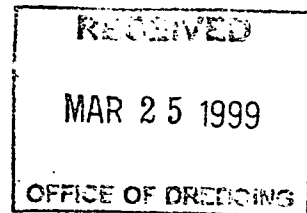


Center for Environmental  
Engineering

Stevens Institute of Techno  
Castle Point on Hudson  
Hoboken, NJ 07030  
201.216.5326  
Fax: 201.216.8303



March 21, 1999

Mr. Richard Dewan  
New Jersey Department of Environmental Protection  
Office of Dredging & Sediment Technology  
PO Box 028 401 East State Street  
Trenton, New Jersey 08625

**Re: Status report #2, Project - (Iron Powder In-Situ treatment of Contaminated River Sediment)**

Dear Mr. Dewan:

Enclosed is a brief summary identifying the completed tasks associated with Phase 1 activities for the NJDEP funded grant entitled "Iron Powder In-Situ Treatment of Contaminated River Sediment", submitted by the Center for Environmental Engineering at Stevens Institute of Technology and ARS Technologies of Highland Park, NJ.

Since the submission of the first status report dated February 8, 1999, work has continued to focus on the preliminary treatability studies utilizing iron powder, the evaluation of alternative iron powders, acquisition of additional data for site selection, and purchasing of sample equipment.

- Preliminary Treatability Studies

### ***PCBs***

As indicated in the Status Report dated February 8, 1999, the preliminary results of a 45 day treatability study indicated a total PCB mass reduction of 38% for a sediment water slurry within a 10 day period. Results correlating to the 20 and 30 day analysis were performed, indicating a substantial drop in PCB congener concentrations. Reductions of up to 60% were observed for the more highly chlorinated PCB compounds, specifically 2,2',4,4'-tetrachlorobiphenyl, 2,2',3',4,6-Pentachlorobiphenyl and 2,2',4,4',5,6'-Hexachlorobiphenyl.

### ***Inorganics***

A treatability study utilizing iron powder and sediment spiked with chromium, lead and arsenic has been initiated in order to obtain preliminary reaction kinetics associated with each metal. Initial concentrations of the each metal in the sediment were 167 mg/kg. A complete reduction of lead was achieved to below 500ppb within a 20 day period. Reductions were also observed with arsenic and chromium, but at slower rates.

7

A Business Resource at

**STEVENS**  
Institute of Technology

The adsorptive characteristics of the metals were also evaluated within the sediment, indicating that both arsenic and chromium have tendencies to significantly adsorb to the sediment.

- **Alternative Iron Powder Evaluation**

Iron powder obtained from a New Jersey manufacturer, designated as ATW 100, was evaluated for its reactivity relative to the E-200 Japanese powder currently imported and used commercially by ARS. The test was performed within a sandy clay soil contaminated with TCE. The results demonstrated that the ATW 100 powder was significantly more reactive than the E-200 powder in reducing TCE. In total, three types of powder, including the ATW 100, were supplied by the New Jersey manufacturer and will be evaluated during Phase 2 of the project.

- **Site Selection Options and Additional Data Research**

#### ***Site Selection***

As outlined in the first progress report, three (3) locations have been identified as being prospective sampling collection points along the Passaic River. The locations were selected in accordance with the criteria outlined in Phase 1, Task I-1 of the Scope of Work report dated June 3, 1998. The prospective sampling locations were selected based upon the following criteria: contamination history, priority and accessibility.

#### ***Additional Data Research***

Additional information has been obtained from the USEPA, which identify the locations and concentrations of samples collected from within the upper, middle and lower reaches of the Passaic. The data consists of samples collected from 1993 through 1995, and provide a detailed characterization of a broad range of contamination present within the sediment. A majority of the data had to be obtained at the Region 2 offices located in New York City from Ms. Sharon Jaffess of the USEPA Emergency & Remedial Response Division.

Evaluation of the data identifies several additional locations where representative samples could be collected with greater accessibility to the river. Site visits have are scheduled to coincide with sample collection during the week of 3/22/99.

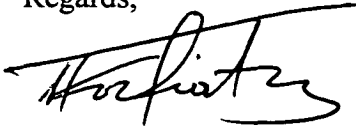
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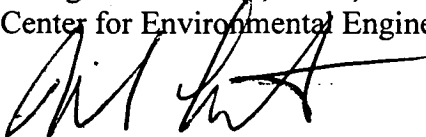
- Scheduled Work

- Collect samples during the week of 3/22/99 from four (4) locations along the Passaic.
- Initiate baseline analysis on sediment obtained from sampling.
- Complete preliminary treatability analysis on PCBs, inorganics and dieldrin.

Regards,



George P. Korfiatis, Ph.D., Principal Investigator  
Center for Environmental Engineering



Michael Liskowitz  
Project Engineer  
ARS Technologies, Inc.



Stevens Institute of Techn  
Castle Point on Hudson  
Hoboken, NJ 07030  
201.216.5326  
Fax: 201.216.8303

Center for Environmental  
Engineering

**FAX COVER SHEET**

**DATE** MARCH 23, 1999 **TIME:** 2:30PM

**ATTENTION** RICHARD DEWAN

**COMPANY** NJ DEP - OFFICE OF DREDGING & SEDIMENT TECHNOLOGY

**FAX NO.** 609-777-1914 **TEL NO.** 609-984-4426

**SENT BY:** GEORGE P. KORFIATIS

**TOTAL OF PAGES INCLUDING THIS SHEET** 4

**MESSAGE** STATUS REPORT #2 - IRON POWDER IN-SITU TREATMENT OF CONTAMINATED RIVER SEDIMENT. ORIGINAL WILL BE SENT TO YOUR ATTENTION @ DEP.

**IF YOU HAVE ANY PROBLEMS RECEIVING THIS TRANSMISSION, PLEASE CONTACT** MARTA QUIGLEY **AT** (201)216-5326

**PLEASE DISTRIBUTE TO THE APPROPRIATE PERSON AS SOON AS POSSIBLE.**





Stevens Institute of Technology  
Castle Point on Hudson  
Hoboken, NJ 07030  
201.216.5326  
Fax: 201.216.8303

Center for Environmental  
Engineering

March 21, 1999

Mr. Richard Dewan  
New Jersey Department of Environmental Protection  
Office of Dredging & Sediment Technology  
PO Box 028 401 East State Street  
Trenton, New Jersey 08625

**Re: Status report #2, Project - (Iron Powder In-Situ treatment of Contaminated River Sediment)**

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- **Site Selection Options and Additional Data Research**

#### ***Site Selection***

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#### ***Additional Data Research***

Additional information has been obtained from the USEPA, which identify the locations and concentrations of samples collected from within the upper, middle and lower reaches of the Passaic. The data consists of samples collected from 1993 through 1995, and provide a detailed characterization of a broad range of contamination present within the sediment. A majority of the data had to be obtained at the Region 2 offices located in New York City from Ms. Sharon Jaffess of the USEPA Emergency & Remedial Response Division.

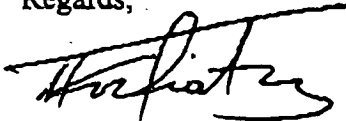
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Several sampling apparatus were researched for their applicability to the tasks associated with the Phase 1 sampling activities. The equipment was purchased upon specific criteria, which will enable accurate representative samples to be collected at the desired depths from both a research vessel and/or the riverbank.

- Scheduled Work
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  - Initiate baseline analysis on sediment obtained from sampling.
  - Complete preliminary treatability analysis on PCBs, inorganics and dieldrin.

Regards,



George P. Korfiatis, Ph.D., Principal Investigator  
Center for Environmental Engineering



Michael Liskowitz  
Project Engineer  
ARS Technologies, Inc.



Center for Environmental  
Engineering

Stevens Institute of Technology  
Castle Point on Hudson  
Hoboken, NJ 07030  
201.216.5326  
Fax: 201.216.8303

FILE COPY

February 8, 1999

Mr. Richard Dewan  
New Jersey Department of Environmental Protection  
Office of Dredging & Sediment Technology  
PO Box 028 401 East State Street  
Trenton, New Jersey 08625

Re: Status report, Project - (Iron Powder In-Situ treatment of Contaminated River Sediment)

Dear Mr. Dewan:

As requested, enclosed is a "brief summary" identifying the completed tasks associated with Phase I activities for the NJDEP funded grant titled "Iron Powder In-Situ Treatment of Contaminated River Sediment", awarded to the Center for Environmental Engineering at Stevens Institute of Technology and ARS Technologies of Highland Park, NJ.

Since the initiation of the project, work has focused on the development of laboratory analytical methods, preliminary treatability studies utilizing iron powder, use of alternative iron powders, and site selection.

- Development of laboratory analytical methods

Work has focused primarily on the evaluation of the analytical methods that will be employed for the baseline analysis and treatability studies on the Passaic River sediment. Investigations are being performed in order to optimize the extraction efficiency of the contaminants under consideration from the sediment for both the baseline analysis and the treatability studies.

Clean sediment was spiked with eight (8) PCB congeners. The compounds under evaluation are 2-chlorobiphenyl, 2-3-Dichlorobiphenyl, 2-4-5-trichlorobiphenyl, 2-2'-4-4'-tetrachlorobiphenyl, 2-2'-3'-4-6-pentachlorobiphenyl, 2-2'-4-4'-5-6' hexachlorobiphenyl, 2-2'-3'-3'-4-4'-6'-heptachlorobiphenyl, 2-2'-3'-3'-4-5'-6-6' Octachlorobiphenyl and a chlorinated pesticide referred to as dieldrin.

EPA Extraction Methods were evaluated based upon total PCB mass recovered. The results obtained from the extraction experiments indicate that PCB volatilization is significant and occurring during extractions. Recoveries ranged between 50 and 70 percent for the eight PCB congeners.

- Preliminary Treatability Studies



The treatability experiments have focused primarily on the reduction capability that iron powder has on 8 individual PCB congeners, 3 types of metals (lead, arsenic and lead), and a chlorinated pesticide that are prevalent within sediment collected from the Passaic River. The treatability studies were initiated by spiking aqueous and sediment samples with PCBs, a chlorinated pesticide and metals.

Preliminary results indicate total PCB mass reduction of 69% were achieved within a 70 day period for sediment water, and a 38% mass reduction for a sediment water slurry within a 10 day period. Further analysis correlating to 20, 30 and 40 day studies will be performed.

A preliminary metals analysis was conducted on  $\text{Cr}^{+6}$ ,  $\text{Pb}^{+2}$  and  $\text{Cu}^{+2}$  in sediment water, indicating reductions of 55% for  $\text{Cr}^{+6}$  over 20 days, and 50% reduction of  $\text{Pb}^{+2}$  and  $\text{Cu}^{+2}$  over a 15 day period.

- Iron Powder Vendor Research

Three (3) grades of iron powder were obtained from a southern New Jersey manufacturer. The powder will be compared and evaluated for reactivity relative to the DOWA E-200 powder imported from Japan currently being used by ARS Technologies for the remediation of chlorinated organics.

- Site Selection Options

#### Task I-1 Site Selection and Sample Collection

Three (3) locations have been identified as being prospective sampling collection points along the Passaic River. The locations were selected in accordance with the criteria outlined in Phase 1, Task I-1 of the Scope of Work report dated June 3, 1998. The prospective sampling locations were selected based upon the following criteria: contamination history, priority and accessibility.

The contamination history of the three locations located downstream of the former Diamond Alkali Facility were obtained from reports and maps provided by Mr. Eric Stern of the USEPA and NJDEP. The contaminants under investigation were: chlorinated pesticides (mirex, total DDTs), total PCBs, dioxins (2,3,7,8-tcdd) and metals (Cu, Hg, Pb, As, Al, Cd, Cr).

We are scheduled to meet with Eric Stern of EPA during the week of 2/8/99 in order to obtain a detailed characterization of the proposed sampling locations through previous sampling data currently archived at EPA in New York City.

#### Site 1

Site 1 is located in Newark on the southern bank east of the Highway 95, on the bend where the river flows in a southerly direction, and is situated approximately  $\frac{1}{4}$  of a mile downstream from the former Diamond Alkali Facility. Photographs of the site taken from

the opposite bank indicate that the location provides direct accessibility to the river, where sampling activities and a contained test facility can be set up. The property is believed to be occupied by PSE&G.

- No contact name or phone number obtained

The location was selected based upon the presence of elevated concentrations of PCB's and dioxins, which demonstrate a high priority for remediation. This location ranked 1<sup>st</sup> for PCB concentrations, 2<sup>nd</sup> for dioxin concentrations, 2<sup>nd</sup> with regards to overall chlorinated pesticide concentrations and 2<sup>nd</sup> for overall metals concentrations.

Previous sediment samples collected from within this area have indicated concentrations in excess of 10 ppm for total PCBs and 3 ppb @ 38" for 2,3,7,8-TCDD.

### Site 2

Site 2 is situated within the vicinity of the former Diamond Alkali Plant, which is located at 80 Lister Avenue, Newark New Jersey. An attempt was made to view the site on 1/25/99, but access was denied by site security. As a result, the site has not yet been inspected for accessibility to the river for sample collection. *have*

The location was selected based upon the presence of elevated concentrations of PCB's and dioxins demonstrating a high priority for remediation. This location ranked 2<sup>nd</sup> for PCB concentrations, 1<sup>st</sup> for dioxin concentrations, 1<sup>st</sup> with regards to overall chlorinated pesticide concentrations and 1<sup>st</sup> for overall metals concentrations.

Previous sediment samples collected from within this area have indicated concentrations below 10 ppm for total PCBs and 55 ppb @ 36" depth for 2,3,7,8-TCDD.

### Site 3

Site 3 is situated on the southern bank of the river, on Blanchard Street in Newark, 1/2 mile downstream of the former Diamond Alkali Plant. A site visit indicated the location provides direct accessibility to the river for sampling.

This location was selected based upon, both its relative proximity to the Diamond Alkali Site and the presence of elevated concentrations of contaminants in the sediment. This location ranked 3<sup>rd</sup> for PCB concentrations and 3<sup>rd</sup> for dioxin concentrations. Data with regards to metals and chlorinated pesticides were not available for this location, but samples collected near this area indicated elevated concentrations.

Previous sediment samples collected from within this area have indicated concentrations below 1 ppm for total PCBs, and 1.4 ppb @ 12" depth for 2,3,7,8-TCDD.

- No contact name or phone number obtained

### *Additional Site Investigations*

Two (2) additional sites were investigated as potential sampling locations. The first site is occupied by Stevens Distribution Company, and is located at 250 Passaic Avenue in Newark. The second site is a heliport pad owned and operated by the city of Newark, located adjacent to the New Jersey Performing Arts Center in Newark. Both sites are located within a mile of each other 2-3 miles upstream of the Former Diamond Alkali Facility. These locations were selected for the presence of high concentrations of PCBs and dioxins and for their accessibility to the river.

Chlorinated pesticides and metal concentrations could not be obtained for these sample locations, therefore, until additional data is obtained, these locations fail to meet the priority pollutant criteria established within the SOW.

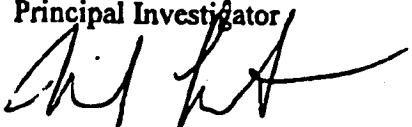
Previous sediment samples collected from within this area have indicated total PCB concentrations in excess of 10 ppm and 2,3,7,8-TCDD concentrations of 32 ppb @ 22" depth.

- Contact for Heliport Location – John Jones at Division of Properties Management, Newark, NJ.
- Contact for Stevens Distribution Center – Danielle Lynch (973-483-5015).
  
- Scheduled work
  - A meeting with Mr. Eric Stern is scheduled for the week of 2/8/99 in order to obtain additional data on contaminant concentrations within the proposed sampling stations.
  - Continue running the treatability studies on river sediment spiked with PCBs, dieldrin and metals.
  - Schedule sampling for the week of 2/22/99, and begin baseline studies of the contaminants present in the sediment.

Regards,



George P. Korfiatis Ph.D.  
Principal Investigator



Michael Liskowitz  
Project Engineer  
ARS Technologies, Inc.



**New Jersey Department of  
Environmental Protection  
Office of Dredging and  
Sediment Technology**



**To:** Kevin Robertson

**Company:** ARS Technologies

**Phone:** (732) 296-6620

**Fax:** (732) 296-6625

**From:** Richard DeWan

**Bureau:** Office of Dredging and Sediment  
Technology

**Phone:** (609) 984-4426

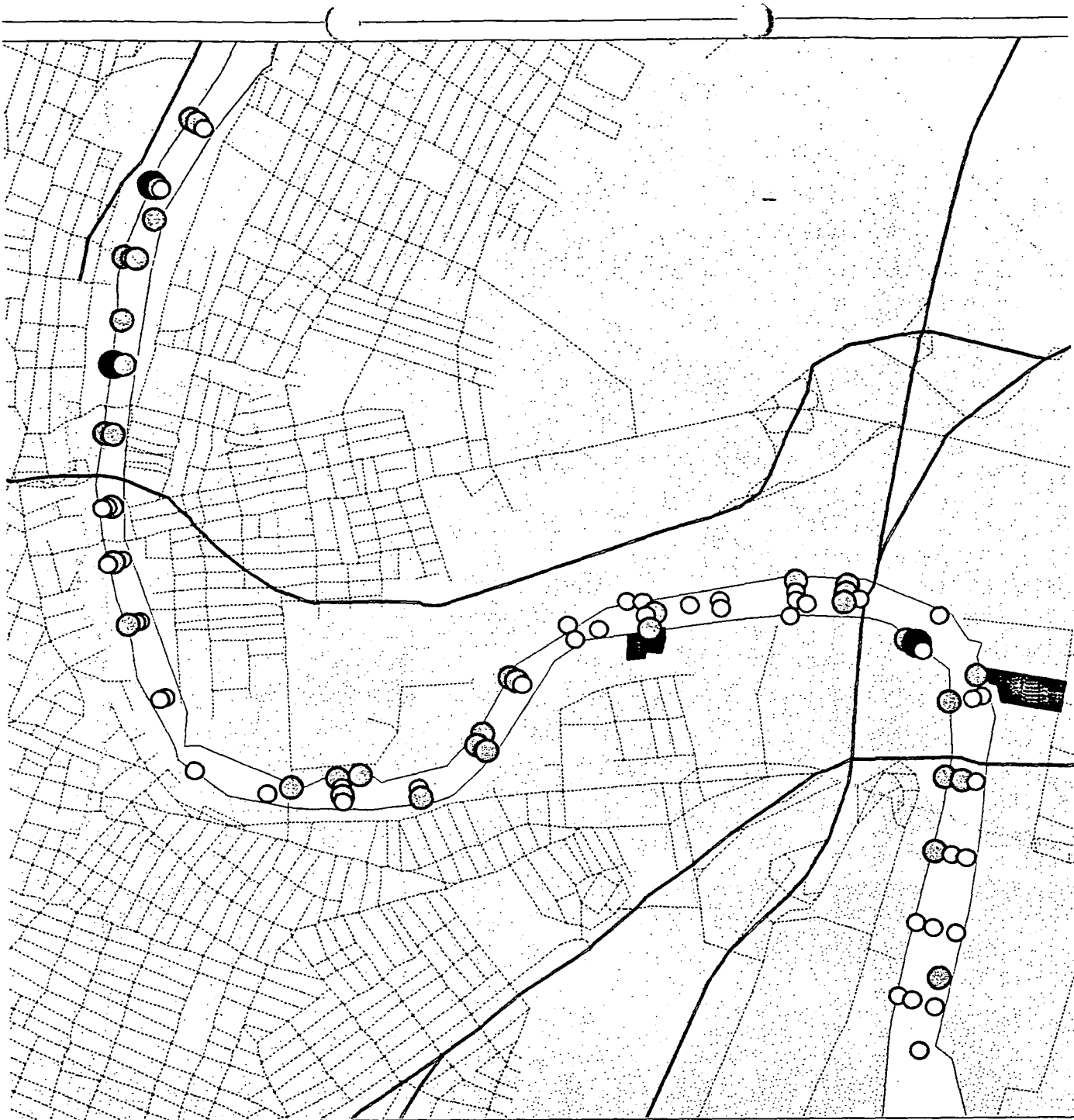
**Fax:** (609) 777-1914

**Date:** 12/16/98

**Pages including this  
cover page:** 2

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Comments: Dear Mr. Robertson: As per our telephone conversation of this afternoon, here is a copy of the referenced map of EPA data. Please call me if you have any questions.



# PCB Concentrations in Passaic River Sediment



This computer representation has been compiled by the Environmental Protection Agency (EPA) from sources which have supplied data or information that has not been verified by the EPA. The data is offered here as a general representation only and is not to be used for commercial purposes without verification by an independent professional qualified to verify such data or information.

The EPA does not guarantee the accuracy, completeness, or timeliness of the information shown and shall not be liable for any loss or injury resulting from reliance.

## Legend

### Roads

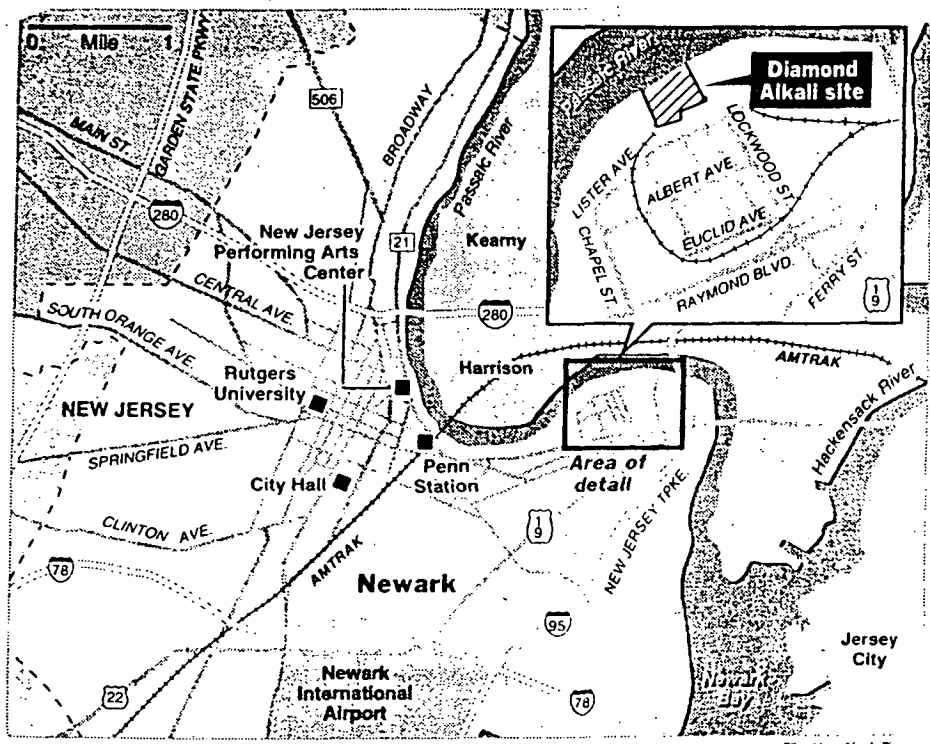
- Highways
- Interstates
- Roads
- NPL Sites
- Shore

### Total PCBs in ppb

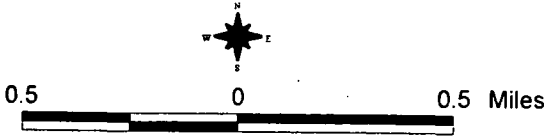
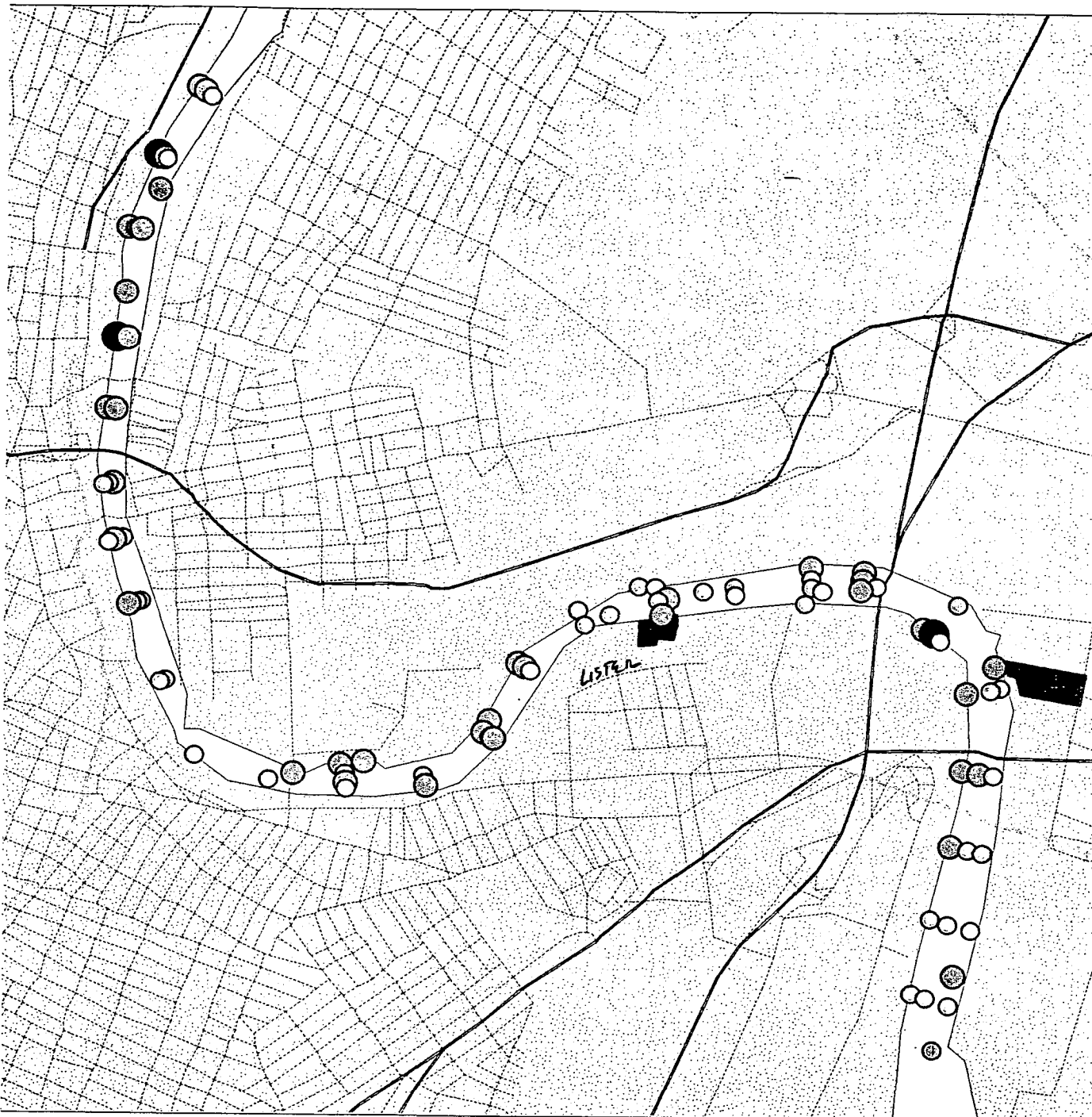
- Under 10
- 11 - 100
- 101 - 1000
- 1001 - 10000
- Over 10000

PCB Sampling Data from 1995 EPA  
Remedial Investigation, Transects  
and Nearshore Supplementary Locations

Rick - I thought you might want this map, it shows the D.A. Site location.  
JR



The New York Times



# PCB Concentrations in Passaic River Sediment



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## Legend

- |             |                   |              |
|-------------|-------------------|--------------|
| Highways    | Total PCBs in ppb | Under 10     |
| Interstates |                   | 11 - 100     |
| Roads       |                   | 101 - 1000   |
| NPL Sites   |                   | 1001 - 10000 |
| Shore       |                   | Over 10000   |

PCB Sampling Data from 1995 EPA Remedial Investigation, Transects and Nearshore Supplementary Locations



R. DeWan - SR

State of New Jersey

Christine Todd Whitman  
Governor

Department of Environmental Protection

Robert C. Shinn, Jr.  
Commissioner

Stevens Institute of Technology  
Castle Point on the Hudson  
Hoboken, NJ 07030

DEC 07 1998

Attn: Keith Axsom - Contracts Office

Dear Keith,

Regarding Third Party Contract number NJDEP-RG-1, I have summarized certain contract administration issues we discussed during our phone conversation of December 3, 1998.

The contract proposed budget submitted by Stevens Institute of Technology (Stevens) is broken down into three (3) main categories. They are: Steven's salaries (\$40,530.00), Steven's Other Direct Costs for materials, travel (\$14,132.00), and subcontracted costs to ARS Technologies Inc. (\$55,339.00). These categories should be considered separate line item budgets and costs should be contained within these separate budgets. If there is a need to transfer funds from one category to another this can be done, however, a written request to do such a transfer should be forwarded to my office.

The contract Scope of Work (SOW) is comprised of three project phases. Stevens should submit an invoice upon completion of each separate phase. Prior to submittal of said invoice, all deliverables as well as all other work required by the contract for the particular phase being invoiced for must be satisfied. In addition, since this contract is for a total not-to-exceed amount of \$110,000.00, Stevens should limit each invoice to an amount not to exceed one third of the total contract amount. For example, I wish to avoid the hypothetical scenario where only one phase of the contract is completed but payment has been made for substantially more than one third of the total contract value. If Stevens expends more than one third of the contract value for a particular phase and there is a need to "play catch up" to reimburse Stevens at the time invoices are submitted for phase 2 or 3, then this can be done, up to the maximum contract not-to-exceed amount.

Retainage in the amount of 2% will be held from each invoice. It is the intent of the State to audit this contract upon completion of all work. Retainage will be released upon completion of the audit and resolution of all audit questions.

Invoices minimally should include a breakdown of all costs being invoiced for. This includes personnel, hours worked, rates, materials purchased, etc. As discussed, it is not



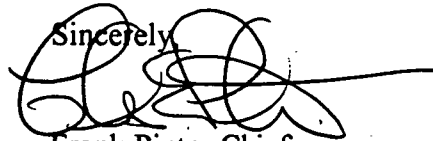
necessary to attach receipts, time reports, etc., but understand these items will be reviewed as part of the audit. I have enclosed some blank State of New Jersey Payment Vouchers (Vender Invoices). Instructions for completing these invoices are found on the back of each form. Completed invoices should be sent to:

Fiscal Support Unit  
NJDEP/DPFSR  
P.O. Box 413  
401 East State Street  
6<sup>th</sup> Floor  
Trenton, NJ 08625-0402

Attention: Art Esposito

If you have any questions regarding this contract or any of the issues discussed above, please feel free to contact me at (609) 777-0101.

Sincerely,



Frank Pinto, Chief  
Bureau of Contract Administration  
NJDEP/DPFSR  
P.O. Box 413  
401 East State Street  
Trenton, NJ 08625

**ENCLOSURES**

C: w/o enclosures  
Rick Gimello, Assistant Commissioner, SRP  
Len Romino, Assistant Director, CFSE  
Rich DeWan, Site Remediation



Stevens Institute of Techno.  
Castle Point on Hudson  
Hoboken, NJ 07030  
201.216.5326  
Fax: 201.216.8303

11/16 mtg  
1:30

Center for Environmental  
Engineering

**FAX COVER SHEET**

**DATE** NOVEMBER 10, 1998 **TIME:** 4:00PM

**ATTENTION** RICK GIMELLO

**COMPANY** NJDEP

**FAX NO.** 609-777-1914 **TEL NO.** 609-292-1250

**SENT BY:** GEORGE P. KORFIATIS

**TOTAL OF PAGES INCLUDING THIS SHEET** 2/0

**MESSAGE** MATERIAL FOR MEETING ON MONDAY, NOV. 16th @ 1:30PM.

**IF YOU HAVE ANY PROBLEMS RECEIVING THIS TRANSMISSION, PLEASE CONTACT** MARTA OLLIGLEY **AT** (201)216-5326

**PLEASE DISTRIBUTE TO THE APPROPRIATE PERSON AS SOON AS POSSIBLE.**

RY  
11-2



Stevens Institute of Technology  
Castle Point on Hudson  
Hoboken, NJ 07030  
201.216.5326  
Fax: 201.216.8303

Center for Environmental  
Engineering

## **MEMO**

**TO:** R. Gimello  
S. Boyle  
R. DeWan  
J. Liskowitz

**DATE:** November 10, 1998

**FROM:** G.P. Korfiatis

**REF:** ARS Meeting

---

*This will confirm a meeting at NJDEP on Monday, November 16th @ 1:30 with ARS Technologies and Stevens Institute of Technology.*

*Attached please find Task I Work Plan for the "Iron Powder In Situ Treatment of Contaminated River Sediment" Project.*

# IRON POWDER IN SITU TREATMENT OF CONTAMINATED RIVER SEDIMENT

## TASK I-1 Work Plan

Submitted by:

Center for Environmental Engineering  
Stevens Institute of Technology  
Hoboken, NJ 07030

Dr. George P. Korfiatis  
Tel: (201) 216-5348

and

ARS Technologies  
Tel: (732) 298-6620

October 26, 1998

## **Start Task I-1**

Task I-1, which encompasses site selection, sample collection, and baseline analyses is comprised of several intermediate planning phases. Because the remainder of the work for this project is dependent upon the results of this phase, organization of this task on a timely and efficient manner is critical to the completion of this project.

### **Project Planning**

Before initiating the project, several key steps are required to ensure the clarity and consensus of the objectives for Task I-1. Through meetings, document review, and decision-making a preliminary work plan will be developed.

#### **Project Start/Kick-off Meeting**

A meeting consisting of ARS and Stevens personnel will be planned to discuss the results obtained from current PCB treatability experiments and what additional work needs to be done to clarify the objectives for this work. A second meeting will be set to finalize the objectives based on the updated results.

#### **File Review**

All material that has been prepared to date including the June 3, 1998 scope of work proposal, and laboratory results from prior work was reexamined. Based on experience with PCB treatability studies, modifications to the proposal will be noted and brought up at the status meeting.

#### **Work Plan Preparation**

This involves the development of this work plan which encompasses a description of each subobjective for this phase of work, and a timeline for which the steps are expected to take place.

#### **Data Interpretation and Presentation**

The data that has been collected from prior PCB treatability studies in the laboratory will be examined and included in a short report to be presented at the status meeting. Conclusions will be drawn from apparent trends in the data, and be used in the report to justify a proposed action plan for future experiments.

#### **Identify Target Contaminants**

Although it was proposed in the June 3, 1998 scope of work plan that certain groups of contaminants be investigated (PCBs, Halogenated Organics, Dioxins/Furans, Metals,

and Chlorinated Pesticides), specific contaminants within these classifications need to be identified. Justification for the decisions will be based upon high priority compounds judged on their potential health effects, and quantity which is naturally present in the sediment.

### **Status Meeting to Finalize Objectives**

A meeting will be set up at Stevens to discuss the data obtained to this point. From this information the project objectives will be finalized, and any changes to the proposed schedule will be made at this point.

### **Site Selection**

Although preliminary suggestions have been made for the selection of a site to study along the Passaic River, a more in-depth investigation will be made to ensure that all project objectives can be met using this site.

### **Review of DEP Data**

A brief overview of prior contaminant delineation reports done for areas along the Passaic River will be performed. Only 3-4 potentially severely contaminated areas will be considered for final site selection.

### **Meeting at DEP**

A meeting will be set up with appropriate personnel from the DEP with regards to selecting a site from which to conduct further activities. Through discussions with all project team members 3-4 areas along the Passaic will be considered further. Any previous contaminant characterization projects which are available for these sites will then be reviewed.

### **Select Sample Locations**

Based upon discussions with team members and a review of historical contaminant characterization along the Passaic River, a site will be selected from which to take sediment samples, and design an in-situ treatment scheme. A joint agreement between project members will mark the progression to the field.

### **Sediment Sampling**

The collection of sediment samples from the chosen location along the Passaic River will proceed according to a sampling plan prepared in advance. Enough samples need to be collected to obtain a good understanding of the chosen site's properties, as well as to provide sufficient sediment for Task I-2 experimentation.

### **Prepare Sampling Plan**

In preparation for the sampling event, a detailed sampling plan will be devised which will discuss specific sampling locations, number of samples to be taken, how samples will be collected and preserved, quality control measures, and depth of samples. Appropriate sampling equipment and sample storage containers will be included.

### **Procure and Schedule Equipment**

According to the sampling plan, the required equipment and personnel will be projected and gathered to mobilize to the selected location along the Passaic River. Such equipment includes: properly sterilized sample vials, quality control samples, field logbook, sample labels, preservatives, coolers, personal safety equipment, decontamination equipment, materials for waste collection, and sampling devices.

### **Field Sampling**

Sediment sampling will be conducted within the chosen location along the Passaic River to confirm the presence of satisfactory levels of the targeted contaminants, as well as to obtain sufficient sediment to be used in subsequent treatability experiments at Stevens. The objective of this work is not to thoroughly delineate the area, but rather to ensure that the sediment samples provide a representative cross-section of the sampling location and that sufficient concentrations are present to be quantifiable in the treatability experiments. To accomplish this goal, a limited number of samples will be taken within the selected site location. The information obtained from these operations will be used in the design of both the laboratory treatability and in-situ design.

The Stevens research vessel, R/V Phoenix, will be mobilized to the selected site where sediment samples will be collected. The collection of samples will be accomplished by using a split spoon sampler. Since the target analytes include both metals and organics, cores will be transferred using a decontaminated trowel to acid-rinsed polyethylene jars for metals analyses, and solvent-rinsed amber borosilicate glass jars with Teflon®-lined lids for organics analyses. Segmentation of samples will proceed according to depth as long as the samples themselves are fairly uniform in color and texture. Preservation of samples intended for volatile organics analyses will incorporate the new NJDEP Methodology for Field Extraction/Preservation of Soil Samples with Methanol for Volatile Organic Contaminants (VOC), as referenced in the *Technical Requirements For Site Remediation*, under [N.J.A.C. 7:26 E-2.1 (a) 4], dated February 1997.

### **Sample Track and Archive**

A clear and meaningful nomenclature system will be created and used for labelling the sediment samples. Special adherence to chain of custody and labelling requirements for samples sent to the certified laboratory must be considered. To maintain the integrity of samples, their transport and storage will occur in a reduced temperature (approx. 4°C) environment.

## Sample Analysis

After the sediment samples have been collected they will be analyzed for their baseline contaminant concentration, geo-mechanical, and geo-chemical properties.

### Contaminant Profile – Stevens

All analyses for the selected contaminants will be conducted at Stevens, with the exception of dioxins and/or furans which will be done at a certified laboratory. The analyte classifications to be monitored for include PCBs, halogenated organics, total and leachable metals, and chlorinated pesticides. Analyses for non-/semi-volatile organics will require extraction from the sediment according to USEPA Method 3540 using the appropriate extraction solvent. Volatile organic compounds will have already been extracted into the methanol used for preservation of the samples.

Analyses of the organic extractants will depend upon the analyte to be detected. Methods 680, 502.2, and 8270 will be used for PCBs, halogenated organics, and chlorinated pesticides, respectively.

Baseline metals concentrations will be determined as both total and leachable. Although the method used to detect the selected metals is the same for both (Inductively Coupled Plasma), the extraction procedures differ. For the total baseline metals content USEPA Method 3050B will be used. Extraction for total leachable metals analysis uses the toxicity characteristic leaching procedure, Method 1311.

### Geo-Mechanical – Stevens

Baseline physical sediment properties deemed influential in the iron powder reaction will be investigated in the samples collected. These properties include: moisture content, grain size distribution, specific gravity, and organic content. All analyses will follow in accordance with standard procedures published by the American Society for Testing and Materials (ASTM) and be conducted at Stevens.

Percent moisture will be determined on a homogenized sub-sample.

Grain size analysis will be performed on the sediment collected from the Passaic River.

The specific gravity of the sediment will be determined using ASTM D 854 (1992 c).

Organic content will be measured using ASTM D 2974 (1987).

### Geo-Chemical – Stevens

The geo-chemical sediment analysis will consist of total iron, total chloride, and pH analyses. These analyses are critical in providing baseline information from which the results from treatability experiments can be compared. All geo-chemical analyses will be performed at Stevens.



Naturally existing total iron in the sediment will be determined in the laboratory in accordance with USEPA Method 3050B "Acid Digestion of Sediments, Sludges, and Soils". The resulting extract will be analyzed by Inductively Coupled Plasma through direct aspiration.

Total chloride and pH will be followed using Methods 9253 and 9045C, respectively.

### **Contaminant Profile – Certified Laboratory**

As a means to verify the accuracy of the analytical work performed at Stevens, 5% of the sediment samples will be split into replicate samples, with one half being analyzed at Stevens and the other sent to a certified laboratory for analysis. The results will be compared to ensure that the analytics data obtained from Stevens for the remaining samples are representative of the site conditions. All dioxin and/or furan analyses will be conducted at a certified laboratory.

## **Data Analysis**

A complete analysis of all data collected will begin.

### **Data Review/Interpretation**

Following the collection of all the contaminant, geo-mechanical, and geo-chemical data, the information will be compiled and presented in graphical format. An evaluation of the data will proceed and be included in the Task I-1 summary report.

### **Interim Project Team Meeting**

The Task I-1 summary report will be distributed to team members and discussed in an interim project team meeting. At the conclusion of this meeting it will be determined whether further work is necessary to complete this phase of work, and whether any revisions are needed for Task I-2 as currently proposed. Also, recommendations for additions/alterations to data presented in the Task I-1 summary report will be mentioned at this time.

### **Finalize Data Interpretation**

From the suggestions given in the interim project team meeting, a final copy of the Task I-1 summary report will be prepared and submitted.

## End Task I-1

This marks the completion of Task I-1. The information collected during this phase of work will subsequently be used in the design of Task I-2. A work plan for Task I-2 will have been processed by this time to enable a smooth transition.

2802

ID	Task Name	Start	Finish	Sep	Oct	Nov	Dec	Jan	Feb
1	Start Task I-1	6/4/98	2/2/99	[Summary bar]					
2	Project Planning	8/4/98	10/29/98	[Task bar]					
3	Project Start/Kick-off Meeting	9/4/98	9/4/98	[Milestone]					
4	File Review	9/7/98	10/28/98	[Task bar]					
5	Work Plan Preparation	9/7/98	10/28/98	[Task bar]					
6	Data Interpretation and Presentation	9/7/98	10/28/98	[Task bar]					
7	Identify Target Contaminants	10/29/98	10/29/98			[Milestone]			
8	Status Meeting - Finalize Objectives	10/29/98	10/29/98			[Milestone]			
9	Site Selection	10/30/98	11/18/98		[Task bar]				
10	Review of DEP data	10/30/98	11/13/98		[Task bar]				
11	Tentative Meeting at DEP	11/16/98	11/18/98			[Milestone]			
12	Select Sample Locations	11/17/98	11/18/98			[Milestone]			
13	Sediment Sampling	11/19/98	12/11/98			[Task bar]			
14	Prepare sampling plan	11/19/98	12/2/98		[Task bar]				
16	Procure and schedule equip.	11/19/98	12/2/98		[Task bar]				
18	Field Sampling	12/3/98	12/8/98			[Task bar]			
17	Sample Track and Archive	12/10/98	12/11/98			[Milestone]			
18	Sample Analysis	12/14/98	1/11/99				[Task bar]		
19	Contaminant Profile - Stevens	12/14/98	1/11/99				[Task bar]		
20	Geo-Mechanical - Stevens	12/14/98	1/11/99				[Task bar]		
21	Geo-Chemical - Stevens	12/14/98	1/11/99				[Task bar]		
22	Contaminant - Certified Laboratory	12/14/98	1/11/99				[Task bar]		
23	Data Analysis	1/12/99	2/2/99					[Task bar]	
24	Data Review/Interpretation	1/12/99	1/25/99					[Task bar]	
25	Interim Project Team Meeting	1/26/99	1/26/99					[Milestone]	
26	Finalize Data Interpretation	1/27/99	2/2/99					[Task bar]	
27	End Task I-1	2/2/99	2/2/99						[Milestone]

Project: Task I-1    Task [Task bar]    Milestone [Milestone diamond]    Summary [Summary bar]

# IRON POWDER IN SITU TREATMENT OF CONTAMINATED RIVER SEDIMENT

## Site Selection

Submitted by:

Center for Environmental Engineering  
Stevens Institute of Technology  
Hoboken, NJ 07030

Dr. George P. Korfiatis  
Tel: (201) 216-5348

and

ARS Technologies  
Tel: (732) 296-6620

November 12, 1998

## Site Selection Criteria

A review of the contaminant data within the report entitled "Magnitude and Extent of Sediment Toxicity in the Hudson-Raritan Estuary" written by the National Oceanic and Atmospheric Administration (NOAA) Coastal Ocean Office, Silver Spring, Maryland, August, 1995 was done, and can be summarized as following:

- 20 sites along the Passaic River, Hackensack River, Newark Bay, and the Upper New York Harbor were discussed
- Contaminants investigated included: chlorinated pesticides (mirex, total DDTs), total PCBs, dioxins (2,3,7,8-tcdd), total PAHs, and metals (Cu, Fe, Hg, Pb, As, Al, Cd, Cr)

The criteria that will be used to select the location of the site to be sampled includes: contamination profile, accessibility, and priority.

## Contaminant Profile

For the contaminants mentioned, each of the 20 sites were ranked according to the highest concentrations present (Table 1). The data used to obtain these rankings is attached as

**Table 1** Site rankings based on overall contaminant concentrations.

Field Station ID	Rank
5	1
8A	2
7C	3
7B	4
10	5
7A	6
11	7
8B	8
3	9
14	10
26	11
36	12
21	13
56	14
1	15
31	16
20	17
17	18
12	19
57	20

Appendix A for organic (Tables A – F) and metal contaminants (Tables G – L). Based upon the results for each individual contaminant, an overall rank was assigned to each location. Additionally, the contaminants were broken-down into organics and metals classifications, and the sites arranged accordingly. An assessment of the variability associated with the specific contaminants within each grouping (overall, organic, and metals) was done to evaluate the presence of a narrow or broad spectrum of compounds existing at the sites. The results were used to select five sites worth further consideration:

#### **Station 5**

Station 5 was ranked first overall as well as for contamination with organics. For metals contamination, it was ranked fourth. This location is a good choice because it is heavily contaminated with most of the compounds studied; it ranked in the top five for eight out of the ten contaminants even though it was never ranked number one. The only disadvantage, in terms of contamination, is that it has lower levels of arsenic and chromium.

#### **Station 8A**

Station 8A was ranked second overall, fourth for organics, and first for metals contamination. This location exhibited moderately high to very high levels of most of the contaminants considered.

#### **Station 7C**

Station 7C was ranked third overall, fifth for organics, and third for metals contamination. This location contained high levels of contamination for all compounds except PAHs, and arsenic. It also possessed the highest levels of 2,3,7,8-tcdd which was 32% more than Station 26 which was ranked second.

#### **Station 7B**

Station 7B was ranked fourth overall, third for organics, and seventh for metals contamination. Notable points is that it had the highest concentration of total DDTs, but only average concentrations of metals.

#### **Station 3**

Station 3 was ranked ninth overall, second for organics, and fourteenth for metals contamination. Although this location does not contain high levels of contamination with metals, it is heavily polluted with organics, especially PCBs. PCB contamination is over one-and-a-half times higher than Station 5 which is the next most contaminated. Its disadvantages are that it has only moderate levels of metals contamination, with very low levels of arsenic and chromium.

**APPENDIX A**

## A. Mirex

Field Station ID	Rank	Concentration (ng/g)
3	1	25
5	2	23
8B	3	20
7A	4	14
7C	5	14
8A	6	14
7B	7	13
10	8	12
11	9	11
1	10	8
14	11	4
36	12	4
20	13	3
26	14	3
31	15	3
56	15	3
21	16	3
17	17	2
57	18	2
12	19	1

## B. Total PCBs

Field Station ID	Rank	Concentration (ng/g)
3	1	2850
5	2	1800
8A	3	1609
7C	4	1454
7B	5	1363
8B	6	1341
10	7	1324
7A	8	1206
11	9	1087
14	10	671
36	11	577
31	12	565
21	13	539
56	14	485
20	15	400
1	16	320
26	17	232
17	18	207
12	19	110
57	20	106

## C. Total DDTs

Field Station ID	Rank	Concentration (ng/g)
7B	1	287
5	2	240
8A	3	230
3	4	218
11	5	210
7C	6	210
7A	7	195
10	8	193
36	9	192
8B	10	182
14	11	156
31	12	152
26	13	142
56	14	124
21	15	65
1	16	60
20	17	57
17	18	26
57	19	11
12	20	10

## D. 2,3,7,8-tcdd

Field Station ID	Rank	Concentration (pg/g)
7C	1	620
26	2	470
5	3	450
8A	4	440
7A	5	390
7B	6	377
10	7	363
8B	8	300
11	9	280
3	10	270
21	11	140
1	12	99
14	13	62
31	13	62
36	14	55
20	15	38
56	16	30
17	17	29
12	18	7
57	19	4

## E. Total PAHs

Field Station ID	Rank	Concentration (ng/g)
1	1	167498
3	2	97710
14	3	44050
5	4	43250
20	5	38562
7A	6	36070
21	7	35230
7B	8	33864
8B	9	31301
11	10	27650
8A	11	21093
7C	12	19559
17	13	13661
10	14	9986
36	15	9476
26	16	7824
31	17	7773
56	18	7003
12	19	3320
57	20	972

## F. Total Organic Contaminants

Field Station ID	Rank
5	1
3	2
7B	3
8A	4
7C	5
7A	6
8B	7
11	8
10	9
14	10
1	11
36	12
21	13
26	14
20	15
31	16
56	17
17	18
12	19
57	20



## G. Total Cu

Field Station ID	Rank	Concentration (µg/g)
8A	1	232
5	2	224
7C	3	217
10	4	206
11	5	191
8B	6	185
7B	7	184
7A	8	178
26	9	141
3	10	125
56	11	116
14	12	114
36	13	113
21	14	83
31	15	82
20	16	59
17	17	31
12	18	31
57	19	15
1		N/A

## H. Total Pb

Field Station ID	Rank	Concentration (µg/g)
8B	1	353
5	2	344
7C	3	310
8A	3	310
7A	4	289
7B	5	264
10	6	259
3	7	246
11	8	241
26	9	159
56	10	135
14	11	125
36	12	124
1	13	100
31	14	96
20	15	87
21	16	84
12	17	64
17	18	41
57	19	32

## I. Total As

Field Station ID	Rank	Concentration (µg/g)
26	1	17
11	2	16
10	3	15
14	4	14
56	5	14
36	6	13
21	7	13
8A	8	12
7C	9	11
7A	10	10
7B	11	10
31	12	10
5	13	9
12	14	8
8B	15	8
20	16	8
17	17	7
57	18	7
3	19	5
1	20	2

## J. Total Cd

Field Station ID	Rank	Concentration (µg/g)
8A	1	6
7C	2	5
5	3	5
7B	4	5
10	5	5
8B	6	5
7A	7	5
26	8	4
11	9	4
3	10	3
14	11	3
36	12	1
21	13	1
56	14	1
31	15	1
1	16	1
20	17	1
17	18	1
12	19	0
57	20	0

## K. Total Cr

Field Station ID	Rank	Concentration (µg/g)
26	1	277
10	2	217
14	3	213
7C	4	188
11	5	184
8A	6	174
7B	7	137
5	7	137
21	8	135
7A	9	134
8B	9	134
36	10	122
17	11	111
31	12	106
56	13	104
20	14	96
3	15	76
12	16	59
57	17	36
1	18	30

## L. Total Metals

Field Station ID	Rank
8A	1
10	2
7C	3
5	4
26	5
11	6
7B	7
8B	8
7A	9
14	10
36	11
56	12
21	13
3	14
31	15
20	16
17	17
1	18
12	19
57	20

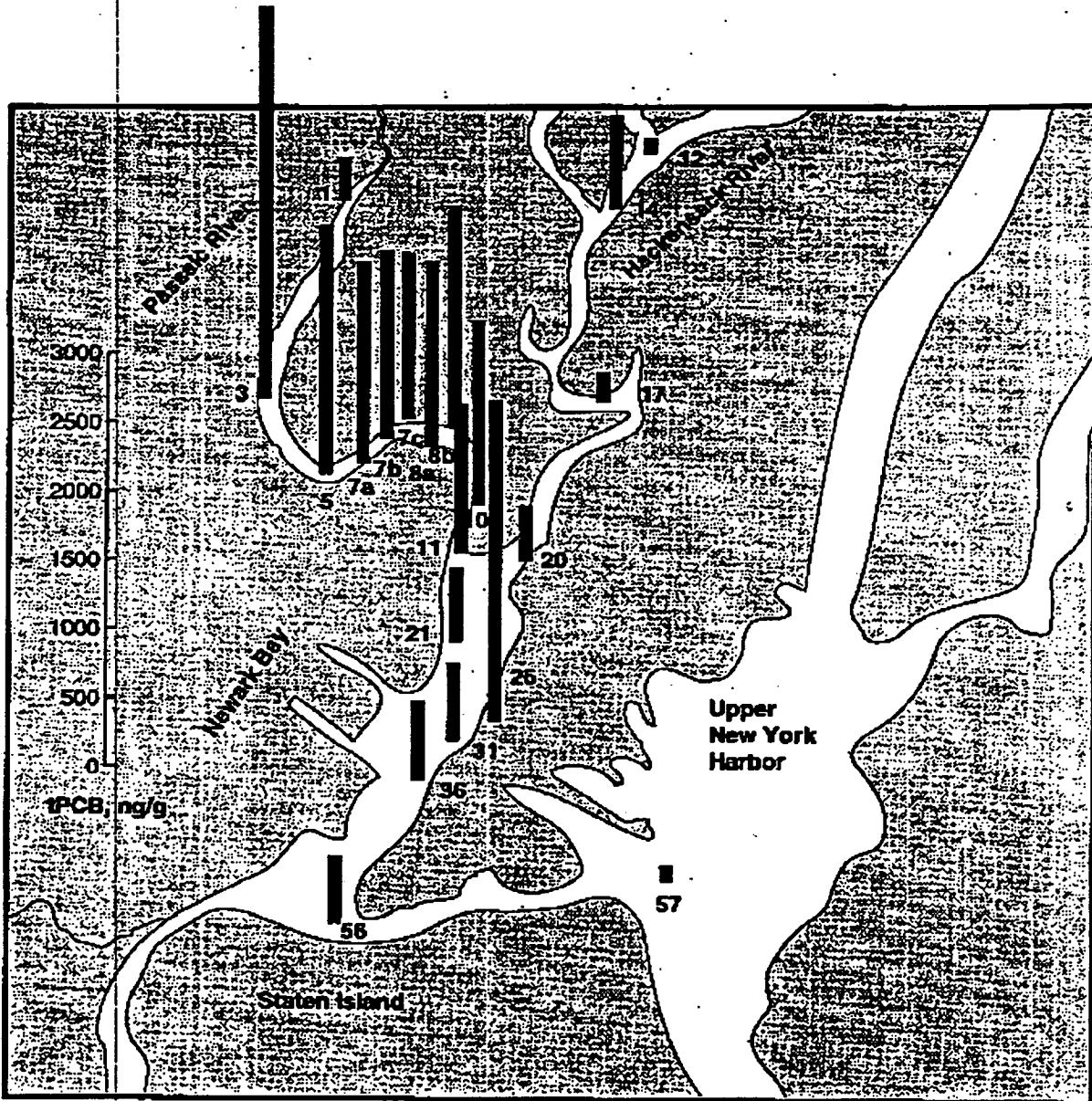


Figure 24. Concentrations of total PCBs at selected stations in Newark Bay and vicinity.

**MEMORANDUM**

**TO:** GEORGE KORFLATIS, STEVENS INSTITUTE OF TECHNOLOGY

**THROUGH:**

**FROM:** TERUO SUGIHARA, TECHNICAL COORDINATOR, BEERA

WILLIAM LOWRY, CHIEF, BEMQA

**SUBJECT:** THE MARCH 15, 1998 SCOPE OF WORK ENTITLED, "IRON POWDER *IN-SITU* TREATMENT OF CONTAMINATED RIVER SEDIMENT" AND THE MAY 15, 1997 SCOPE OF WORK ENTITLED, "COST PROPOSAL FOR IRON POWDER TREATABILITY OF SEDIMENT AND DREDGE MATERIALS."

Review of the subject documents was requested on May 7, 1998 with a due date prior to May 21, 1998 which is when the associated contracting work is also to be completed (Job Code: 35270000, Activity Code: V34H). The comments resulting from this review follow.

GENERAL COMMENTS:

1. The specific comments made below reflect deficiencies that require appropriate corrective action in order for the New Jersey Department of Environmental Protection (Department) to consider the scope of work (SOW) acceptable
2. The Department further requires that the two subject documents be combined into a single SOW with comments herein incorporated as appropriate.
3. Note that the review focused on the March 15, 1998 SOW because it is the most current version available.
4. There is a general lack of detail in the SOWs for both PHASES I and II. In particular, the SOW lacks performance evaluation criteria that will be applied to determine if the proposed technology has merit for its intended use.
5. Stevens Institute of Technology (SIT) must supply justification as to why from a contracting perspective they should be considered a "sole source" for conducting the proposed work.

6. All applicable OSHA requirements and Department operational certifications (i.e. laboratory certifications) should be the responsibility of the subcontractors. The Department questions why it is necessary for us to pay for baseline OHSA training for project personnel. This type of qualification should have been already obtained prior to submission of the SOW.
7. A copy of the total project budget including the funding originating from the Department of Commerce and Economic Development (DCED); Accutech Remedial Systems, Inc. (ARS); and SIT should be presented. It is our understanding that this budget has undergone revision as illustrated by the \$27,000 reduction in DCED funding in the May 15, 1997 SOW versus the March 15, 1998 SOW.
8. A cost analysis comparing in house analysis versus outsourcing to a certified laboratory should be done.
9. The resubmitted SOW should be paginated.

SPECIFIC COMMENTS:

1. **GENERAL:** A section identifying the purpose of the work proposed in the SOW and how it relates to funding eligibility from DCEDA should be added to the text. This would provide an initial frame of reference for the reader as well as organizational structure. The Project Tasks section in the May 15, 1997 SOW partially does this by referring to the treatability work; however, even here there is no reference to any PHASE II work.
2. **PHASE I, Task I-1, Page 1:** While site selection criteria are identified, the primary basis for site selection is unclear. If it is desired to sample a "representative" location based on chemical contaminant presence, there will be an apparent contradiction with the "priority of remediation" criterion. The most highly contaminated areas are likely to have the highest priority for remediation, not the average areas. There is also the incomplete knowledge of chemical contaminant presence in the Passaic River, which will impede a determination of what is representative.. Furthermore, the "ease of access" criterion while a consideration, is likely not related to either a representative location or the site with the highest priority for remediation. Please amend the text accordingly.
3. **PHASE I, Task I-1, Page 1:** The mechanism for specifying the sample location (i.e. global positioning system, etc.) should be identified.
4. **PHASE I, TaskI-1, Page 1:** The mechanism for collecting the sample should be specified.
5. **PHASE I, Task I-1, Page 1:** Dioxins are included in the characterization parameters in the earlier SOW, but not the March 15, 1998 SOW. Dioxins and furans are a major concern in the Passaic River and need to be included.

6. PHASE I, Task I-1, Page 2: Analytical methods are referred to in the second SOW; however, a more formal presentation to include quality assurance and quality control measures is needed. There is also the question of data validation. It is recommended that a Quality Assurance Project Plan type document be developed. In consideration of the nature of the potential contaminants in the Passaic River, the development of a Health and Safety Plan should also be considered.
7. PHASE I, Task I-2, Page 2: It is presumed that the second SOW supercedes the earlier SOW with respect to this section as they are significantly different. While a description of the proposed work is provided, important details are lacking. Will the closed reactor vessel have a void volume? What is the proposed mixing rate? Is it intended to run the reactors in an aerobic mode? Will the reactors be at field temperature or at ambient laboratory temperature? What is the relationship of the material previously characterized to the material in the reactors? Are the samples for the different time periods to be withdrawn from the same reactor for a given treatment? What are the "targeted levels"? Most importantly, what is the experimental design to include replication (the table on page 3 indicates none), statistical analysis, and significance levels?
8. PHASE I, Task I-3, Page 3: Aside from the issue of extrapolating a column study to the field, the most critical factor is whether or not the iron powder can penetrate to the required depth in the sediment and do so in sufficient concentration to effectively remediate the contamination present. The specific experimental design proposed to evaluate this occurrence and the evaluation criteria to be used need to be stated in the SOW.
9. PHASE II, Task II-1, Page 3: Again the SOW is vague on how the described parameters will be measured and what constitutes a success or significant difference.. For example, a major concern with the pressurized injection of iron powder into an in-situ sediment is sediment disruption with concomitant loss of contaminants. Will this phenomenon be measured by analyzing for chemical contaminant concentration changes? Is total suspended solids to be used as a surrogate for chemical testing? The text must be appropriately amended.
10. PHASE II, Task II-2, Page 4: The report description lacks sufficient detail. It is recommended that a proposed table of contents be presented.

If there are any questions concerning this memorandum, please contact Teruo Sugihara at (609) 633-1356.

cc: Richard Gimello, Assistant Commissioner, SRP  
Michael Waldman, BEMQA  
Files



May 15, 1997

Richard Gimello  
Assistant Commissioner, NJDEP  
CN028, 6th Floor  
401 East State Street  
Trenton, New Jersey 08625  
(Transmittal Via Fax # 609-777-1914)

**RE: Cost proposal For Iron Powder Treatability of Sediment and Dredge Materials**

Dear Mr. Gimello:

As a follow-up to our correspondence dated April 17 which consisted of technical information regarding our zero valence iron powder treatment technology, Accutech is pleased to provide this cost proposal for treatability and benchscale tests to evaluate the feasibility of treating Passaic River sediments using zero valence iron powder.

The scope of this proposal is as follows:

### **Project Tasks**

The project entails the laboratory investigation of the effectiveness of the proposed iron powder technology in treating target contaminants in a sediment matrix. These may include PCB's, chlorinated pesticides and herbicides, chlorinated semi-volatiles, dioxins, Furans and metal salts. The zero valence iron has successfully been used to remediate chlorinated volatile organic compounds and lindane, its use in treating the above halogenated organics has not been investigated.

### **PHASE I Laboratory Investigation**

**Task I-1 Site selection and Sample Collection:** This task entails the selection of a location in the Passaic river from which sediment samples will be collected and where a future in-situ demonstration may be conducted. The sampling location will be made on the basis of certain criteria which include the following:

Previous knowledge of contamination history of site and levels of target contaminants

How representative is the location with respect to the levels of contamination and the priority for remediation.

Samples will be collected from the selected site and will be characterized in the laboratory. Characterization parameters will include, naturally occurring organic matter (NOM), grain size, PCBs, dioxins, and heavy metals concentrations. The leachability of the pollutants will be evaluated using the toxicity characteristic leaching procedure (TCLP).

**Task I-2 Direct Contact Treatment of Sediment:** This task entails the execution of shaker flask scale treatability studies to determine the effectiveness of the E-200 iron powder in treating the various toxic contaminants present in the sediment under well mixed conditions. In these experiments, the organic pollutants and heavy metals in the sediment samples will be treated by mixing the Fe powder with sediment samples under batch conditions in closed reactors employing shaker tables. Different dosages of Fe powder will be added in the sediment samples. The effectiveness of different percentages of Fe powder on the concentration reduction of the various contaminants will be measured. A control sample without the addition of Fe powder will be prepared and tested alone with the treated samples. All experiments will be performed in duplicate. The Fe and contaminants in the sediment samples will be mixed for different time periods. Two batch samples will be analyzed at 2, 5, 10, and 20 days of reaction times. The total contents of the organic pollutants, such as PCBs, dioxins, and other halogenated organic compounds in the samples will be determined with solvent extraction procedures according to EPA standard methods. The leachability of the heavy metals in the samples will be evaluated using TCLP test. The experimental results obtained will be used to determine the optimal Fe dosage required for the treatment of the contaminated sediments. The data obtained will also be used to design the insitu sediment treatment process that will reduce the chlorinated organics and metal salt to targeted levels in the sediment.

**Task I-3 Laboratory Column Tests:** An in-situ Fe treatment may be developed by placing a layer of Fe powder on the surface of the sediment. The iron powder can potentially migrate downward into the sediment bed due to its high specific gravity of 7.8 and mixing of the sediment with the iron powder due to the turbulence induced by river flow. Also, the reactive hydrogen produced from the reduction of water by the iron powder can diffuse into the sediment and reduce the chlorinated organic compounds in contact with the catalyst that exist in the sediments naturally occurring organic matter.

In order to simulate this treatment scenario, column tests will be conducted. A series of columns will be filled with the sediment sample. Then, Fe powder will be placed on top of the sediment in the columns. Control columns without Fe powder will also be

prepared. Various advection and diffusion transport mechanisms will be simulated. After several weeks of reaction, sediment samples will be collected at different depths. The samples will be analyzed for total PCB, dioxin, and PAH contents and TCLP leachability. The water column will also be analyzed for the content of target contaminants. All experiments will be conducted with water collected from the field site.

At the completion of this testing, we expect to have all the necessary parameters to design and execute a pilot scale demonstration project of the technology.

## **Phase II In-Situ Delivery Method**

**Task II-1 Selection of Iron Powder Delivery Method:** In order for in-situ application of this technology to become possible, a suitable delivery mechanism of the iron powder to the contaminated sediment must be investigated. We intend to investigate several methods of achieving the delivery. The important issues associated with the iron powder delivery are:

- Minimum loss of the powder to areas outside the target sediment
- Ability to deliver powder to targeted locations
- Minimum re-suspension of contaminated sediment during placement operations

These issues will form the basis upon which various delivery techniques will be evaluated. A two phase program is proposed. In the first phase various delivery techniques will be evaluated in the laboratory. These techniques include:

- a) Direct application of iron powder to the surface of the sediment
- b) Surface application in a slurry form
- c) Shallow injection of iron powder/sediment slurry

Experiments will be conducted in a laboratory experimental tank to assess the effectiveness of each technique in delivering the iron powder. Parameters that will be used to evaluate the suitability of each method include:

- Uniformity of iron powder distribution
- Stability of powder in the sediment surface under varying water column current conditions (varying bottom shear stresses)
- Re-suspension of sediment during delivery



Equipment adaptability and cost issues

The results of this study will be used to design a delivery system suitable for field scale operations.

**Task II-2 Final Report:** Upon completion of all the project tasks, the feasibility of the application of the technology will be demonstration. This will include in addition to the technical issues, cost and technology market potential as well as a final plan for commercialization. A final report will be prepared to document the project results and identify the critical steps needed to implement the commercialization plan.

An attached cost breakdown to show the allocation of the funding is attached to this correspondence.

Please contact us at 908-739-6444 with any questions you may have regarding our technology.

Sincerely



John J. Liskowitz  
Accutech Remedial Systems



## Cost Budget Allocation

	NJDEP Funding Contribution	Accutech Funding Contribution	Stevens Funding Contribution	Total Funding
<b>Accutech -Labor</b>				
Project Manager - John Liskowitz	25,000	25,000		50,000
Sr. Scientist	18,500	32,000		50,500
Staff Engineer/Scientist	32,500			32,500
<b>Stevens-Labor</b>				
Co-PI Dr. George Korfiatus	11,000		6,000	17,000
Chemist Post-Doctoral Assistant	15,000			15,000
Administrative Assistant			4,000	4,000
Graduate Res. Assistant	5,000		4,025	9,025
<b>Materials and Supplies (lab)</b>				
Printing/Offices	1,200	2,400		3,600
Library/Materials			1,100	1,100
Consumable		1,500	1,300	2,800
Utilities	2,300	900	1,200	4,400
Iron Powder	4,500	2,500		7,000
<b>Non-labor Services/Expenses</b>				
Travel	2,000			2,000
Telephone	1,900	500	550	2,950
Postage	350	350		700
Insurance	250	550	1,100	1,900
Data Processing software	1,500	550	4,000	6,050
Subcontractor/Consultants	9,500	2,500		12,000
<b>Maintenance/Fixed Charges</b>				
Maintenance Equipment	1,900	550	1,800	4,250
Rent		2,100	3,000	5,100
Rental Equipment	5,500	3,200	4,500	13,200
<b>Totals</b>	<b>137,900</b>	<b>74,600</b>	<b>32,575</b>	<b>245,075</b>



April 17, 1997

Richard Gimello  
Assistant Commissioner, NJDEP  
CN028, 6th Floor  
401 East State Street  
Trenton, New Jersey 08625  
(Transmittal Via Fax # 609-777-1914)

**RE: Iron Powder Treatment of Sediment and Dredge Materials**

Dear Mr. Gimello:

Accutech is pleased to provide this summary overview of an innovative method for treating marine sediments and dredge materials.

The results of recent published investigations have shown that in the presence of moisture and in the absence of oxygen, zero valence iron powder dechlorinates halogenated hydrocarbons that are dissolved in water. In addition, DOWA Mining and Accutech Remedial Systems Incorporated have developed a commercial batch waste stream treatment system for reducing dissolved heavy metals more noble than iron such as lead, copper, nickel, arsenic, cadmium, ect. to their insoluble, stable, zero valence state and hexavalent chromium to its trivalent state.

Conventional work in the insitu chemical treatment field is based upon the mechanism that soluble chlorinated organic solvents and heavy metals must be transported in ground water to "reaction" beds or walls of zero valence iron to initiate the reduction reaction. The basis for this approach is that the current understanding of the reduction of the organics and heavy metals using zero valence iron particles states the treatment reaction occurs at the surface of the particle only. However, recent findings show that this reduction reaction extends well beyond the zero valent iron particle surface and in essence does not dictate that the iron particle be in direct contact with the chlorinated organics and leachable heavy metals to reduce these pollutants. In addition, the recent findings support the mechanism that hydrophobic halogenated hydrocarbons such as PCB's, herbicides, pesticides, chlorinated semi-volatile organics, dioxins and furans that are strongly sorbed to the sediment can also be reduced in the presence of zero valence iron powder.

Therefore, insitu mixing of the reactive zero valent iron powder recently developed by Accutech/DOWA directly into the marine sediment has the potential to reduce the

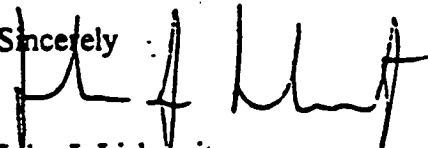
halogenated hydrocarbons and leachable metals in the sediment to less toxic forms. Several delivery mechanisms such as deep tilling, hydraulic injection or multiphase liquid gas injection utilizing nitrogen are available to emplace the zero valence iron particles in the upper depths of the sediment to reduce the halogenated hydrocarbons to targeted cleanup levels. As the treatment reactions occur and the upper sediment zone is remediated, this upper zone of sediment transforms itself into a clean material cap to encapsulate the lower depths of contaminated sediment. This treat and encapsulate method could minimize the migration of toxic halogenated hydrocarbons and leachable metals in deeper sediment zones and eliminate its costly treatment when encountered as dredge spoils during dredging operations to keep the waterways and ports navigable.

A laboratory investigation needs to be undertaken to demonstrate that the several representative insoluble chlorinated organics commonly found in river sediments can be dechlorinated and the leachable heavy metals more noble than iron such as arsenic, cadmium, lead and copper can be reduced to targeted rates in a cost effective manner. This will be achieved using minimal quantities of reacting zero valent iron powder based upon the recently discovered reaction mechanism for the reduction of halogenated hydrocarbon and leachable metals.

In addition, deep tilling, hydraulic injection or multiphase liquid gas injection utilizing nitrogen will be evaluated in the laboratory as delivery mechanisms for introducing insitu the zero valence iron powder with a specific gravity of 7.8 into the sediment. It is the objective of this investigation to identify the method that will provide the needed dispersion of iron powder within the sediment to yield targeted reduction rates for the halogenated hydrocarbons and leachable metals.

Please contact us at 908-739-6444 with any questions you may have regarding our technology.

Sincerely



John J. Liskowitz  
Accutech Remedial Systems

ACCUTECH REMEDIAL SYSTEMS, INC.

CREATING NEW SPACES IN ENVIRONMENTAL TECHNOLOGY



December 2, 1997

Richard Gimello  
Assistant Commissioner, NJDEP  
CN028, 6th Floor  
401 East State Street  
Trenton, New Jersey 08625  
(Transmittal Via Fax# 609-777-1914)

**RE: Revised Cost Estimate - Zero Valent Iron, Sediment Project**

Dear Mr. Gimello:

Please find attached to this letter, a revised cost budget for ARS's sediment proposal previously submitted to you under separate cover. The revised budget numbers reflect more accurate cost allocation based upon ARS's continued experience level working with the zero valence iron technology. Please contact us with any questions at 732-739-6444.

Sincerely,

*[Handwritten signature of John J. Liskowitz]*

John J. Liskowitz

*[Handwritten initials and date: RL 12-33]*

**Cost Budget Allocation**

	<u>DCED</u> <u>NJDEP Funding</u> <u>Contribution</u>	<u>Accutech Funding</u> <u>Contribution</u>	<u>Stevens Funding</u> <u>Contribution</u>	<u>Total</u> <u>Funding</u>
<b>Accutech-Direct Labor</b>				
Co-PI - PM - John Liskowitz	12000	38000		50000
Sr. Scientist	10000	40500		50500
Staff Engineer/Scientist	27500	5000		32500
<b>Subtotal</b>	<b>49,500</b>	<b>83,500</b>		<b>133,000</b>
<b>Stevens-Direct Labor</b>				
Co-PI Dr. George Korfiatus	8000		9000	17000
Chemist Post-Doctoral Assistant	7000		8000	15000
Administrative Assistant			4000	4000
Graduate Res. Assistant	4000		5025	9025
<b>Subtotal</b>	<b>19,000</b>		<b>26,025</b>	<b>45,025</b>
<b>Direct Materials, Supplies, Expenses</b>				
Printing/Communications	2400	1200		3600
Field Supplies/materials	10700			10700
Laboratory Consumables	4700			4700
Utilities	2000	900	1200	4100
Iron Powder/Slurry	12500			12500
Subcontractor/Laboratory Services	16000			16000
Rental Equipment	11000		2500	13500
Travel	3200			3200
<b>Subtotal</b>	<b>62,600</b>	<b>2,100</b>	<b>3,700</b>	<b>68,400</b>
<b>Overhead Services/Expenses/Admin.</b>				
Telephone	1900	500	550	2950
Postage	350	350		700
Insurance	250	550	1100	1900
Data Processing/Software	2500	550	3000	6050
Equipment Maintenance	1900	550	1800	4250
Office/Laboratory Rent		2100	3000	5100
<b>Subtotal</b>	<b>6,900</b>	<b>4,800</b>	<b>9,450</b>	<b>20,950</b>
<b>Grand Totals</b>	<b>137,900</b>	<b>90,200</b>	<b>39,175</b>	<b>267,275</b>



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# TECHNICAL MEMORANDUM UPDATE

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**DATE:** July 18, 1997

**RE:** Zero Valence Iron Powder Treatment of PCB's

In Accutech's correspondence dated May 18, 1997, we indicated our technical hypothesis that treatment of PCB's was possible using zero valence iron powder. However, it was indicated that this area of research had not been investigated to date. We are happy report that a recently published technical paper describes research that supports our hypothesis that PCB's can be treated using our zero valence iron powder.

In the most recent July, 1997, publication of Environmental Science and Technology, 31, (1997), 2154-2156 reported that the reduction of a PCB mixture (Aroclor 1254) solution to yield the non-chlorinated biphenyl was achieved using a reactive zero valence iron powder.

The published article describes tests using standard commercial grade iron powder which showed that this powder caused little to none degradation of the PCB's. However, a second series of tests were then performed using a synthesized iron powder possessing a high specific surface area. These tests showed that the PCB compound was degraded to bi-phenyl.

This latest published research confirms our hypothesis that engineered zero valence iron powder can be utilized to treat PCB sediment. Accutech with its partner DOWA, has the unique ability to engineer a wide range of zero valence iron powders which possess large specific surface areas. With DOWA's capability of being one of the worlds leading iron powder manufacturers, the ability to cost effectively produce custom reactive iron powder on both the pilot scale and full commercial scale basis is feasible.



July 21, 1997

Richard Gimello  
Assistant Commissioner, NJDEP  
CN028, 6th Floor  
401 East State Street  
Trenton, New Jersey 08625

**RE: Transmittal of Original Correspondences Regarding Iron Powder Treatment  
for Dredge and Marine Sediment.**

Dear Mr. Gimello:

As you requested, please find original correspondences which were previously faxed to your offices. In addition, we have provided a **Technical Memorandum Update** which cites a recently published research paper which confirms our earlier hypothesis which stated that PCB degradation using our zero valence iron powder is possible. In addition, we have provided duplicate copies of each original for your convenience.

Please contact us at 908-739-6444 with any further questions or requests.

Sincerely

  
John J. Liskowitz  
Accutech Remedial Systems

attachment



Tony  
FYI



State of New Jersey

Christine Todd Whitman  
Governor

Department of Environmental Protection  
Division of Publicly Funded Site Remediation  
PO Box 407  
Trenton, New Jersey 08625-0407  
(609) 584-4280

Robert C. Shinn, Jr.  
Commissioner

MEMORANDUM

MAY 05 1998

To: Frank McDonough, Director  
New Jersey Maritime Resources  
Department of Commerce and Economic Development

From: *Michael Waldman*  
Michael Waldman, Supervising Contract Administrator  
Environmental Measurements and Site Assessment Section  
Department of Environmental Protection

Subject: Budget Items for NJDEP/Stevens Institute of Technology  
Third Party Contract

Talk about six degrees of separation! It was nice talking with you this morning. Can you believe what Mayor McKenna is doing to Red Bank!? The town is becoming one the *nations* most talked about up-and-coming areas to live and work. He and my brother are close friends, and in fact, the mayor married Dan and his wife, Karen.

As you suggested I am sending you the Stevens budget representing the items to be funded by the Maritime Resources grant to the NJDEP. This grant is to be in the amount of \$110,000.00.

As you can see, the Stevens budget line items add to this amount. These items have been analyzed by me, and have found to be allowable, allocable and acceptable.

I understand that you will use these items to prepare the agreement to be signed by the department that authorizes the transfer of funds for the project. I also understand that you will issue a check for the money to the department.

I am pleased to be of assistance to you. If you should have any further questions, or if you should need assistance of any kind, please call me. My number is (609) 588-7306.

Thank you!

Attachment

C:  Rick Gimello, Assistant Commissioner  
 Barry Frasco, Assistant Director

**Proposed Budget**

	<b>Rate \$/hour*</b>	<b>Hours/ Est. Quant.</b>	<b>TOTAL</b>	
<b>1. Salaries</b>				
1.1. Principal Investigator (Dr. X. Meng)	56	300	16,751	
1.2. Principal Investigator (Dr. G. Korfiatis)	133	50	6,672	
1.3 Analytical Chemist	45	379	17,107	
		<b>TOTAL</b>	<b>40,530</b>	<b>40,530</b>
<b>2. Materials</b>				
2.1 Laboratory Supplies			4,950	
2.2 Chemical Supplies/Standards			5,000	
2.4 Office Supplies			1,000	
2.5 Field Supplies			1,000	
		<b>TOTAL</b>	<b>11,950</b>	
<b>3. Travel</b>				
5 days	\$75/diem		375	
2008 miles	\$.26/mile		522	
		<b>TOTAL</b>	<b>897</b>	
<b>4. Stevens Direct Costs (other than salaries)</b>				
4.1 Stevens Overhead @ 10% on item 4			12,847	
			1,285	
		<b>TOTAL</b>	<b>14,132</b>	<b>14,132</b>
<b>5. Subcontract to ARS Technologies</b>				
Labor with OH and GA				
John Liskowitz Project Manager/ Co-Investigator	45	182	8,124	
Kevin Robertson - Staff Scientist	24	1,820	43,355	
		<b>TOTAL</b>	<b>51,479</b>	
5.1. Supplies			2,000	
5.2 Other Direct Costs			1,860	
<b>Total Direct Costs/ARS Technologies</b>			<b>55,339</b>	<b>55,339</b>
<b>TOTAL PROJECT COST</b>				<b>110,000</b>

- NOTES:**
1. Stevens salary rates are loaded with fringe benefits and overhead
  2. Stevens will wave administrative costs on the ARS subcontract
  3. Detailed breakdown on supplies and materials provided in the attached explanation

**ARS COST BREAKDOWN** Supplier Quantity Unit price Total

**Materials/Supplies**

Zero Valence Iron	DOWA	600 lb	\$2.00 per lb	1200
Phone/fax Calls		300/yr	0.25 per call	75
Fedex		8	\$15	120
Analytical Scale	Fisher	1	\$400	400
Syringes	Fisher	40	\$1.00	40
Copies		1000	\$0.10	100
Color Copies		30	\$1.00	30
Computer disks		40	\$0.50	20
Postage		47	\$0.32	15
<b>Total</b>				<b>2000</b>

**Other Direct Costs**

Travel		1000 miles	\$0.26/mile	260
Rental of Sample Van		5 days	\$125/day	600
Tolls		15	\$2.00	30
Parking		10	\$5.00	50
OSHA 40 hour Training		1	\$770	770
OSHA 8 hr. refresher		1	\$150	150
<b>Total</b>				<b>1860</b>

BUDGET EXPLANATION PAG.

**Laboratory Supplies**

Description	Unit	Unit Price, \$	Quantity	Total Cost
Pyrex Soxhlet Extraction Unit (Fisher, Cat. # 09-556A)	set	190	4	760
Kontes Concentrators Unit (Fisher, Cat. # K570025-0250)	set	130	4	520
Extraction Thimbles (Fisher, Cat. # 09-656C)	pks	61	8	366
Pipette tips, 101-1000 $\mu$ L (Fisher, Cat. # 21-375E)	pks	31	10	310
Pipette tips, 1-100 $\mu$ L (Fisher, Cat. # 21-375D)	pks	40	10	400
Capillary column, DB-5 (J&W, Cat. # 122-5032)	each	403	1	403
Capillary column, DB-502.2 (J&W, Cat. # 122-1464)	each	722	1	722
V-groove Nebulizer kit(ICP) (Varian, Cat. #99-100574-00)	each	1	1	911
Frit Sampler (Purge & Trap) (Tekmar, Cat. # 14-2337-024)	each	62	9	558
<b>Total</b>				<b>4950</b>

**Chemical Supplies/Standards**

UHP Helium gas for GC/MS (CGI, Code # SG221)	each	140	10	1400
Argon gas for ICP (CGI, Code # AR330)	each	30	10	300
PCBs & Chrysene- $d_{12}$ Standards, (Accustandrd, Cat. # M-680)	pks	45	10	450
Dieldrin Standard, 1mL (Accustandrd, Cat. # P-037S-10X)	each	20	10	200
Trichloroethene Standard, 1mL (Accustandrd, Cat. # M-502-51-10X)	each	8	10	80
Fe Standard solution, 500mL (Fisher, Cat. # PLFE2-2X)	each	72	1	72
Methylene Chloride (Fisher, Cat. # D150-4)	case	202	2	808
Methanol (Fisher, Cat. # A452-4)	case	149	2	298
Toluene (Fisher, Cat. # T290-4)	case	184	1	184
Vials w/septa (Varian, Cat. # 03-906195-90)	pkg	72	10	720
Sulfuric Acid (Fisher, Cat. # A300C-212)	case	171	1	171
Nitric Acid (Fisher, Cat. # A200C-212)	case	154	1	154
Heavy Metal Standard Solutions (Fisher, Cat. # FLAS2-2Y, CLPB2-2Y)	each	41	4	163
<b>Total</b>				<b>5000</b>

**Office Supplies**

<u>Description</u>	<u>Unit</u>	<u>Unit Price \$</u>	<u>Quantity</u>	<u>Total Cost</u>
Xerox toner cartridge (Xerox 6R135)	each	175	1	175
Printer toner cartridge (HP 92275A)	each	71	2	142
Xerox copies	page	0.15	3000	450
Misc. (fax cartridge, diskettes, etc.)				233
			<b>Total</b>	<b>1000</b>

**Field Supplies**

Sediment Sampler (constructed at Stevens)				500
Boat (gasoline)				200
Other boat supplies				300
			<b>Total</b>	<b>1000</b>

**Vendor Information:**

Fisher Scientific	800-766-7000
J&W Scientific	800-223-3424
Accustandrd Inc.	800-442-5290
Varian	800-926-3000
Tekmar	800-874-2004
CGI	973-773-8700

## Scope of Work

# IRON POWDER *IN-SITU* TREATMENT OF CONTAMINATED RIVER SEDIMENT

submitted by:  
Center for Environmental Engineering  
Stevens Institute of Technology  
Hoboken, NJ 07030

Dr. George P. Korfiatis  
Tel: (201) 216-5348

March 15, 1998

### PHASE I

#### Task I-1: Site Selection and Sample Collection

This task entails the selection of a location in the Passaic River from which sediment samples will be collected and where a future in-situ demonstration may be conducted. The sampling location will be made on the basis of certain criteria which includes the following:

- Previous knowledge of contamination history of site and levels of target contaminants (PCB's, halogenated organic compounds, chlorinated pesticides, and heavy metals);
- How representative is the location with respect to the levels of contamination and the priority for remediation;
- Easy of access for the set up of an in-situ demonstration treatment.

Samples will be collected from the selected site and will be characterized in the laboratory at Stevens Institute of Technology. Characterization parameters will include natural organic matter (determined as total organic carbon content), grain size, PCB's, halogenated organic compounds, chlorinated pesticides, and heavy metals concentrations.

EPA Method 3550 or 3540 will be used to extract semivolatile and nonvolatile organic compounds from the sediment samples. Method 3550 is a simple sonication extraction with methylene chloride:acetone (1:1, v:v). However, the solvent may not be separated well with the aqueous phase in the sediment. In case that Method 3550 can not be used for the extraction, a soxhlet extraction (Method 3540) will be used. In Method 3540, sediment sample are extracted with hot solvent (methylene chloride or methanol/toluene) for 16-24 hours. The organic compounds in the solvent will be concentrated by distillation for analysis. High content of sulfur in the extraction solvent may interfere

with the analysis of the target organic compounds. Pretreatment may be necessary to remove sulfur prior to organic analysis. PCB's and chlorinated pesticides (dieldrin (1,2,3,4-diepoxybutane)) will be analyzed using GC/MS according EPA Methods 680, respectively. Halogenated organic compounds (TCE (trichloroethene)) will be measured using EPA Method 502.2.

Total contents of heavy metal in the sediment will be determined using microwave assisted acid digestion (Method 3051) and atomic absorption spectrometer. Since the Fe treatment will not change the total content of the heavy metals in the sediment, the effectiveness of the treatment will be evaluated with the toxicity characteristic leaching procedure (TCLP) (Method 1311).

**Task I-2: Direct Contact Treatment of Sediment:**

This task entails the execution of batch studies to determine the effectiveness of the E-200 iron mixed powder in treating the various toxic contaminants present in the sediment under well mixed conditions. In these experiments, the organic pollutants and heavy metals in the sediment samples will be treated by mixing the Fe powder with sediment samples in closed reactors employing an end-to-end mixer. Different dosages of Fe powder will be added in the sediment samples (Table 1). The effectiveness of different percentages of Fe powder on the concentration reduction of the various contaminants will be measured. A control sample without the addition of Fe powder will be prepared and tested along with the treated samples. All experiments will be performed in duplicate. The Fe and contaminates in the sediment samples will be mixed for different time periods. The samples will be analyzed at 2, 5, 10, 30, and 60 days of reaction times. The total contents of the organic pollutants, such as PCB's and other halogenated organic compounds in the samples will be determined with solvent extraction procedures according to EPA standard methods. The leachability of the heavy metals in the samples will be evaluated using TCLP test.

The effectiveness of dechlorination of PCB's by the Fe powder is affected by the numbers of chlorine atoms in the PCB molecules. PCB's with high chlorine contents are more difficult to be treated by Fe powder. Therefore, the contents of a series of PCB compounds in the control and treated samples will be determined. The PCB's to be tested include 2-chlorobiphenyl, 2,3-dichlorobiphenyl, 2,4,5-trichlorobiphenyl, 2,2',3,4,5'-pentachlorobiphenyl, 2,2',4,6-tetrachlorobiphenyl, 2,2',3,3',4,4',5,5',6,6'-decachlorobiphenyl, 2,2',3,3',4,5',6,6'-octachlorobiphenyl, 2,2',3,4',5,6,6'-heptachlorobiphenyl, 2,2',4,4',5,6'-hexachlorobiphenyl.

The experimental results obtained will be used to determine the optimal Fe dosage required for the treatment of the contaminated sediments. The data obtained will also be used to design the in-situ sediment treatment process that will reduce the chlorinated organic contents and heavy metal leachability to targeted levels in the sediment.

Table 1. Schedule for Batch 1

Fe Content (g/100 g dry sediment)	Analysis Time (day)				
	2	5	10	30	60
0 (control samples)	X	X	X	X	X
0.01	X	X	X	X	X
0.1	X	X	X	X	X
1	X	X	X	X	X
5	X	X	X	X	X

### **Task I-3: Laboratory Column Tests:**

An in-situ Fe treatment may be developed by placing a layer of Fe powder on the surface of the sediment. The iron powder can potentially migrate downward into the sediment bed due to its high specific gravity of 7.8 and mixing of the sediment with the iron powder due to the turbulence induced by river flow. Also, the reactive hydrogen produced from the reduction of water by the iron powder can diffuse into the sediment and reduce the chlorinated organic compounds in contact with the catalyst that exist in the sediments (natural organic matter).

In order to simulate this treatment scenario, column tests will be conducted. A series of columns will be filled with the sediment sample. Then, Fe powder will be placed on top of the sediment in the columns. Control columns without Fe powder will also be prepared. After several weeks of reaction, sediment samples will be collected at different depths. The contents of Fe powder added in the columns and the reaction time will be determined based on the results obtained in Task I-2. The samples will be analyzed for total PCB and halogenated organic compounds contents and TCLP metal leachability. The water column will also be analyzed for the content of target contaminants. All experiments will be conducted with water collected from the field site.

At the completion of this testing, we expect to have all the necessary parameters to design and execute a pilot scale demonstration project of the technology.

## **Phase II: In Situ Delivery Method**

### **Task II-1: Selection of Iron Powder Delivery Method**

In order for in-situ application of this technology to become possible, a suitable delivery mechanism of the iron powder to the contaminated sediment must be investigated. We intend to investigate several methods of achieving the delivery. The important issues associated with the iron powder delivery are:

- Minimum loss of the powder to areas outside the target sediment
- Ability to deliver powder to targeted locations
- Minimum re-suspension of contaminated sediment during placement operations



These issues will form the basis upon which various delivery techniques will be evaluated. A two phase program is proposed. In the first phase, various delivery techniques will be evaluated in the laboratory. These techniques include:

- a) Direct application of iron powder to the surface of the sediment
- b) Surface application in a slurry form
- c) Shallow injection of iron powder/sediment slurry

Experiments will be conducted in a laboratory experimental tank to assess the effectiveness of each technique in delivery the iron powder. Parameters that will be used to evaluate the suitability of each method include:

- Uniformity of iron powder distribution
- Stability of powder in the sediment surface under varying water column current conditions (varying bottom shear stresses)
- Re-suspension of sediment during delivery
- Equipment adaptability and cost issues

The results of this study will be used to design a delivery system suitable for field scale operations.

**Task II-2: Final Report**

Upon completion of all project tasks, the feasibility of the application of the technology will be demonstrated. This will include in addition to the technical issues, cost and technology market potential as well as a final plan for commercialization. A final report will be prepared to document the project results and identify the critical steps needed to implement the commercialization plan.

**TIME SCHEDULE**

TASKS	TIME (Months)					
	2	4	6	8	10	12
1. Site selection and sample collection	[Bar from 0 to 2]					
2. Direct contact treatment		[Bar from 4 to 6]				
3. Laboratory Column Tests				[Bar from 8 to 10]		
4. Selection of iron powder delivery method					[Bar from 10 to 12]	
5. Evaluation of the results and final report						[Bar from 12 to 12]

Proposed Budget	Rate	Hours/ Est/Quant	TOTAL	
<b>1. Salaries</b>				
1.1. Principal Investigator (Dr. X. Meng)		2.26 months	10,000	
1.2. Principal Investigator (Dr. G. Korfiatis)		0.15 month	1,600	
1.3 Analytical Chemist		2.12 months	7,584	
Fringe Benefits (30% on 1.1, 1.3)			5,275	
		<b>TOTAL</b>	<b>24,459</b>	
<b>2. Materials</b>				
2.1 Laboratory Supplies			4,950	
2.2 Chemical Supplies/Standards			5,000	
2.4 Office Supplies			1,000	
2.5 Field Supplies			1,000	
		<b>TOTAL</b>	<b>11,950</b>	
<b>3. Travel</b>				
5 days	\$75/diem		375	
2019 miles	\$.26/mile		525	
		<b>TOTAL</b>	<b>900</b>	
<b>4. Stevens Direct Costs</b>				
6. Stevens Overhead @ 0.4652 on direct costs			37,309	
			17,356	
		<b>TOTAL</b>	<b>54,665</b>	<b>54,665</b>
<b>5. Subcontract to ARS Technologies</b>				
Labor with OH and GA				
John Liskowitz Project Manager/ Co-Investigaor		1.2 months	8,125	
Kevin Robertson - Staff Scientist		12 months	43,350	
		<b>TOTAL</b>	<b>51,475</b>	
<b>5.1. Supplies</b>				
			2,000	
<b>5.2 Other Direct Costs</b>				
			1,860	
<b>Total Direct Costs/ARS Technologies</b>			<b>55,335</b>	<b>55,335</b>
<b>TOTAL PROJECT COST</b>				<b>110,000</b>

# Research Communications

## Synthesizing Nanoscale Iron Particles for Rapid and Complete Dechlorination of TCE and PCBs

CHUAN-BAO WANG AND WEI-XIAN ZHANG\*

Department of Civil and Environmental Engineering, Lehigh University, Bethlehem, Pennsylvania 18015

Transformation of halogenated organic compounds (HOCs) by zero-valent iron represents one of the latest innovative technologies for environmental remediation. For example, iron can be used to construct a reactive wall in the path of a contaminated groundwater plume to degrade HOCs. In this paper, an efficient method of synthesizing nanoscale (1–100 nm) iron and palladized iron particles is presented. Nanoscale particles are characterized by high surface area to volume ratios and high reactivities. BET specific surface area of the synthesized metal particles is 33.5 m<sup>2</sup>/g. In comparison, a commercially available Fe powder (<10 μm) has a specific surface area of just 0.9 m<sup>2</sup>/g. Batch studies demonstrated that these nanoscale particles can quickly and completely dechlorinate several chlorinated aliphatic compounds and a mixture of PCBs at relatively low metal to solution ratio (2–5 g/100 mL). Surface-area-normalized rate constants (*K<sub>SA</sub>*) are calculated to be 10–100 times higher than those of commercially available iron particles. The approach presented offers unique opportunities for both fundamental research and technological applications of zero-valent metals. For example, a potential application of the nanoscale particles is to inject the metal particles directly into contaminated aquifers instead of building iron walls.

### Introduction

Destruction of halogenated organic compounds (HOCs) by zero-valent iron represents one of the latest innovative technologies for environmental remediation (1, 2). Laboratory research in the past few years has shown that granular iron can degrade many HOCs, including chlorinated aliphatics (3), chlorinated aromatics (4), and polychlorinated biphenyls (PCBs; 5). Prospect for field application also looks promising. Granular iron can be adapted in the "funnel and gate" treatment system (1, 6), in which a porous wall of granular iron is constructed in the path of a contaminated groundwater plume. As contaminated water passes through the reactive barrier, HOCs react with the surface of iron and form mostly benign compounds such as hydrocarbons, chloride, and water.

Implementation of the zero-valent iron technology still faces several challenges (7): (i) production and accumulation



FIGURE 1. Transmission electron microscopy image of nanoscale Fe particles.

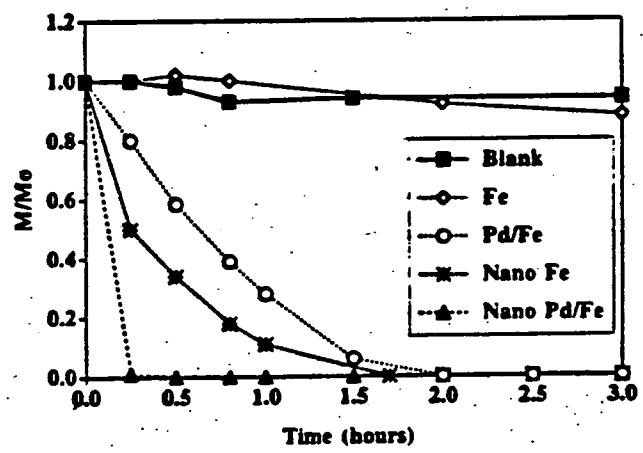


FIGURE 2. Reactions of TCE with commercial Fe powders (Fe), Pd-modified commercial Fe powders (Pd/Fe), nanoscale Fe particles (Nano Fe), and nanoscale Pd/Fe particles (nano Pd/Fe). Initial TCE concentration was 20 mg/L. Metal to solution ratio was 2 g/100 mL.

of chlorinated byproducts due to the low reactivity of iron powders toward lightly chlorinated hydrocarbons. For example, reduction of tetrachloroethene (PCE) and trichloroethene (TCE) by zero-valent iron has been observed to produce *cis*-1,2-dichloroethene (DCE) and vinyl chloride (VC; 3, 8). Both are of considerable toxicological concern; (ii) decrease of iron reactivity over time, probably due to the formation of surface passivation layers or due to the precipitation of metal hydroxides [e.g., Fe(OH)<sub>2</sub>, Fe(OH)<sub>3</sub>] and metal carbonates (e.g., FeCO<sub>3</sub>) on the surface of iron; (iii) engineering difficulties for constructing metal wall in deep aquifers (e.g., >30 m).

Many other metals, particularly zinc and tin, can transform HOCs more rapidly than iron (9). Palladium, with its catalytic ability, produces dramatic results as well. For example, recent studies have demonstrated that palladized iron can completely dechlorinate many chlorinated aliphatic compounds to hydrocarbons (10). The Pd/Fe bimetallic complexes have also been found to degrade PCBs with all the chlorines replaced by hydrogen to yield biphenyl (11).

\* To whom all correspondence should be addressed: phone: (610)-758-5318; fax: (610)758-6405; e-mail: wez3@lehigh.edu.

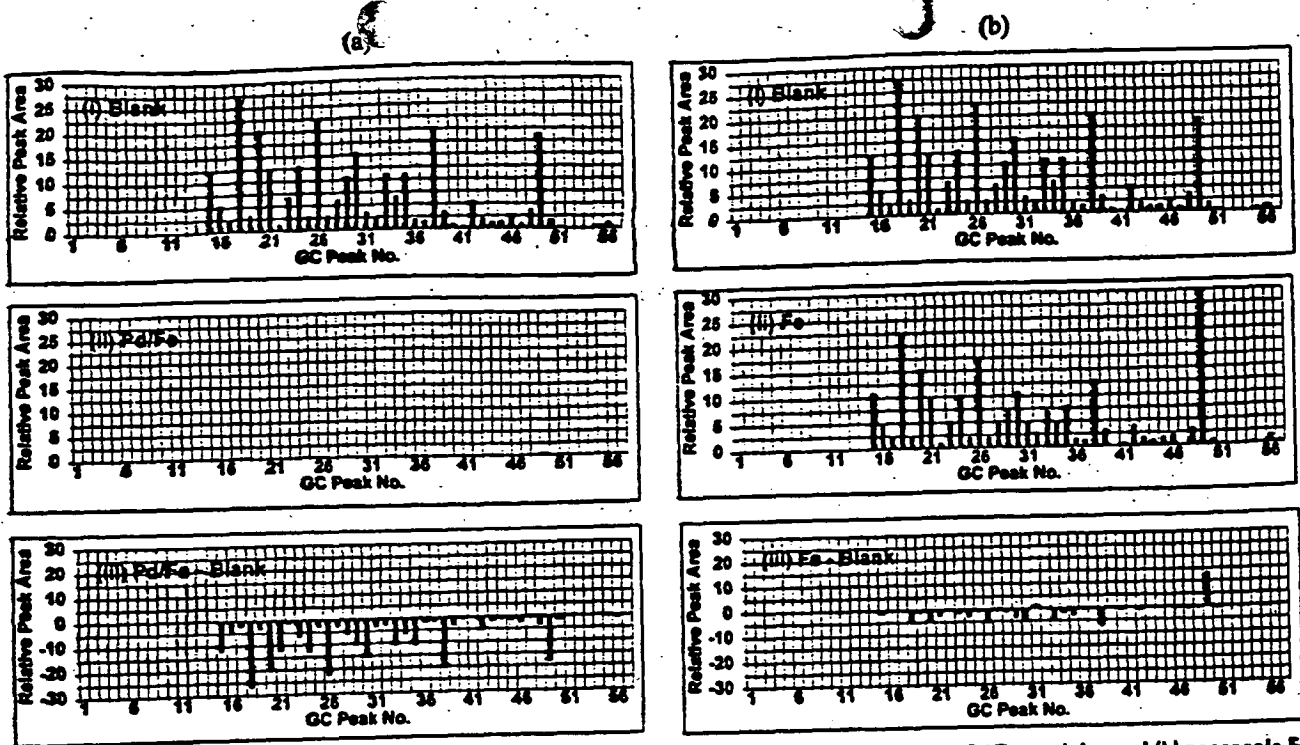
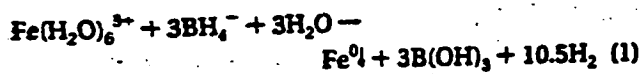


FIGURE 3. Changes in GC relative peak areas of an Aroclor 1254 solution in 17 h with (a) nanoscale Pd/Fe particles and (b) nanoscale Fe particles. GC peaks in (i) were from blank samples. Peaks in (ii) were from samples containing the nanoscale Fe or Pd/Fe particles. Peaks in (iii) were the difference between (ii) and (i) and represented the net degradation. Initial PCB concentration was 5 mg/L. Metal to solution ratio was 5 g/100 mL.

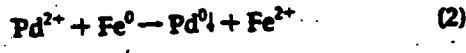
We report here an efficient method of synthesizing nanoscale iron and palladium particles and the results of using these metal particles for transformation of TCE and PCBs. Nanoscale metal particles, with diameter in the range of 1–100 nm ( $10^{-9}$  to  $10^{-7}$  m), are characterized by high surface area to volume ratios, high levels of stepped surface, and high surface energies (12, 13). Instead of building metal walls, nanoscale metal particles may be applied through direct injection of metal particle suspensions to contaminated sediments and aquifers (14). Freshly prepared metal particles free of surface contamination and with very high reactivities also provide ideal tools for elucidating fundamental mechanisms of dechlorination at the metal–solution interface. Furthermore, nanoscale metal particles can be anchored on solid supports such as activated carbon, zeolite, and silica for ex-situ treatment of contaminated water and industrial effluent.

**Experimental Methods**

**Methods for Synthesis.** Nanoscale Fe particles were produced by adding 1.6 M NaBH<sub>4</sub> (98%, Aldrich) aqueous solution dropwise to a 1.0 M FeCl<sub>3</sub>·6H<sub>2</sub>O (98%, Aldrich) aqueous solution at ambient temperature with magnetic stirring. Ferric iron (Fe<sup>3+</sup>) was reduced according to the following reaction (15):



The wet Fe precipitates were coated with a thin layer of palladium by saturating the above precipitates with an ethanol solution of [Pd(C<sub>2</sub>H<sub>3</sub>O<sub>2</sub>)<sub>2</sub>]<sub>2</sub> (47.5%, Alfa Aesar). This caused the reduction and subsequent deposition of Pd on the Fe surface through the following reaction (11):



Similar procedures were also employed to coat Pd on commercial iron powders (Aldrich, >99.9%, <10 μm).

**Characterization of Synthesized Metal Particles.** Surface areas (BET area) of the synthesized particles were measured using the nitrogen adsorption method with a Gemini 2360 surface analyzer. Prior to the measurements, dry Fe and Pd/Fe particles were obtained by washing the wet precipitates with acetone and drying them at 110 °C for 6 h under a flow of N<sub>2</sub>. Morphology of the particles was observed with a Phillips EM 400T transmission electron microscopy (TEM) at 120 kV to characterize the size and size distribution of the metal particles. Crystal structures were examined with an APD 1700 automated powder X-ray diffractometer (XRD) with nickel-filtered CuKα radiation (λ = 0.1542 nm).

**Batch Experiments with TCE.** Batch experiments were conducted to investigate reactivity of the synthesized particles for dechlorination of TCE. A 50-mL sample of 20 mg/L TCE aqueous solution and 1.0 g of the Fe or Pd/Fe particles were charged into a 50-mL serum bottle capped with a Teflon Mininert valve. The bottle was mixed on a rotary shaker (30 rpm) at ambient temperature (22 ± 1 °C). Parallel experiments were also performed without metal particles (blank) or commercial Fe powders (Aldrich, >99.9%, <10 μm). Periodically, 0.5 mL of the aqueous solution was withdrawn by a 1-mL gas-tight syringe into a 2-mL vial and extracted with 0.5 mL of pentane. Concentration of TCE was analyzed with a Hewlett-Packard Model 5890 GC equipped with an electron capture detector (ECD) and a BD-624 capillary column (Alltech Associates, Inc.). Hydrocarbon products in the headspace were identified with a Hewlett-Packard 5970 GC/MS.

**Batch Experiments with PCBs.** A 50-μL sample of 200 μg/mL Aroclor 1254 was combined with 0.1 g of the wet Fe or Pd/Fe particles and 2 mL of ethanol/water solution (volume ratio = 1:9), followed by mixing on a rotary shaker (30 rpm) for 17 h. Analytical methods were similar to those described above for TCE experiments. A 0.5-mL sample PCB solution was extracted by 0.5 mL of pentane and analyzed with GC-ECD.

## Results

Figure 1 shows a transmission electron microscopy image of the synthesized Fe particles. More than 90% of the particles were in the size range of 1–100 nm. BET specific surface area of the particles was 33.5 m<sup>2</sup>/g. In comparison, a commercially available fine iron powder (Aldrich, >99.9%, <10 μm) has a specific surface area of about 0.9 m<sup>2</sup>/g, or 37 times less than that of the synthesized particles. XRD analysis further revealed the periodic lattice arrangement of iron atoms, indicating crystalline structure of the nanoscale particles.

Degradation of TCE by various metal particles is presented in Figure 2. In all experiments, initial TCE concentration was 20 mg/L. Metal to solution ratio was 2 g/100 mL. The amounts of TCE in blank samples (without metal particles) and in the commercial Fe solution (Fe) remained relatively constant within a period of 3 h. TCE was completely dechlorinated by palladized commercial Fe powders (Pd/Fe) within 2 h, by the synthesized nanoscale Fe particles within 1.7 h, and by the synthesized nanoscale Pd/Fe bimetallic particles within less than 0.25 h (the soonest our measurement had been made). In the solutions containing the nanoscale particles, no chlorinated byproduct (i.e., DCEs, and VC) was detected. Final reaction products in the headspace of nanoscale particle solutions were identified to be hydrocarbons, including ethene, ethane, propene, propane, butene, butane, and pentane.

Degradation of a PCB mixture (Aroclor 1254) solution by nanoscale Pd/Fe and Fe particles at ambient temperature (22 ± 1 °C) is shown in Figure 3. Initial PCB concentration was 5 mg/L. Metal to solution ratio was 5 g/100 mL. GC peaks in (i) were from blank samples. Peaks in (ii) were from samples containing the nanoscale Fe or Pd/Fe particles. Peaks in (iii) were the difference between (ii) and (i) and represented the net degradation within 17 h. Few changes were observed for GC peaks in the blank samples over a period of 17 h (data not shown), indicating no natural degradation of PCBs in the absence of the metal particles. In the presence of synthesized nanoscale Pd/Fe particles (Figure 3a), GC peaks disappeared completely within 17 h, suggesting complete dechlorination of PCB congeners of Aroclor 1254 by the nanoscale Pd/Fe particles at ambient temperature. In solution containing the nanoscale Fe particles (Figure 3b), only partial PCB reduction (<25% of the total mass) was observed within the same time period. Accumulation of biphenyl was confirmed by GC/MS in both solutions. In contrast, little degradation of PCBs was observed with the commercial iron powders under the same experimental conditions.

In summary, freshly synthesized nanoscale Fe particles were more reactive than the commercial Fe powders, likely due to the high specific surface area and higher surface reactivity. Surface-area-normalized rate constants ( $K_{SA}$ ; 16) for the synthesized nanoscale particles (nano Fe) are calculated to be  $3.0 \times 10^{-3} \text{ L hr}^{-1} \text{ m}^{-2}$ . In comparison, values of  $K_{SA}$  for commercially available iron particles are generally below  $1.0 \times 10^{-3} \text{ L hr}^{-1} \text{ m}^{-2}$  (16). Nanoscale Pd/Fe bimetallic particles (nano Pd/Fe) were even more reactive than the pure

Fe.  $K_{SA}$  for the synthesized nanoscale Pd/Fe particles is about  $0.1 \text{ L hr}^{-1} \text{ m}^{-2}$ , much higher than those of pure iron particles. Palladium could promote dechlorination reactions by serving as a catalyst accelerating the dissociation of chlorinated hydrocarbons (17). Palladium could also promote the dechlorination reactions by preventing the formation of iron oxides. Experiments have confirmed that the nanoscale Fe particles exposed to air reacted much more slowly with PCE and TCE than the freshly prepared iron particles. Addition of Pd onto Fe surface significantly reduced the oxidation of iron, thus preserving the reactivity of the zero-valent iron (17). We believe that the approach outlined here offers opportunities for both fundamental research and technological applications of zero-valent metals. Further studies are needed to delineate the underlying mechanistic steps of dechlorination on metal surfaces and to expand the scope of this synthesis method to other metals.

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April 17, 1997

Richard Gimello  
Assistant Commissioner, NJDEP  
CN028, 6th Floor  
401 East State Street  
Trenton, New Jersey 08625  
(Transmittal Via Fax # 609-777-1914)

**RE: Iron Powder Treatment of Sediment and Dredge Materials**

Dear Mr. Gimello:

Accutech is pleased to provide this summary overview of an innovative method for treating marine sediments and dredge materials.

The results of recent published investigations have shown that in the presence of moisture and in the absence of oxygen, zero valence iron powder dechlorinates halogenated hydrocarbons that are dissolved in water. In addition, DOWA Mining and Accutech Remedial Systems Incorporated have developed a commercial batch waste stream treatment system for reducing dissolved heavy metals more noble than iron such as lead, copper, nickel, arsenic, cadmium, ect. to their insoluble, stable, zero valence state and hexavalent chromium to its trivalent state.

Conventional work in the insitu chemical treatment field is based upon the mechanism that soluble chlorinated organic solvents and heavy metals must be transported in ground water to "reaction" beds or walls of zero valence iron to initiate the reduction reaction. The basis for this approach is that the current understanding of the reduction of the organics and heavy metals using zero valence iron particles states the treatment reaction occurs at the surface of the particle only. However, recent findings show that this reduction reaction extends well beyond the zero valent iron particle surface and in essence does not dictate that the iron particle be in direct contact with the chlorinated organics and leachable heavy metals to reduce these pollutants. In addition, the recent findings support the mechanism that hydrophobic halogenated hydrocarbons such as PCB's, herbicides, pesticides, chlorinated semi-volatile organics, dioxins and furans that are strongly sorbed to the sediment can also be reduced in the presence of zero valence iron powder.

Therefore, insitu mixing of the reactive zero valent iron powder recently developed by Accutech/DOWA directly into the marine sediment has the potential to reduce the

halogenated hydrocarbons and leachable metals in the sediment to less toxic forms. Several delivery mechanisms such as deep tilling, hydraulic injection or multiphase liquid gas injection utilizing nitrogen are available to emplace the zero valence iron particles in the upper depths of the sediment to reduce the halogenated hydrocarbons to targeted cleanup levels. As the treatment reactions occur and the upper sediment zone is remediated, this upper zone of sediment transforms itself into a clean material cap to encapsulate the lower depths of contaminated sediment. This treat and encapsulate method could minimize the migration of toxic halogenated hydrocarbons and leachable metals in deeper sediment zones and eliminate its costly treatment when encountered as dredge spoils during dredging operations to keep the waterways and ports navigable.

A laboratory investigation needs to be undertaken to demonstrate that the several representative insoluble chlorinated organics commonly found in river sediments can be dechlorinated and the leachable heavy metals more noble than iron such as arsenic, cadmium, lead and copper can be reduced to targeted rates in a cost effective manner. This will be achieved using minimal quantities of reacting zero valent iron powder based upon the recently discovered reaction mechanism for the reduction of halogenated hydrocarbon and leachable metals.

In addition, deep tilling, hydraulic injection or multiphase liquid gas injection utilizing nitrogen will be evaluated in the laboratory as delivery mechanisms for introducing insitu the zero valence iron powder with a specific gravity of 7.8 into the sediment. It is the objective of this investigation to identify the method that will provide the needed dispersion of iron powder within the sediment to yield targeted reduction rates for the halogenated hydrocarbons and leachable metals.

Please contact us at 908-739-6444 with any questions you may have regarding our technology.

Sincerely



John J. Liskowitz  
Accutech Remedial Systems