Chem. Listy *91,* 438 - 443 (1997)

AN ATTEMPT TO IMPLEMENT SOIL WASHING FOR CENTRAL-EUROPE CLEANUP ACTIVITIES

EVA CHMIELEWSKÁ[a], MATTHEW T. NUSSBAUM[b] and RAYMOND SZYTENCHELM[b]

[a]*Department of Ecosozology and Physiotactics, Faculty of Sciences, Comenius University, Bratislava, Slovak Republic,* [b] *Comco Martech Europe AG, Wyttenbachstr. 2, 2502 Biel, Switzerland*

Received March 28, 1996

Contents

1. Introduction

Soil washing is an aqueous-based technology that, in general, uses mechanical processes to separate particles that contain contaminants[1].

The basic point of soil washing is to physically reduce the amount of soil which requires remediation. The key behind soil washing is that contamination tends to adhere to fine material and to separate from coarse material. Coarse material can be cleaned quickly, while the fine material can be separated for further treatment. The economic advantage of soil washing over other technologies is that it reduces the amount of waste requiring expensive treatment, i.e. incineration, bioremediation, landfilling, etc.[2,3]

Soil washing is an water based process for mechanically scrubbing soils extra-situ to remove undesirable contaminants. The process removes the contaminants from treated soils in one of two ways:

- by concentrating contaminants into a smaller volume of soil through a simple particle-size separation technique,
- by dissolving or suspending contaminants in the wash solution.

The washing solution is then treated by conventional wastewater treatment methods, before being recirculated back into the washing process. Washing process that separates the fine soil particles (clay and silt) from coarser sand and gravel soil particles, effectively separates and concentrates the contaminants into a smaller volume of soil that can be further treated or disposed. The clean, larger fraction is returned to the site for continued use.

Soil washing can be used either as a self-contained technology or in combination with other treatment technologies. In some cases, the process can deliver the performance needed to reduce contaminant concentrations to acceptable levels and serve as a self-contained technology. In general, soil washing is effective for coarse sand and gravel with a wide range of organic and inorganic contaminants[1,2,4].

2. Experimental

The parent company of Comco Martech, Martech USA, Inc. is currently operating a soil washer system in the Kenai Penisula, Alaska. Using this design and practical expertise, the company constructed another soil washer (CMSW) in Vítkovice Metal Work, Ostrava – Czech Republic.

CMSW system is a combination of two remediation techniques. One of them uses a drum which rotates and physically separates the contamination from the coarse material. The drum is 9 m long and 2 m in diameter and alone can remove up to 90 % of the contaminants from the coarse material. Additional removal efficiency for the coarse material can be achieved with the use of oil-soil-water separation basin and screw presses. Application of surfactants to the separation basin also improves cleaning efficiency. Total-system removal efficiency for the coarse material is typically between 90 % and 96 %. The coarse material process components in CMSW system are: grizzly, conveyor belt and hopper, drum, shaker, classifying screw, separation basin and exit screw. The fine material process components are: grizzly, conveyor belt and hopper, drum, shaker, thickening tank and a settling basin with optional screw press. Figure 1 presents some view of CMSW equipment. Instead of biotanks, used as in the Alaskan Soil Washer, fine material biotreatment after CMSW was proposed to be performed on external HDPE biopad.

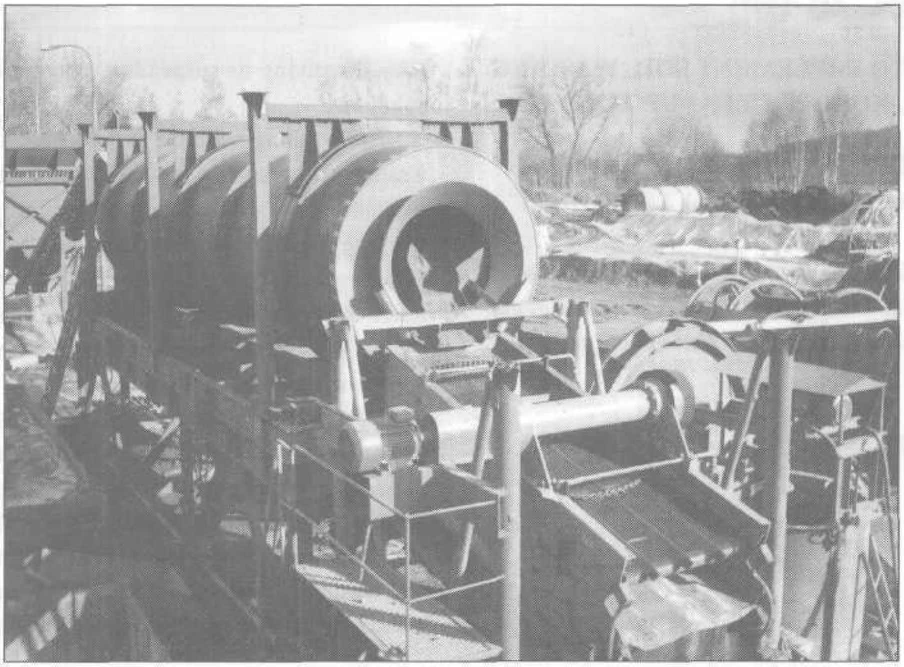

Fig. 1. View of CMSW equipment

Aerobic methanotrophic bacteria in the presence of methane as a co-substrate as well as oxygenase enzymes may accelerate a reductive removal of chlorine atoms and cleavage of aromatic rings. Bioremediation of soil with PCBs content was therefore assumed to be enhanced by applying the enzyme produced by Solimar, Inc., Carlsbad, California; consists of large protein molecules, mixture of peptone, yeast extract and starch. Further biotreatment is not discussed in present paper.

The maximum field capacity of CMSW is between 15 and 20 m^3.hour^{-1}. CMSW is designed to recirculate water continuously without discharge until remediation is complete. The volume of wastewater to be recirculated is approximately 60 l.min^{-1}.

2.1. Waste characterization

An asphalt production plant in former Czechoslovakia, contaminated by petroleum hydrocarbons (PH) as well as by PCB (production of asphalt was stopped in 1986, when the contamination was identified) has been planned for cleanup using CMSW system.

Commercial product of PCB, Delor 103, produced in Czechoslovakia till 1984, was used in heat exchanger medium, by the processing of asphalt. Because the surface area was protected by concrete and asphalt insufficiently, the leachate of heating medium caused the pollution with PCB.

Since 1986, the site has been continuously analysed. The main zone of contamination (PCB concentration higher than 6 mg.kg^{-1}) estimated by volume of 2500 m^3 was excavated and temporally placed at the protected deposit, for the planned soil washing. Structure of this material was appropriate to undergo soil washing process on the base of approximately 60 % content of sandy particles, of the size higher than 3 mm.

Soil washing technology according to the contract had to provide cleanup of a large volume of waste, contaminated mostly with PCB and partly with the accompanying PH in extent 1-2 g.kg^{-1}, below the concentrations 6 mg.kg^{-1} for PCBs and 250 mg.kg^{-1} for TPH. Since this year, the underground water is pumped to stop the pollution spreading and to create a hydraulic barrier. On the surface, the water is treated by means of 1 Vapex and 3 active coke filters and than reinjected back into the subsurface.

On the basis of continuous screening tests at the sites, contaminated material from beneath the plant, up to the depth of 4 m was designed for decontamination, together with demolished construction material originated from the concrete protection basin and with the near river sediments. Finally, the total volume of material, contaminated by various concentration of PCB and PH at the site, was estimated to be 8000 m^3. Several tens tons of material contaminated with the highest concentration of PCB as well as the exhausted filtration media were transported to an incineration facility. The above activity was provided by Company BRGM/ AQUATEST. A rotary kiln (T > 1100 °C) with additional burning retention chamber (French license) was recommended for waste liquidation.

Table I
Contaminants in feed soil of asphalt plant area

Contaminant	Concentration [mg.kg^{-1}]
TPH	200-158 000
Oil	105-43 000
PCB	0.001-24
PAH	0.2-530
BTX	0.04-48
Pb	76-665
Cu	33.8
As	31.4
Cd	4.7
Ni	69
V	101

Table II
Contamination of a typical sample of railway gravel bed

Contaminant	Concentration [mg.kg^{-1}]
Petroleum hydrocarbons (as extract into solvent)	5 100–274 400
Oil	9 600-120 700
Phenol	0.027-3.36
PCB	0.025
Asphaltenes	85 300
Pb	16.1-71.7
Cr (total)	3.7-214
Cd	0.5-4.2
Fe	148 000
Hg	2.55
Ni	69.3
V	101.3
As	43.5
Cu	79.3
Co	25.8
Mn	22 100

Incineration of this material was the only action in the past. Nowadays safe deposition is preferred so that the afterwards depleted filtration media from the underground water treatment, together with floated oils containing PCBs and other segregated concentrates from separation basin of the intended soil washing technology, have been dumped into containers and deposited. Table I illustrates the soil contamination of the asphalt plant area.

Other intention of applied CMSW was cleanup of gravel, covered mostly with heavy PH, such as oil, mazut, asphalt. This gravel material is filled in the depth of 40–50 cm under the *railway-lines*, for stabilization of railway bed. Tabele II illustrates some typical contamination of such a material.

2.2. Analytical procedures

AU constituents in the soil were characterized according to soil quality standards[5]. Petroleum hydrocarbons (as extract of unpolar organic compounds in freon) were analysed by IR spectrometry using DIN 38 409/18 and Specord 80 apparatus, Zeiss, Germany[6]. The specific compounds of PH were identified and quantitatively determined by means of MS/GC (Purge & Trap, Tekmar LSC 2000 a ALS 2016, USA). Stripping gas was helium and trap consisted of Tenax-silica gel-active coke mixture.

PCB analysis have been performed by means of GC (Varian 3400, USA) with ECD Detector and capillary column DB 5 (30 m/0,25 mm). Extraction of PCBs was accomplished at a laboratory temperature in apparatus Tekator 1048 (Sweden) using n-hexane. Quantitative determination was provided by external calibration with standard solutions (products of Polyscience, USA and Supelco, Switzerland).

The metals in the soil were analysed by AAS (Perkin-Elmer 30 30B) using *acetylene/air flame* technique. Mercury was measured by Trace Mercury Analyser TMA 254 (Product of CSFR).

3. Discussion of results

3.1. Treatability study

Bench scale treatability study for the railway bed gravel was performed to evaluate the most effective ratios of chemical surfactants needed to enhance washing treatment in the separator - screw units.

Three types of surfactants were tested: DetClean, Universal Acies (mostly utilizable for industrial degreasing purposes) and EarthWash Detergent. The last one is specific product for PCB and PH removal, commercially manufactured by Earth Schield Environmental Products Inc., Great Britain. All of them are biodegradable.

Common chemical composition of all surfactants was based on the non ionic tenzideš. Slovakian DetClean product contents the mixture of ethanolamine and alcohols; German Acies product hydrated silicates, solubilization activators, stabilization and complexing agents without phosphates.

The most favourable EarthWash PCB Detergent is a strong degreaser with a content of KOH, fatty alcohols with ethylenoxid, complexing agents, and sodium silicates. Phosphates, aliphatic solvents, aromates, ketones, glycol ethers, and chlorinated solvents are not present.

Treatment efficiency was calculated as percent of contaminant reduction from the mean concentration of PH in influent and effluent samples using the following equation:

$$\text{Removal Efficiency (RE\%)} = 100.[1-(\text{effluent conc./influent conc.})]$$

Table III
Washing-treatment efficiency at laboratory-simulated conditions

Macadam sample [g]	Washing solution 500 ml	PH^{a} [g.kg^{-1}]	Efficiency [%]
728	Freon	3.91	100
616	10 % DetClean	0.59	15.08
567	3 % Universal Acies	0.69	17.64

[a] As extract by IR

The method simulating the industrial washing process in laboratory was performed in 1 l PE flasks and filled with 500 ml water-surfactant solution and the macadam samples agitated for 15 minutes in a rotary shaker. Water-surfactant solution was prepared from hot tap water. The samples after agitation were rinsed again with hot tap water, to simulate the conditions of the separation basin. For the efficiency comparison, one sample was agitated only with a PH as extract by IR extracting solvent. Freon 11 (fluorotrichloromethane) was applied for PH extraction. Table III presents the results of the described tests.

As it can be seen, the washing treatment efficiency did not met the expected requirements. When some other comparable tests were performed, i.e. PH leachability of the original and washed samples into water, the efficiency of washing process reached 80 % and recategorized the waste material from the eluate class IIa to Ia[6]. Table IV presents the laboratory results with 3 types of EarthWash Detergent differing in price. In this case, the required washing efficiency was not reached.

From the point of health risk, the washing of contaminants that are insoluble in water, from the rocks seems not to be economically very reasonable. These PH are immobile in the environment and therefore are not transported to places where humans may be exposed.

On the basis of economic evaluation, it was concluded that the railways bed soil, containing approximately 40 % of gravel rocks, will be landfilled in the current case. For the clients in the future, it was proposed to separate coarse and clayey material and enhance the washing process with some additives (e.g. citric acid).

Table IV
Efficiency of washing treatment at laboratory-simulated conditions for macadam samples

Detergent^{a}	Surfactant: water solution	Washing solution: soil	Weight of soil [g]			Efficiency
			before treatment	after treatment	after modified treatment^{b}	
D1	1:3	1:3	54.1	50.7	49.0	67.3
D1	1:5	1:3	51.6	49.2	48.2	56.4
D2	1:3	1:3	56.2	55.3	53.1	40.2
D2	1:5	1:3	54.0	51.8	49.6	69.9
D3	1:3	1:3	57.3	56.2	54.7	54.5
D3	1:5	1:3	57.3	53.8	50.2	49.1

[a] Price of D1, D2, and D3 detergent is 25, 30, and 33 Kč (CZC), respectively, PH were determined gravimetrically; [b] the treatment followed by additional cleaning with organic solvent

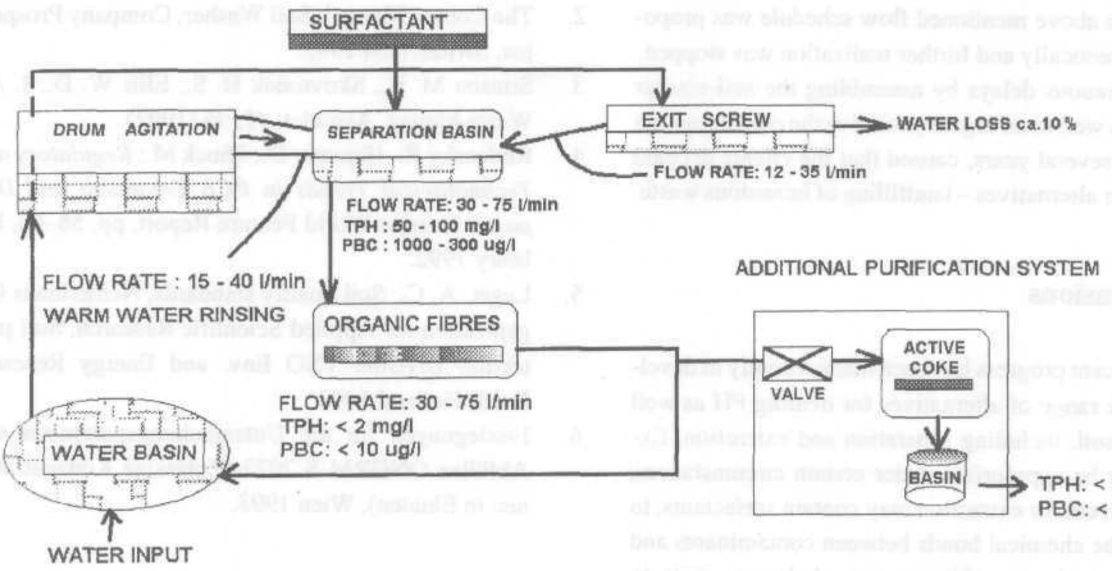

Fig. 2. Flow diagram of water circle

3.2. Process description for coarse material from asphalt plant

Some progress in laboratory-bench scale studies, which demonstrated approximately 60 % efficiency of PCBs and PH washout from the asphalt-plant samples caused that, at the asphalt plant, the coarse material washing process was simultaneously started to examine the treatment efficiency in pilot scale.

The following schedule was designed (Fig. 2.): Soil washing begins with the separation of materials larger than 5 cm in the Grizzly, following a conveyor belt leading to the drum (loading capacity 10 $m^3.h^{-1}$). During optimization, sampling per 25 m^3 of waste soil was proposed. Paddles run along the whole drum interior, so that the rotating action with the addition of water forms a slurry. All material from the drum is discharged into the vibrating shaker. Then, only the coarse material is directed through the classifying screw into the separation basin. The separation basin floats away the free oil and residues from the coarse material. Screws move the material through the separation basin containing steam or heated water and the treatment process is enhanced by the addition of surfactant. Free oil is skimmed from the water surface and dumped into containers (small clay and silt particles as well as depleted filter media are planned for deposition or future incineration, too).

Periodically, the water in the separation basin is pumped through the organic-fibre filter at the flow rate of 30-75 $l.min^{-1}$ to remove hydrocarbon contamination. The quality monitoring of the recycled process water is proposed ones per week to control the soil treatability. After passing through the separation basin, coarse material is routed to a screw elevator and loaded on a truck as cleaned material ready for backfilling.

At the end of the process, the processing water (4 m^3 in drum and 4 m^3 in screw unit) is cleaned to acceptable levels in three active-coke filters and one Vapex filter and then reinjected into the subsurface (Fig. 2.).

The reason for starting the above described process in pilot scale follows from Table V. The increase in washing efficiency seemed to be easily attained by addition of a surfactant into drum reactor or by a 2-phase washing.

Table V
Efficiency of PCB removal by laboratory washing treatments A and B of asphalt-plant samples

PCB_{in}[a]	PCB_{res}[b] [$mg.kg^{-1}$]			
[$mg.kg^{-1}$]	A[c]	Efficiency [%]	B[c]	Efficiency [%]
74.5	34.5	53.4	18.5	75.2
12.9	5.5	57.4	–	–
23.2	–	–	7.9	65.8

[a] PCB_{in} = $PCB_{conc.}$ in soil before washing, [b] PCB_{res} = $PCB_{conc.}$ in soil after washing, [c] A = 10-min drenching and 10-min washing in tap water at 55 °C, B = dtto with 10 % Earth Wash detergent

However, the above mentioned flow schedule was proposed only theoretically and further realization was stopped.

The continuous delays by assembling the soil-washer equipment as well as an urgency to solve the contamination detected for several years, caused that the clients decided to select other alternatives - landfilling of hazardous waste.

4. Conclusions

A significant progress has been made recently in developing a wide range of alternatives for treating PH as well as PCBs in soil, including separation and extraction. Extraction may be appropriate under certain circumstances, when the solvent for extraction may contain surfactants, to help break the chemical bonds between contaminants and soil particles, and some additives, e.g., chelating agents, to help keeping contaminants in solution.

In spite of that, the presented demonstration failed in starting the industrial soil washing in the region, the described technology can still be considered as a possible alternative for future specific cleanup of hazardous material.

There are several reasons for the failure of soil washing technology in the selected locality; the main reason being organization. The project did not manage to keep the time table due to machinery assembling, technology approval by environmental authority, and others. Financial deficiency to continue the work was also significant. Some doubts about the success of PCBs removal in higher capacity scale, inhomogenous by contaminated subsurface, simultaneous waste-water production, and some fears from totally new, unconventional technology contributed to this failure, too.

REFERENCES

1. Innovative Treatment Technologies, Overview and guide to Information Sources, EPA /540/9-91/002, October 1991.
2. The Comco Martech Soil Washer, Company Prospectus, Switzerland 1992.
3. Stinson M. K., Skovronek H. S., Ellis W. D.: J. Air Waste Manag. Associat. *42,* 96 (1992).
4. Rodensky R., Hammer D., Shuck M.: *Regulatory and Technological Trends in PCB Treatment and Disposal.* Hazmat World Feature Report, pp. 58-60, Februry 1992.
5. Leget, A. C: Soil quality standards, Netherlands Organization for Applied Scientific Research, Soil protection Division TNO Env. and Energy Research Delft, Holland 1992.
6. Festlegungen fur die Untersuchungsparameter von Abfällen ONORM S 2072 (Zulässige Konzentrationen in Eluaten), Wien 1993.

E. Chmielewská[a]**, M. T. Nussbaum**[b] **and R. Szytenchelm**[b] *([a]Department of Ecosozology and Physiotactics, Faculty of Natural Sciences, Comenius University, Bratislava, Slovak Republic,*[b]*Comco Martech Europe AG, Biel, Switzerland):*

An Attempt to Implement Soil Washing for Central-Europe Cleanup Activities

Soil washing is a potentially efficient treatment of various organic and inorganic waste. It separates, segregates, and reduces the volume of solid-phase hazardous materials. Efficiency of this treatment applied for PCBs under laboratory conditions was estimated to be about 60 %. Surface contaminants may be removed from soil particles by solubilization in the washing solution and oils and the floated concentrated phase can be then removed and adequately liquidated. Although the washing process has not been realized in a pilot-plant scale, trials simulated in a laboratory confirmed a sufficient efficiency of this method used for the reduction of PCB content in the tested soil.