convenience. You can't ask people to drive across town and make them wait for an hour. It has to be free. When they collected cathode ray tubes (televisions and computer monitors) in Sacramento, and when people found it cost $25, 90% of the cars turned around and drove away. If you throw a television in the trash, the collector may leave it on your door step – the haulers and landfills are educated. But, batteries, broken fluorescent lamps, and things you can hide are virtually impossible to deal with. Our success rate with some of these things will be less than 100%. Education, real convenience and freebees are the things that will drive success.

People get educated at work and find that when they get home they want to do the right thing, but there is no infrastructure so they bring it to work. But regulatory, it's not OK to bring UW from home and ask your employer to take care of it.

We are hoping to convince some of the manufacturers to take on some of the responsibility with take back programs and the like.

Drum-Top Fluorescent Lamp Crusher Evaluation

Suzanne Davis, Hazardous Substance Engineer
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In 2001, Californians disposed of or recycled an estimated 122 million used mercury-containing fluorescent lamps. The Universal Waste Rule now requires businesses and eventually residences to send these lamps to off-site commercial recycling facilities. Presently, these lamps are either disposed of in municipal landfills or recycled at off-site commercial recycling facilities. Landfill disposal, as well as improper handling of mercury-containing lamps during transport, contributes to mercury in California's environment via surface runoff, leaching to groundwater, atmospheric emissions, and potentially, landfill gas emissions.

Safe storage and transport of used lamps presents many challenges. For this reason, many businesses and household hazardous waste facilities are interested in using small drum-top lamp crushers at their facilities to reduce the volume of spent fluorescent lamps and to improve their ability to store, handle and transport these wastes. In the past, small drum-top lamp crushers used in California and other states have contaminated work areas and buildings with mercury. Because of the high interest in these devices, DTSC is currently working with the U.S. EPA to evaluate the effectiveness of these units. Units that can effectively control mercury emissions and meet California Occupational Safety and Health Administration (CalOSHA) requirements will be considered for less stringent permit requirements.

Background

In December 2000, DTSC began research on available lamp crushing technologies. As part of this research, the U.S. EPA and several environmental agencies throughout the United States and Canada were contacted regarding the operation and regulation of these units. The initial survey focused primarily on small drum-top fluorescent lamp crushers (DTCs) but also included a few large fluorescent lamp recycling units that both crush and separate the lamp components. Part of this survey assessed potential performance and worker health and safety issues associated with DTCs based on available information. In September 2002, DTSC partnered with U.S. EPA Region 3 to get data that would help DTSC set regulatory requirements and permit conditions for small drum-top fluorescent lamp crushers in California. This paper summarizes the testing procedures developed for this evaluation and the preliminary data obtained at two testing locations; one in Phoenix, Arizona and the other in Ashland, Virginia.

Small Drum-Top Fluorescent Lamp Crushers

Small drum-top fluorescent lamp crushers have similar designs that consist of a lamp crushing unit, exhaust emission controls, and a collection container (usually a 55 gallon

barrel). Fluorescent lamps are fed into the crusher one at a time via a cylindrical feed tube. A rotating blade or flail located in the crusher shatters the fluorescent lamp on impact. The crushed lamp material (glass, endcaps, and some phosphor powder) drops into a collection container located below the rotating blade or flail. Exhaust air from the unit is drawn through a particulate filter and an activated carbon filter prior to release into the ambient air. **Table 1** lists the different DTC features for each tested unit.

Table 1 Small Drum-top Fluorescent Lamp Crusher Features

Unit Name	Manu-facturer	Dimensions	Feed Rate	Type of Lamp Crushed	Filtration System			Accessories	Unit Cost
					Filter Bag	HEPA Filter	Activated Carbon		
Model 55VRS-U Bulb Eater	Air Cycle Corp.	55 gallon drum; ~5 ft tall	20 lamps per minute (800-1000 lamps/drum)	Straight lamps & U-shaped lamps	Yes	Yes	22 lbs; impregnated with 15% sulfur	DFI	Not Available
ULC-55FDA-E Lamp Disposer	Dextrite	Ht:31 in., W: 24 in., Dia.: 24 in.	25 4 ft lamps per min. (800 4 ft. lamps/drum)	Straight lamps & U-shaped lamps	Yes	Yes	13 oz; impregnated with potassium iodine	LC, DFI	$5,335
Drum-Top Fluorescent Lamp Crusher	RTI	Ht:~94 in., W: 24 in., L: ~94 in., collects glass in 55 gal drum	500 4-ft lamps/hour/ drum	Straight lamps	None; 15 Minute Purge	Yes	85 lbs	DFI, PLC	~$10,000
Fluorescent Lamp Disposal and Mercury Vapor Recovery System	HMS	55 gallon drum; ~5 ft tall	1200 4-ft lamps/drum	Straight lamps	Yes	Yes	5 lbs	None	$3,995
LC = Lamp counter, DFI = Drum Full Indicator, PLC = Programmable Logic Controller									

Test Procedures and Results

Four vendors of commercially available small drum-top fluorescent lamp crushers – *Hazardous Materials Specialist* (HMS), *Resource Technologies Inc.* (RTI), *Aircycle*, and *Dextrite* – participated in the testing at two field test locations. Each vendor provided one new unit that would be used for the entire evaluation. As part of Phase I, new units were tested by crushing one drum full of lamps, changing the drum, and changing the filter as specified by the manufacturer. In Phase II, the same units (after use in Phase I) were tested by crushing two drums full of lamps, changing the drums, and changing the filters as specified by the manufacturer. Separate air samples were collected for the crushing operation, drum change, and filter change. An 8-hour overnight air sample was also collected while the unit was idle at the Phoenix facility. Pre- and post-wipe samples were collected from the walls, ceiling, and floor of the test area along with two background samples from the facility floor. Mercury vapor concentrations were continuously monitored during the tests using a direct reading instrument (Jerome mercury vapor

analyzer). Measured concentrations were compared to the following Occupational Safety and Health Administration (OSHA) exposure levels.

- CalOSHA permissible exposure level (PEL)[5]: 0.025 milligrams per cubic meter of air (mg/m^3)
- Federal OSHA PEL: 0.1 mg/m^3
- CalOSHA and Federal OSHA ceiling limit: 0.1 mg/m^3

Preliminary results from Phase I indicate the units may meet California standards for worker exposure when brand new. However, Phase II preliminary results indicate the units may not meet CalOSHA standards after minimal use (processing more than three drums of lamps). Based on real-time mercury vapor analyzer readings, all the units appear to have a common problem with mercury concentrations exceeding the CalOSHA and FedOSHA ceiling limit values during drum change outs. Any mercury vapors in the headspace of the drum are released during this operation since mercury is volatile at normal room temperature.

During the Phase II testing conducted in Phoenix, Arizona, DTSC observed some units periodically jammed or blew endcaps and glass shards back at the operator while operated. For all three units tested, phosphor powder was released during the drum change out. Phosphor powder adhering to the feed chute and hoses on the drum-top cutter assembly was dispersed on the floor when these parts were detached.
It was also observed that the presence of broken lamps may also elevate the mercury concentration in an enclosed area. Several cardboard boxes, each capable of holding approximately 30 lamps, contained a minimum of 2-3 broken lamps to a maximum of 15 broken lamps. The testing facility noted that they encounter far more broken lamps when stored and shipped in cardboard boxes compared to lamps shipped and stored in fiberboard cylindrical cartons.

Follow-up Activities

In June 2003, the DTC units were tested at facilities in Melbourne, Florida, and Ashland, Virginia. USEPA anticipates making a final report available in 2004.

Summary and Conclusions

Preliminary results for the DTC units tested to date indicate three of the four units tested may meet the CalOSHA PEL when brand new but all units exceeded both the CalOSHA and federal PELs after limited use. These units also appear to have problems with jamming and blowing small amounts of crushed material at the operator.

DTSC has concerns about these units meeting California's standards for worker safety. Based on these preliminary results and DTSC staff observations, use of these units, if allowed, would likely require continuous monitoring during operation. Workers need to be trained in taking appropriate health and safety precautions and donning proper personal protective equipment. The tests also raise concerns about the level of operator skill needed, e.g. to calibrate monitoring equipment. Therefore, it is recommended that a

[5] PELs based on maximum permitted 8-hour time weighted average.

potential user contact the DTSC Hazardous Waste Management Program for information concerning requirements to operate such devices. Currently, these units require a standardized permit to be operated in California.

Sources of Information

Department of Toxic Substances Control (DTSC) website

Universal Waste Fact Sheet
A list of downloadable fact sheets is available at
http://www.dtsc.ca.gov/PublicationsForms/HWM_FS_UWR.pdf

Survey and Initial Evaluation of Small On-site Fluorescent Lamp Crushers
The report can be downloaded at from the web site at
http://www.dtsc.ca.gov/ScienceTechnology/Crusher_Note.html

U.S. Environmental Protection Agency (EPA)

Universal Waste Fact Sheet
A few downloadable fact sheets concerning lamps in the federal universal waste regulations are available at http://www.epa.gov/epaoswer/hazwaste/id/univwast.htm.

Fluorescent Lamp Recyclers

Please note: The following list is not to be considered a comprehensive list and is not an endorsement by DTSC of any of the companies listed below.

AERC-MTI, Inc. (may also be listed as Mercury Technologies Inc.)
30677 Huntwood Avenue
Hayward, California 94544
Phone: (800) 628-3675
Fax: (510) 429-1498
http://www.aerc-mti.com/

Earth Protection Services, Inc. (EPSI)
P.O. Box 23820
Phoenix, AZ 85063-3820
Phone: (800) 414-0443
Fax: (602) 353-9285
http://www.earthpro.com/

Lighting Resources, Inc.
805 E. Francis Street
Ontario, California 91761
Phone: (888) 923-7252
FAX: (909) 923-7510
http://www.lightingresourcesinc.com/index.html

Ecolights Northwest, Inc.
P.O. Box 94291
Seattle, WA 98124-6591
Bus: (206) 343-1247
Fax: (206) 343-7445
http://www.ecolights.com/

Industry Groups and Associations

Association of Lighting and Mercury Recyclers (ALMR)
2436 Foothill Blvd., Suite B
Calistoga, CA 94515
Phone: (707) 942-2197
Fax: (707) 942-2198
http://www.almr.org/

National Electrical Manufacturers Association (NEMA)
1300 North 17th Street, Suite 1847
Rosslyn, VA 22209
Phone: (703) 841-3200
Fax: (703) 841-5900
http://www.nema.org/lamprecycle/recyclers.html

DEPARTMENT OF TOXIC SUBSTANCES CONTROL

Attachment A

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Attachment B

Supporting Correspondence for
GAC Bio-recycling Discussion

Department of Toxic Substances Control

Edwin F. Lowry, Director
1001 "I" Street, 25th Floor
P.O. Box 806
Sacramento, California 95812-0806

Winston H. Hickox
Agency Secretary
California Environmental
Protection Agency

Gray Davis
Governor

Mr. Peter Schmidt
Project Manager
Sub-Surface Waste Management
5922-B Farnsworth Court
San Diego, California 92008

ONSITE RECYCLING OF ACTIVATED CARBON

Dear Mr. Schmidt:

Thank you for your letter to the Department of Toxic Substances Control (DTSC) inquiring about the legality of recycling spent activated carbon onsite. Specifically, you requested a return transmittal stating that a generator could recycle and reuse spent activated carbon onsite through utilizing a microbiological regeneration process developed by Sub-Surface Waste Management (SSWM). Although your letter described the regeneration process in detail, your letter did not describe the recyclable material that would be recycled or how the recycled materials would be used or reused. Therefore, we can only provide a general response to your question.

Ordinarily, persons performing hazardous waste treatment activities (e.g., regenerating spent activated carbon) are required to obtain a hazardous waste permit or other grant of authorization from the DTSC. However, California's Hazardous Waste Control Law contains an exemption from the hazardous waste facilities permit requirements that are potentially applicable to the recycling activity described in your letter. That exemption may be found in the California Health and Safety Code (HSC), Division 20, Chapter 6.5, section 25143.2 (c). Pursuant to that section, any recyclable material (a recyclable material is a hazardous waste that is capable of being recycled) may be recycled at a facility that is not authorized by DTSC if certain requirements are met. Those requirements are as follows:

1. The recyclable material is recycled and used at the same facility at which it was generated.

2. The recyclable material is recycled within the applicable generator accumulation time limits specified in the California Health and Safety Code and corresponding regulations adopted by DTSC.

3. The recyclable material is managed in accordance with all applicable requirements for generators of hazardous wastes.

If the above stated requirements are met, and if none of the stipulations listed in HSC, Section 25143.2(e) supersede a claim to the exemption, a hazardous waste permit would not be required for the onsite recycling activities performed by the generator. The permit exemption would apply solely to the carbon recycling activities. Any wastes generated as a result of the recycling (i.e., including the water, materials and equipment described in your letter) would be subject to all applicable laws and regulations, including the applicable hazardous waste laws and regulations, if the waste(s) is/are hazardous waste(s). Any releases of hazardous waste from the SSWM process to the environment would be fully regulated. In addition, a generator that recycles more than 100 kilograms per month of activated carbon using the SSWM process is required to comply with the reporting requirements specified in HSC, section 25143.10.

DTSC does not endorse products, manufacturers or services. The applicability of the permit exemption [HSC, section 25143.2(c)(2)] to the SSWM process, as discussed in this letter, does not constitute and should not be misconstrued as "approval" by DTSC of any particular product, service, or vendor.

I hope this letter clarifies the applicability of the recycling provision in California's Hazardous Waste Control Law to the SSWM process. A copy of "Excerpts from California's Hazardous Waste Recycling Laws and Regulations" is enclosed for your convenience. If you have additional questions regarding this matter, please contact Mr. Charles Corcoran of my staff at (916) 327- 4499.

Sincerely,

Karl Palmer, Chief
State Regulatory Programs Branch
Hazardous Waste Management Program
Department of Toxic Substances Control

cc: Mr. Charles Corcoran, Section Chief
Waste Identification and Recycling Section
State Regulatory Programs Branch
Department of Toxic Substances Control
1001 "I" Street, 11th Floor
P.O. Box 806
Sacramento, California 95812-0806

Peter Schmidt

From: Charles Tupac [ctupac@aqmd.gov]
Sent: Tuesday, February 05, 2002 5:01 PM
To: 'Peter Schmidt'
Subject: RE: Pilot Study

AQMD has reviewed the information submitted and presented on the website. The information reviewed indicates that the proposed 6 month pilot project is exempt from permit under Rule 219 (c)(6) in that the equipment is not being used on a production scale.

Staff is interested in observing the process and would appreciate your cooperation in scheduling a date in the near future. After the results of the pilot study are complete, AQMD will review and assess the permit status for process. Please also notify me if any of the parameters described in the proposal are being modified.

Please keep in mind that all process are subject to Rule 402 - Nuisance, and although the described operation and refinery site characteristics do not suggest any problems, we request to be notified of any complaints that are received during the project. In addition, please notify me as soon as possible of the exact project location, and then provide five days notice of the initial start-up date.

Attachment C

Supporting Correspondence for Abrasives Recycling Discussion

This Attachment available in hard copy only. To request a copy contact Leslie Goodbody at the Office of Pollution Prevention and Technology Development.

Lgoodbod@dtsc.ca.gov

Attachment D

PowerPoint Presentation Slides from
Industrial Ecology Discussion

Industrial Ecology: Design with Nature

WSPA/DTSC

Joint Pollution Prevention Technical Forum

22 May 2003

Gil Friend, President & CEO

Natural Logic, Inc.

Natural Logic

Building profit and competitive advantage through exceptional environmental performance

Strategy:

Value generation

Strategic Sustainability™ Consulting
Strategic Supply Chain Partnerships™
Marketing and product development
CSR reporting as strategic business tool
Sustainable economic development
Life cycle thinking

Design:

Collaborative Innovation

Integrative design process / charrettes
Green / High performance buildings
LEED training and process management
Green materials research / specification
Permaculture systems: design with nature
Building / Site / Natural system integration

Tools:

Metrics, Dashboards, Reporting

Business Metabolics™ benchmarking software
Key Performance Indicators development
CSR Reporting Power Tools
EcoAudit Toolkit
EQE Checklist

Operations:

Advanced resource productivity

Integrated EcoAudits: process efficiency
Environmental Management Systems
Evaluation & implementation
Green building operation protocols
Profit Discovery processes

Industrial Ecology: What it is, what it isn't, and why

- **Eco-Industrial Development -- the application of industrial ecology principles to industrial development and regional economic development**
- **Idea has captured the imagination of countless analysts and some 60 North American communities.**
- **The industrial ecology concept has deep practical and intellectual roots, stretching far earlier than the oft-cited Kalundborg example.**
- **Considerable promise for improving economic performance while reducing industry's environmental footprint.**
- **Considerable challenges -- technical, entrepreneurial, some of them perhaps intrinsic to the current Eco-Industrial Development model itself -- to realizing that promise.**

Context

Something has shifted

- **Sustainability:**
  Moving from gleam to mainstream
- **More significant than the shift from "pollution prevention" to "pollution control"**
- **Transforming "environment" from a financial burden to a source of strategic business advantage**
  - Process efficiency
  - Design revolution
- **Transforming role of business**

Why should we care?

- **Resource depletion**
- **Pollution, health, productivity**
- **Life support systems: Air / Water / Food / Biodiversity / Climate**
- **Balance of payments**
- **License to operate**
- **Competition**
- **Social equity & social stability**

Massive economic impacts

- **Money down the drain**
- **Profit margins squeezed**
  - **uncontrolled yet avoidable resource costs**
  - **inefficient production processes**
- **Risk management diverts critical resources**
- **High cost & value**
  - **customer and employee loyalty**
  - **brand erosion**

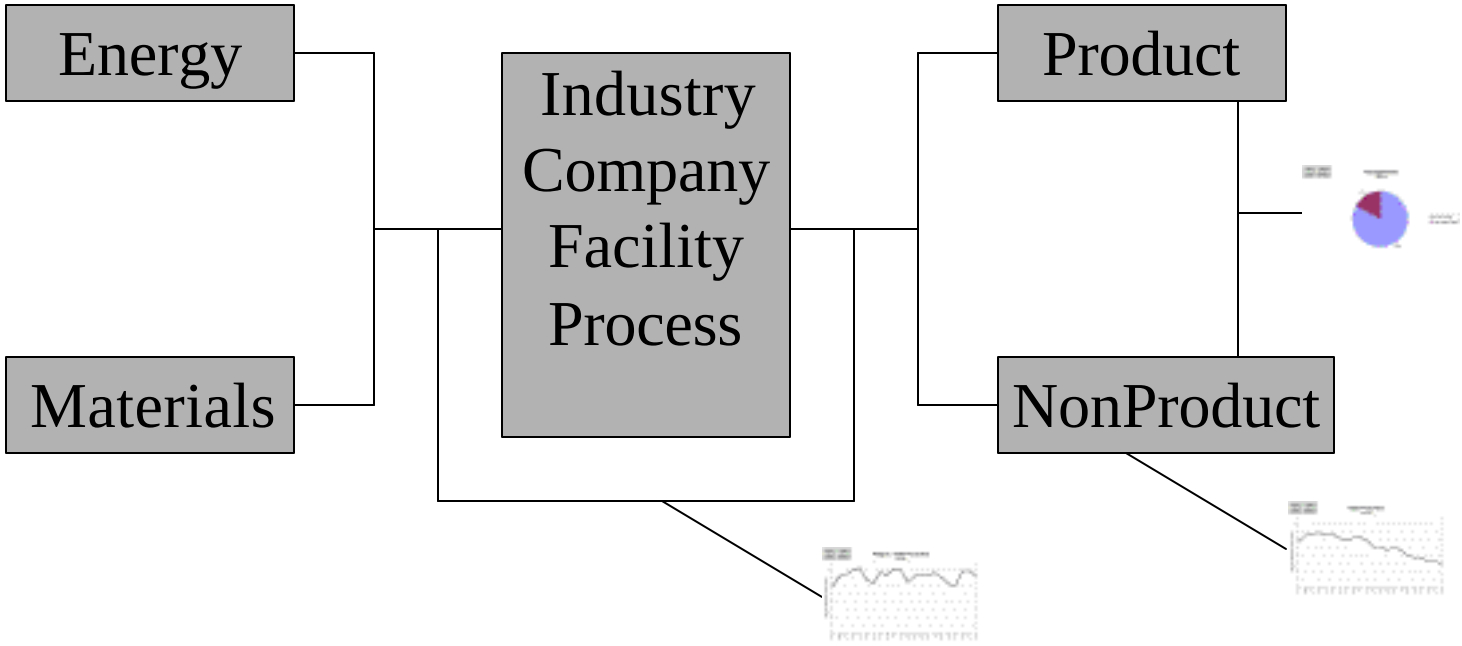
Energy “down the drain”

- **US manufacturing**
  - **$64 billion on fuels and electric energy**
- **US trade**
  - **1999 energy imports $44.6 billion**
  - **1999 trade deficit $218.2 billion**
- **US energy budget**
  - **$200 billion/year national savings if we just match Japan**

Materials “down the drain”

- **US manufacturing**
  - **$1.9 trillion on materials**
- **“Waste” treatment & remediation:**
  - **$81.9 billion annual expenditures**
- **Pollution abatement:**
  - **$8.4 billion capital investment for manufacturers**
    - **(7.5% of total capital investment)**
  - **$19.2 billion operating costs**
- **“Total Cost of Waste”** (Steven Rice)
  - **4-10 times direct (disposal) costs**

Only two things...



“Waste”? No such thing!

- **Contextual - like weeds - yet significant**
- **No “waste” in nature**
- **“Non-Product Output” adds no value to a company’s customers *or* shareholders**
- **The U.S. economy’s physical output?**
  - **94% “waste”**
- **Accounting systems miss full costs**

Enter: Industrial Ecology

Industrial Ecology: Design with Nature

- **Nature's ecosystems have more than 3.5 billion years of experience evolving efficient, complex, adaptive, resilient systems.**
- **Why should companies reinvent the wheel, when the R&D has already been done?**

- Gil Friend, 1991

History

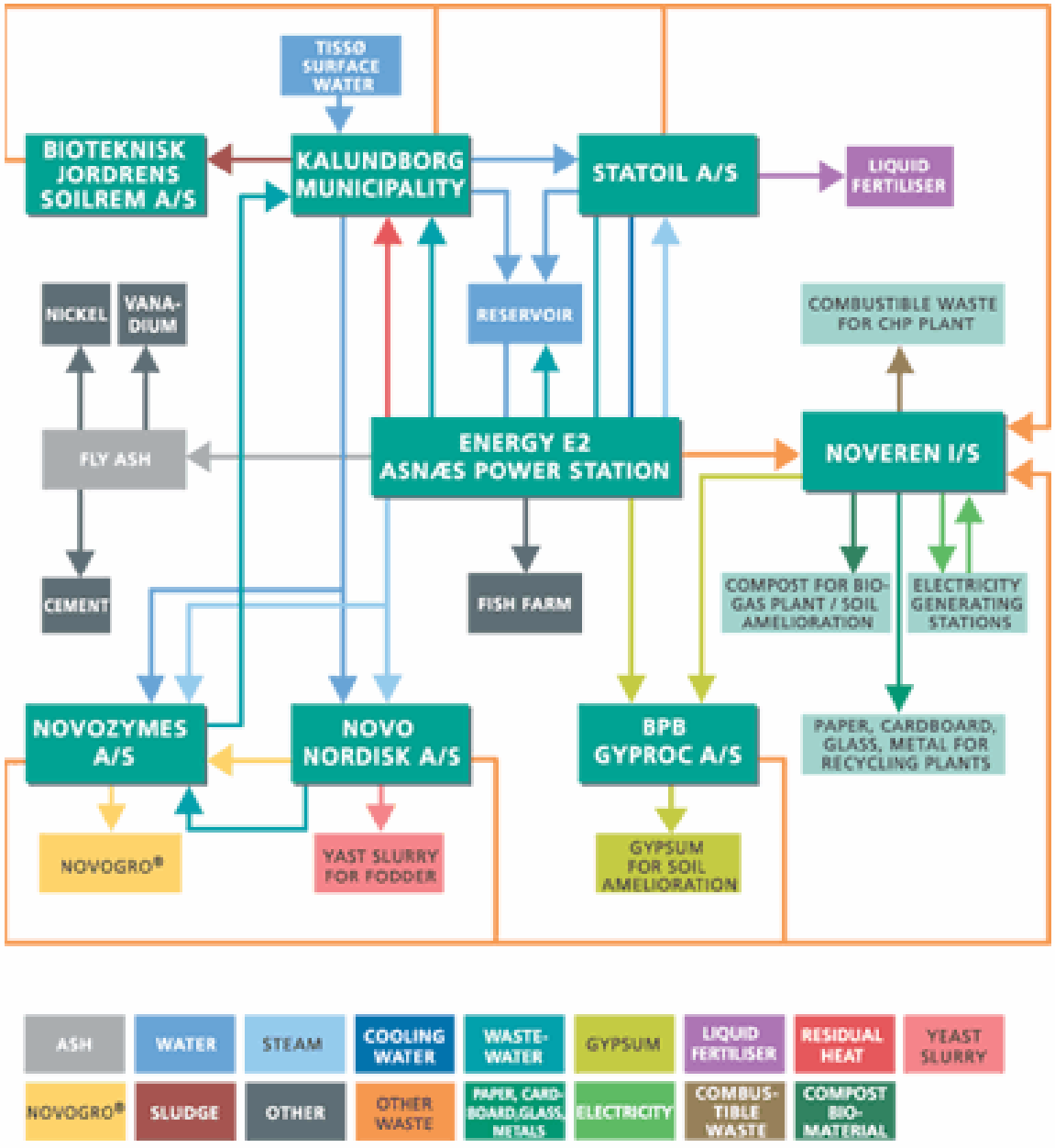
- **Benyus, Biomimicry, 1997**
- **Friend, EcoMimesis 1996**
  - **http://www.natlogic.com/resources/nbl/v05/n04.html**
- **Tibbs, Industrial Ecology 1992**
- **Various, sustainable agriculture 1970s-80s**
- **McHarg, Design with Nature 1972**
- **Van Dresser, Landscape for Humans 1940s**
- **Howard, An Agricultural Testament 1890s**
- **Indigenous agriculture**

Trajectory

- **Kalundborg**
- **EcoIndustrial Parks**
- **EcoIndustrial Estates**
- **EcoIndustrial Networks**
- **Zero Waste strategies**

Kalundborg

- **Collaboration between five industrial businesses for mutual economic and environmental benefit**
  - Power plant
  - Fish farm
  - Pharmaceutical company
  - Agricultural farms
- **Projects**
  - recycling water:
  - exchanging energy at different levels: waste steam, district heat
  - waste products to inputs (e.g. sludge to fertilizer)


TISSØ SURFACE WATER
BIOTEKNISK JORDRENS SOILREM A/S
KALUNDBORG MUNICIPALITY
STATOIL A/S
LIQUID FERTILISER
NICKEL
VANA-DIUM
RESERVOIR
COMBUSTIBLE WASTE FOR CHP PLANT
FLY ASH
ENERGY E2 ASNÆS POWER STATION
NOVEREN I/S
CEMENT
FISH FARM
COMPOST FOR BIO-GAS PLANT / SOIL AMELIORATION
ELECTRICITY GENERATING STATIONS
NOVOZYMES A/S
NOVO NORDISK A/S
BPB GYPROC A/S
PAPER, CARDBOARD, GLASS, METAL FOR RECYCLING PLANTS
NOVOGRO®
YAST SLURRY FOR FODDER
GYPSUM FOR SOIL AMELIORATION
ASH
WATER
STEAM
COOLING WATER
WASTE-WATER
GYPSUM
LIQUID FERTILISER
RESIDUAL HEAT
YEAST SLURRY
NOVOGRO®
SLUDGE
OTHER
OTHER WASTE
PAPER, CARD-BOARD, GLASS, METALS
ELECTRICITY
COMBUS-TIBLE WASTE
COMPOST BIO-MATERIAL

Zero waste

- **Dupont reduced pollutants 80% in five years.**
- **"It was actually easier to motivate the 80 top managers to commit to zero emissions than it was five years ago to motivate them to commit to reduce 80% waste."**
  - Edward Woolard, Chairman & CEO

Industrial Ecosystems: Modeling on natural ecosystems

- **No waste (the output of one process becomes the input for another);**
- **Concentrated toxins are not stored, but synthesized as needed;**
- **"Elegant" cycles of materials and energy weave among the companies;**
- **Systems are dynamic, and information driven;**
- **Independent participants in coordinated action.**

– Hardin Tibbs

Program for Industrial Ecology

- **Creation of industrial ecosystems**
- **Balancing industrial output to natural ecosystem capacity**
- **Dematerialization**
- **Improving metabolic pathways**
- **Systemic patterns of energy use**
- **Policy alignment with long-term perspective of industrial system evolution**

– Hardin Tibbs

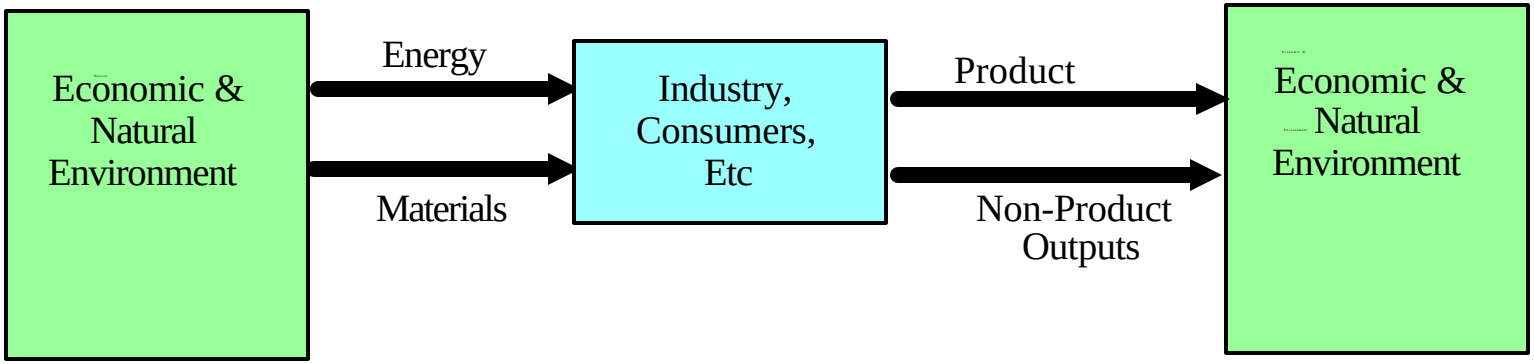
Design Principles

- **Material flows**
  - Close material loops
  - Shorten loops
  - Use "waste" streams
  - Rich interconnections
- **Minimize:**
  - throughput
  - extraction of virgin materials
  - non-renewable energy
  - adverse environment impacts
  - persistent bioaccumulative toxics (PBTs)
  - human health effects
  - transport distances

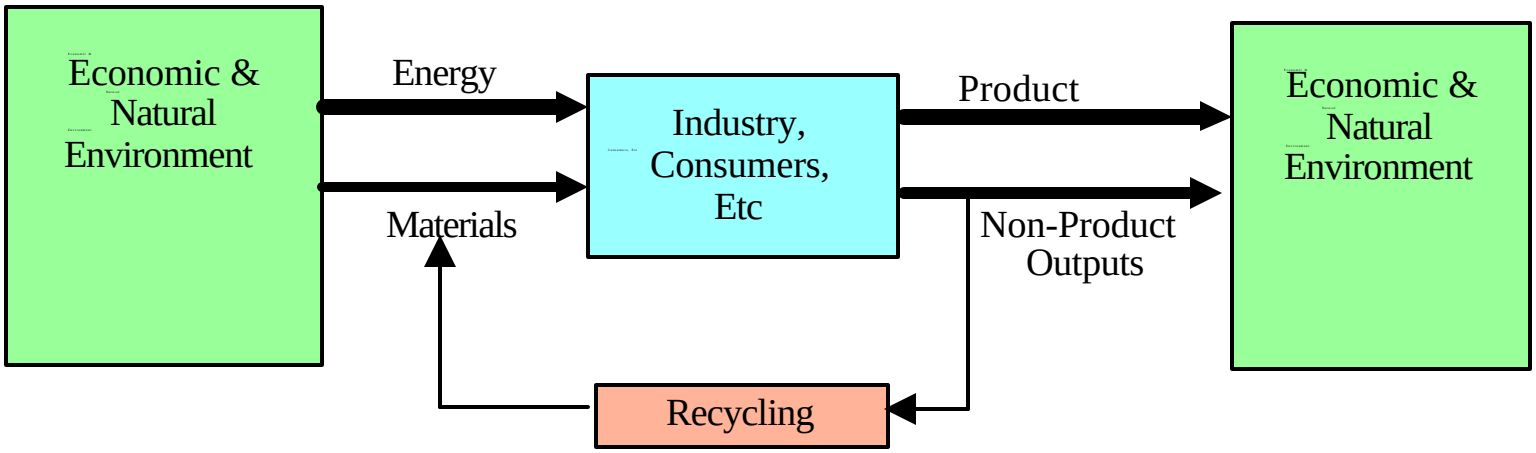
Design Principles

- **Products**
  - Long lasting products
  - More service, less product
- **Maximize**
  - Product life
  - Diversity and interconnection
  - Closed material loops
  - Resource Efficiency
  - Added value

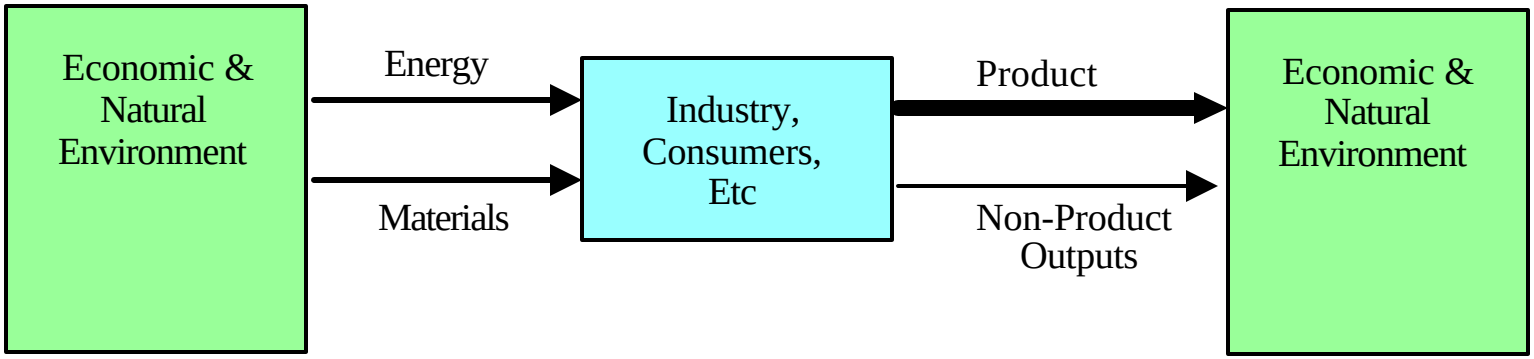
Metabolic Efficiency Strategies



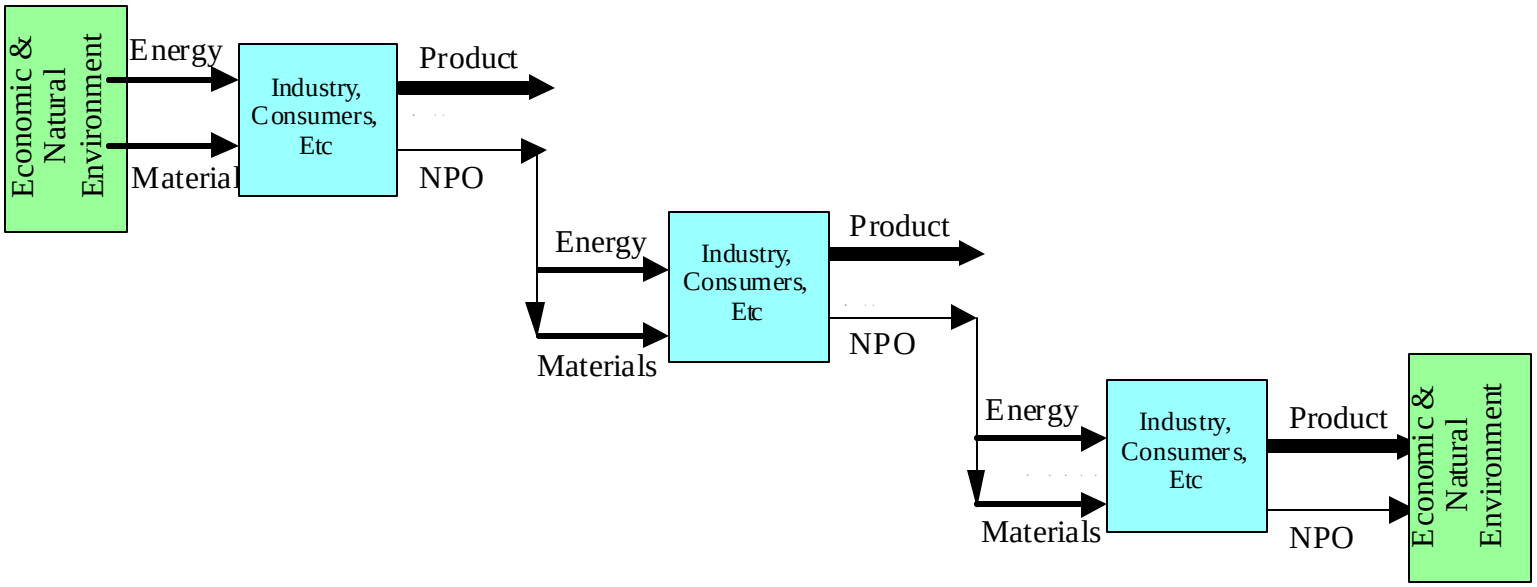
Metabolic Efficiency Strategies: Recycling?



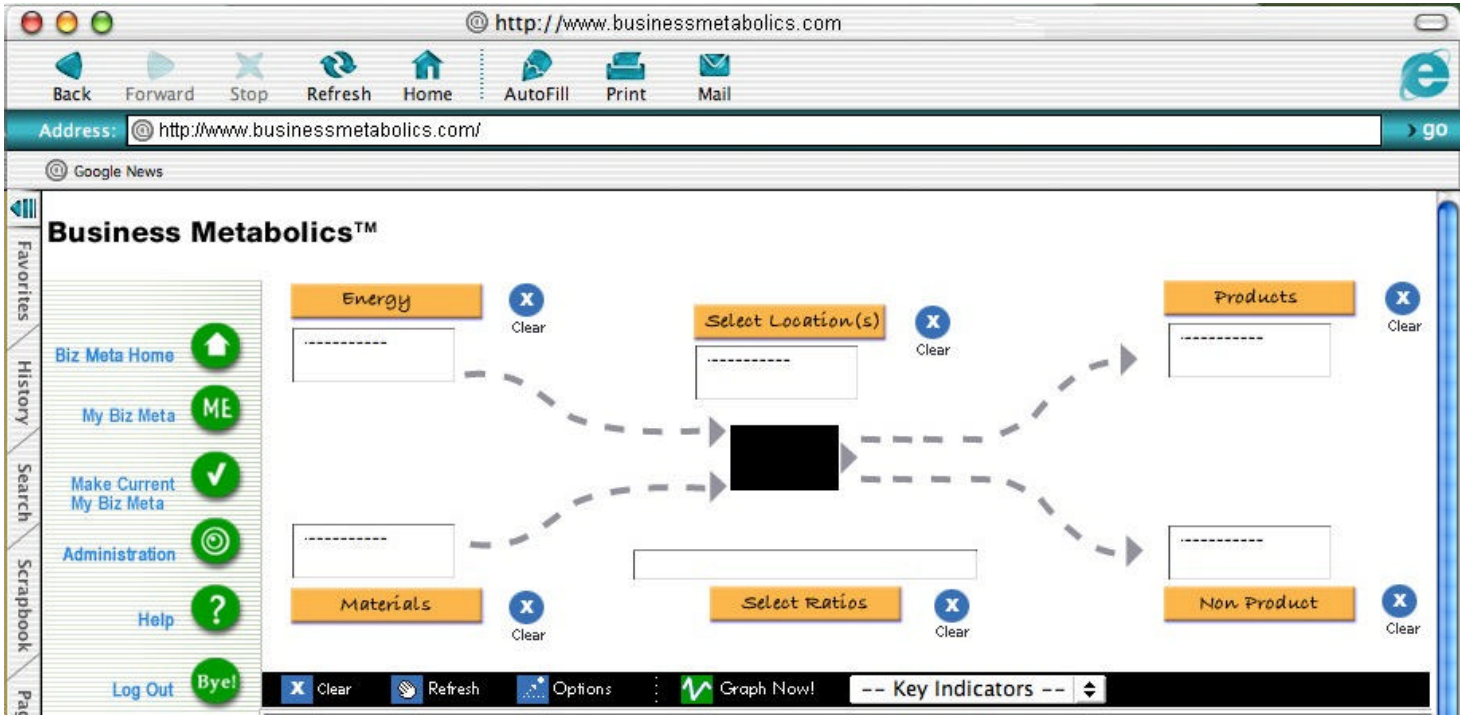
Metabolic Efficiency Strategies: Reduce NPO



Metabolic Efficiency Strategies: Cascading



Business Metabolics™



- Resource productivity trends
- Key ratios
- Throughput Pie™

- Internal+External Benchmarks
- Link “environmental” & business factors

The Challenge Ahead

“New industrial revolution”

- **Products, services and whole businesses that reduce, eliminate or reverse impact on the environment… profitably!**
- **Cars that clean the air**
- **Factories that clean the water**
- **Buildings—and cities—with “zero ecological footprint”**
- **Companies that make more money selling *less* “stuff”**
- **“Making the world work for 100% of humanity”**

Challenges: Industrial Ecology

- **Business issues**
  - Matching resource flows
  - Reliability of supplies
  - Contract design
- **Development issues**
  - Evolved vs purposive systems
  - Entrepreneur vs public authority initiated
- **Regulatory and legal issues**
  - Waste or resource - RCRA
  - Incentives / Disincentives: pollution, waste disposal, virgin materials
  - Technology standards -> peformance standards
  - High-leverage, non-lethal control variables
  - Zero emissions zoning

Challenges: Extractive Sectors

Issues

- Type of material
- Rate of extraction
- Regenerative capacity - ***not*** “running out of resources”

Innovative business responses:

- BP: “beyond petroleum” - solar, wind, “carbon neutral” gas card
- Shell: rural PV and hydrogen business units, cleaner biofuel blends

Challenges: Your customers

Innovative business responses:

- Cargill- Dow: crop-based polymer feedstocks
- DuPont: zero waste, chemical management systems
- Millennium Chemicals: new market in fuel cell production for its zirconia, use of efficient CHP
- ASG Transport: “petroleum is a strategic dead end”

The key strategic question:

What business are we really in?

Getting From Here to There

Asking the right questions

Not “*Can* we?”

“*How* can we?”

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