Soil cleaning at Czechowice Refinery

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Abstract. As a part of the US DOE - IETU Agreement, an U.S. technology for soil cleaning from petroleum contaminants was demonstrated. The Czechowice Refinery, a partner in the project has provided appropriate site and necessary technical assistance.

A lagoon containing mainly wastes from acid refining of motor oils was selected as the focus. The goal is to reduce contamination of the area to the level acceptable for a buffer green zone. The overall objective of the project is to provide a demonstration of biological method capabilities for remediation of petroleum contaminated soil. Generally speaking, the method is based on stimulation of indigenous microorganisms by supplying necessary nutrients and oxygen, and, thus, increasing microbial activity towards organic contaminants present in the targeted soil. Among various possible technical methods of the stimulation, both passive and active variations of a biopile technique were selected for the demonstration.

The lagoon was emptied from tarry deposits, and a drainage system covered with a dolomite layer was laid on the bottom of the lagoon. A divider, made of clay and air-impermeable, separates active section of the biopile from the passive one. The bulk material of the biopile consists of a 1meter high layer of contaminated soil, mixed with 10% (by volume) of wood chips to improve mechanical and chemical properties. The biopile is covered with grass and clean topsoil. Air is periodically pumped to the active section of the biopile through the drainage system. The clay divider prevents air penetration to the passive section. Aeration of the passive section of the biopile results from natural oscillations of atmospheric pressure.

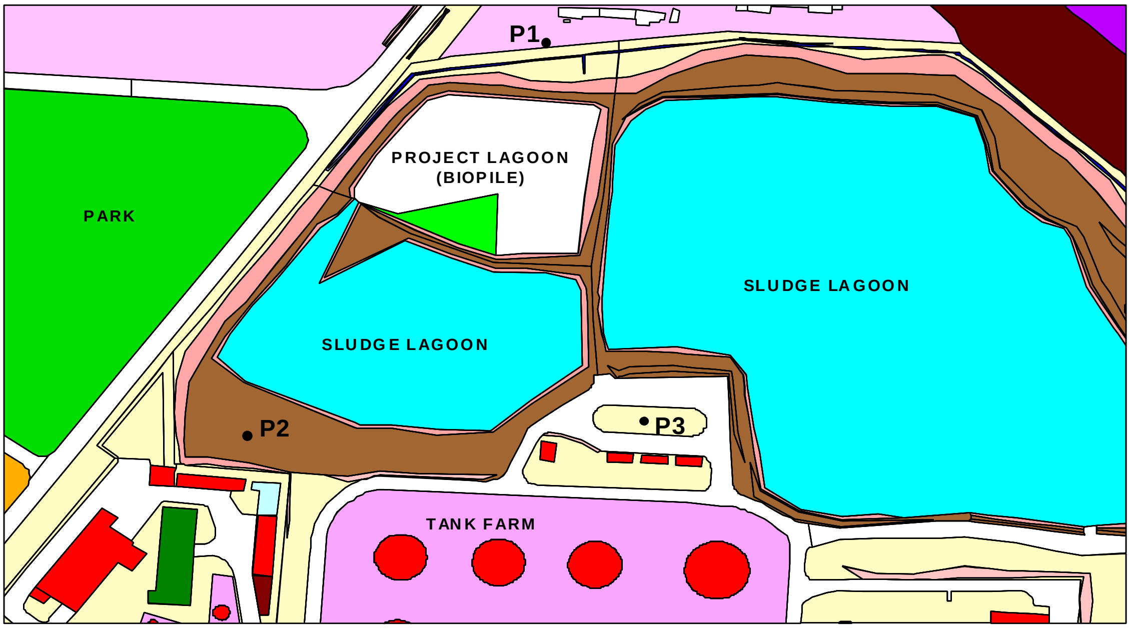
A one year long, detailed monitoring of the biopile functions will enable optimization as well as comparison of contaminants degradation rates in active and passive modes.

Introduction. Since 1995, the U.S. Department of Energy (DoE EM-50 Polish Initiative Program) has been working together with the Institute of Ecology of Industrial Areas (IETU), Poland, in looking for mutually beneficial, cost effective solutions in the areas of environmental remediation. The Czechowice Oil Refinery located in southern Poland (Fig. 1.) was chosen as an industrial partner for this project. Nearly a century of use of a sulfuric acid-based oil refining technology by the Czechowice Refinery has produced an estimated 120 thousand metric tons of acidic, highly weathered, petroleum sludges, which have been deposited into three open process waste lagoons (Fig. 2.). Initial analysis indicated that the sludge were composed mainly of high molecular weight paraffinic and naphtenic hydrocarbons (TPH), as well as mono- and polynuclear aromatic hydrocarbons (BTEX and PAH, respectively, see Tables 1. and 2. The smallest lagoon, a 0.3 hectare site, was selected for remediation using a technology known as biopiling. The overall objective of this project (Altman *et al.*, 1997) was to provide a cost effective bioremediation demonstration of petroleum contaminated soil at the Czechowice Refinery. Specifically, the goal of the remediation was to reduce the environmental risk from PAH compounds in soil and provide a green zone adjacent to the site boundary. The remediation strategies that were applied at the Czechowice Oil Refinery waste

Fig. 1. Localization of Czechowice Refinery

lagoon were designed, managed and implemented under the direction of The Institute for Ecology of Industrial Areas (IETU) and the Westinghouse Savannah River Company (WSRC) for the United States Department of Energy (DOE). Florida State University has the overall lead for the DoE EM-50 Polish Initiative Program. This collaboration between IETU, DOE and its partners, provides the basis for international technology transfer of new and innovative remediation technology that can be applied in Poland and the Eastern European Region as well.

Fig. 2. Refinery lagoons



Biopile design and construction. Initial project discussions with the Czechowice Oil Refinery resulted in finding an immediate cost effective solution for the dense organic sludge in the lagoons. When mixed with other waste materials, the sludge could be sold as a fuel source to local cement kilns, providing a revenue stream for Refinery to cleanup the lagoon. This allowed the bioremediation project to focus on remediation of contaminated soil that was unusable as fuel, less recalcitrant and easier to handle and remediate. The project brought together several proven techniques and remediation tools used by WSRC to remove and/or destroy contaminants, via biostimulation of indigenous microbes found in the environment.

Table 1. Initial concentrations of BTEX and PAH in biopile material

	MCL (MU)	MCL (Ind)	Biopile material
Benzene	0,2	100	27,4
Ethylobenzene	1,0	200	3,3
Toluene	1,0	200	14,6
Xylenes	1,0	100	7,3
Fluoranthene	0,2	50	6,543
Benzo(b)fluoranthene	5	50	1,8
Benzo(k)fluoranthene	5	50	1,3
Benzo(a)pyrene	5	50	2,29
Benzo(g,h,i)perylene	10	50	0,624
Indeno(1,2,3-cd)pyrene	NR	NR	6,16

All values in mg/l
Polish Maximum Contaminant Level (MCL) guidelines
(Industrial Use, 0-2 M)(Multiple Use, 0,3-15 M)
NR = No Recomendation

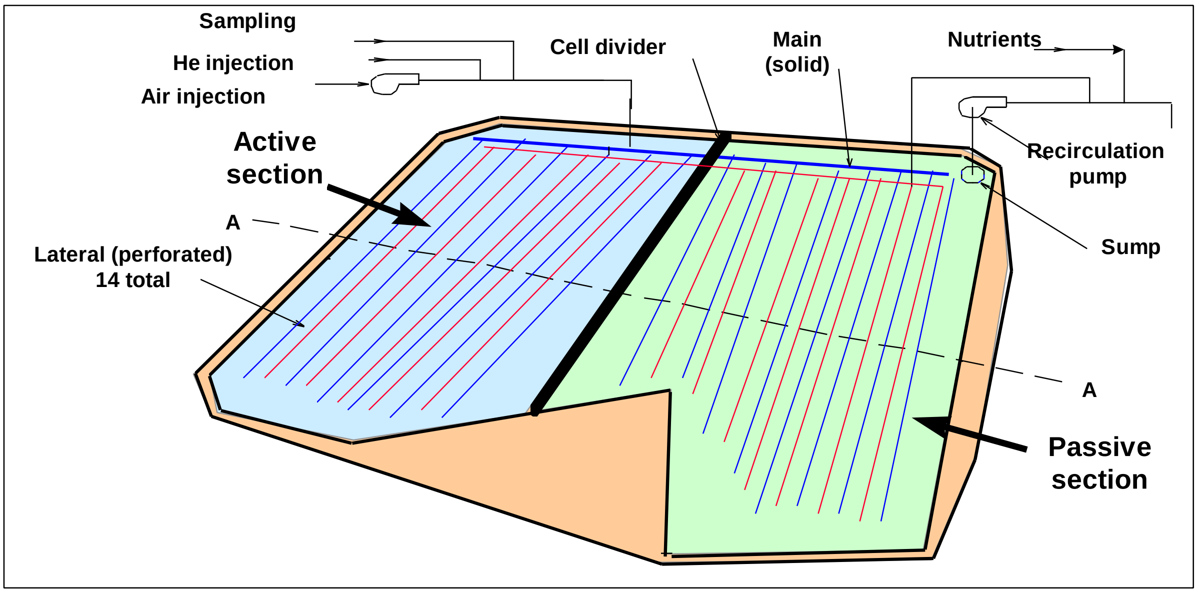
The strategies employed include bioremediation, using the natural cleansing capacity of the environment to degrade the hydrocarbon pollutants. A risk based approach guided the final selection and remedial design. This approach provided a plan that took into account the intended future use of the site as a green zone between the refinery and the local population, and emphasized the natural cleansing methods whenever possible. More aggressive techniques could be taken for sites that are to be developed for future uses that would involve higher potential exposure risks to the general public.

Table 2. TPH concentration

Average	27,42 g/kg
Minimum	<1 g/kg
Maximum	95 g/kg
Total TPH inventory	158 metric tons

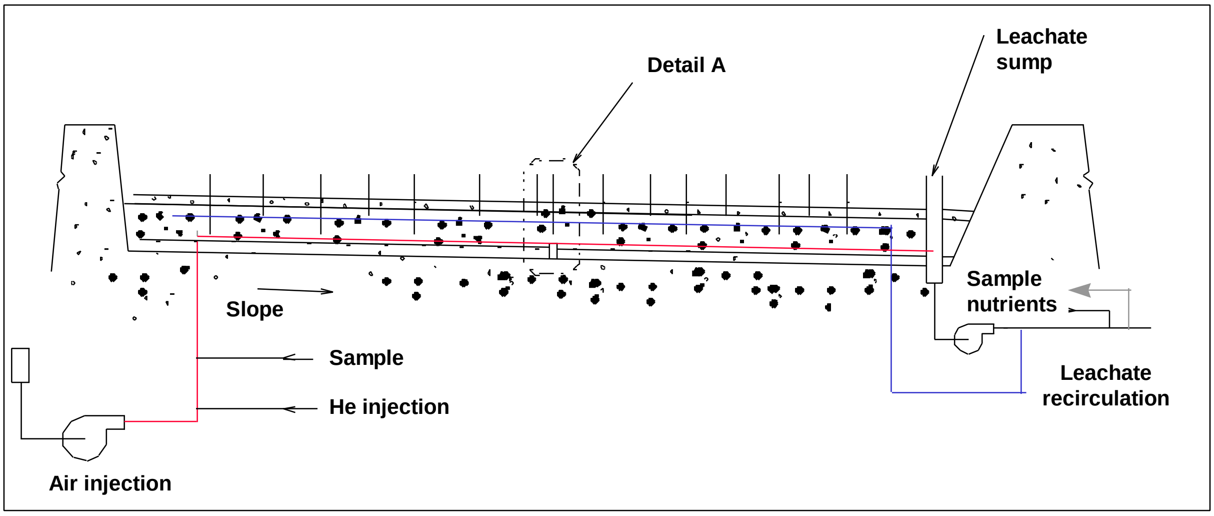
A treatability study (Ulfig *et al.*, 1996) of the material to be remediated determined the physical and chemical parameters necessary to maintain and stimulate an active microbial community that can sustain a high biodegradation rate of the contaminants. The treatability study, along with the characterization data provided the information necessary to design and deploy a bioremediation system capable of producing the stimulus necessary to maintain the biological activity needed to degrade the contaminants to less toxic levels.

Fig. 3. Aeration/leachate collection system



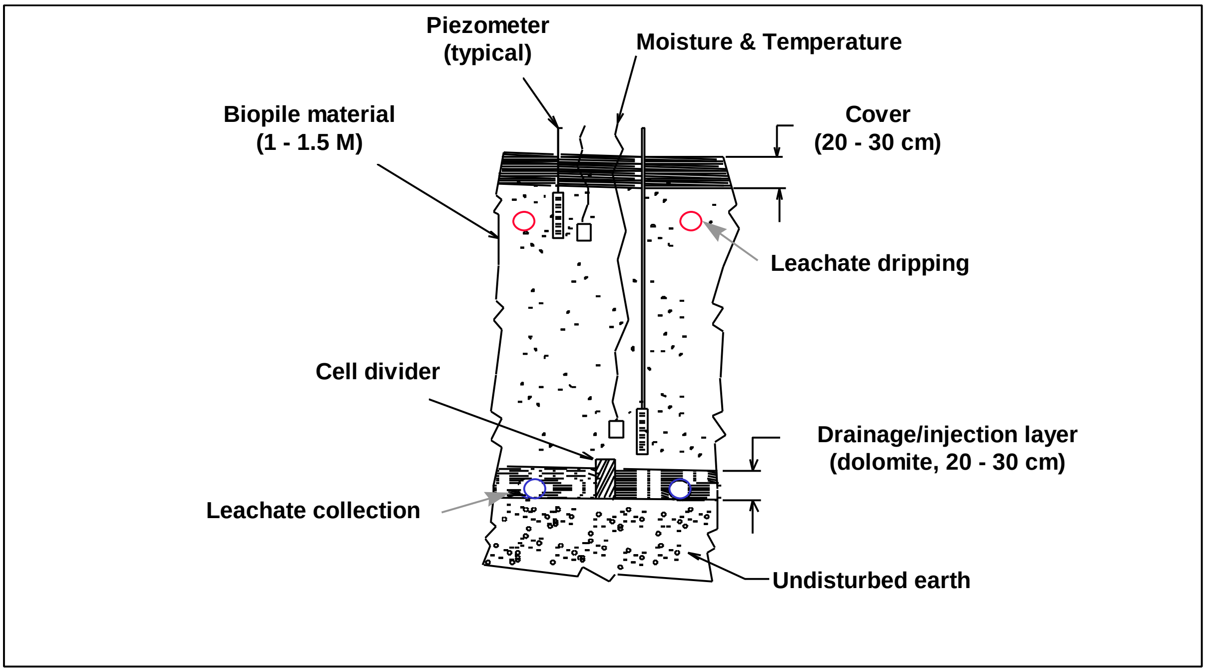
The final biopile design (Figs. 3,4,5) consists of 1) dewatering and clearing targeted lagoon to clean clay, 2) adding a 20 cm layer of dolomite with pipes for drainage, leachate collection, air injection, and pH adjustment, 3) adding a 1.1 m layer of contaminated soil mixed with 10% by volume of wood chips to improve permeability, and 4) completing the surface with 20 cm of top soil planted with grass.

Fig. 4. Section A-A



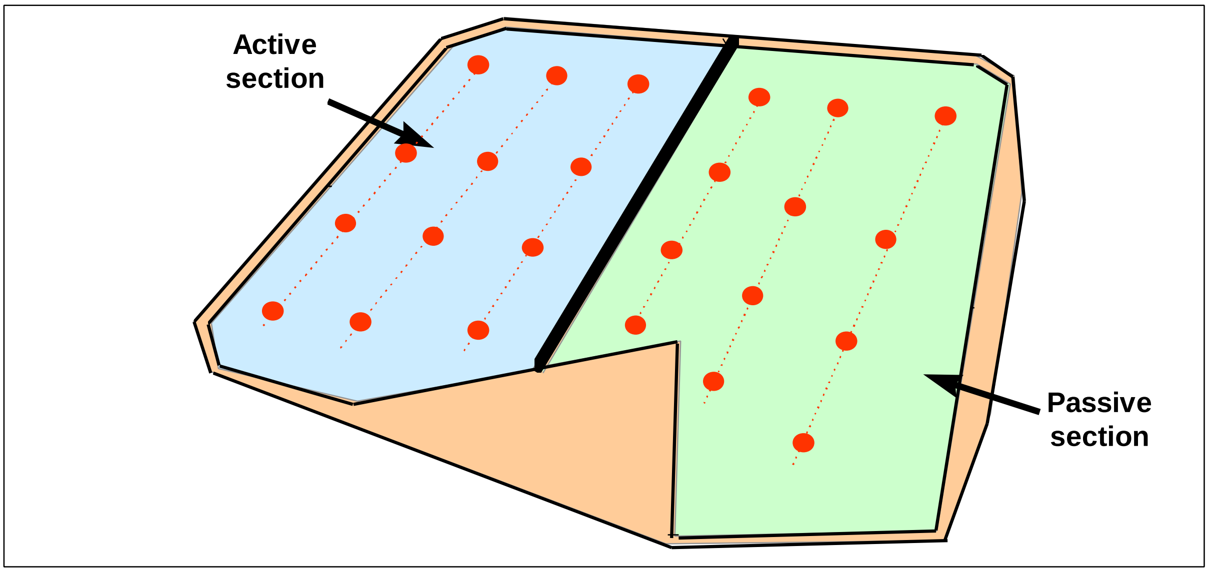
This design allows the retaining walls of the lagoon to be reduced on the property boundary and produce an immediate green zone while the remediation is taking place. The 3000 m^2 treatment area was divided into approximately 1690 m^2 of passive aeration using Baroballs and approximately 1310 m^2 of active aeration via leachate collection system air injection. Use of both passive and active aeration methods will allow an accurate assessment of cost vs. efficiency, and the most appropriate design for future lagoon remediation at the refinery. The proposed design should allow for rapid remediation of all types of oil contaminated soil and has also been shown to be applicable to landfill remediation and various other types of shallow waste sites.

Fig. 5. Detail A



Process monitoring. Process monitoring is accomplished in a variety of ways. Soil gas piezometers (Fig. 6.) were installed in the biopile to monitor carbon dioxide, oxygen, methane, volatile organic hydrocarbons and semi-volatile organic hydrocarbons.

Fig. 6. Sampling points



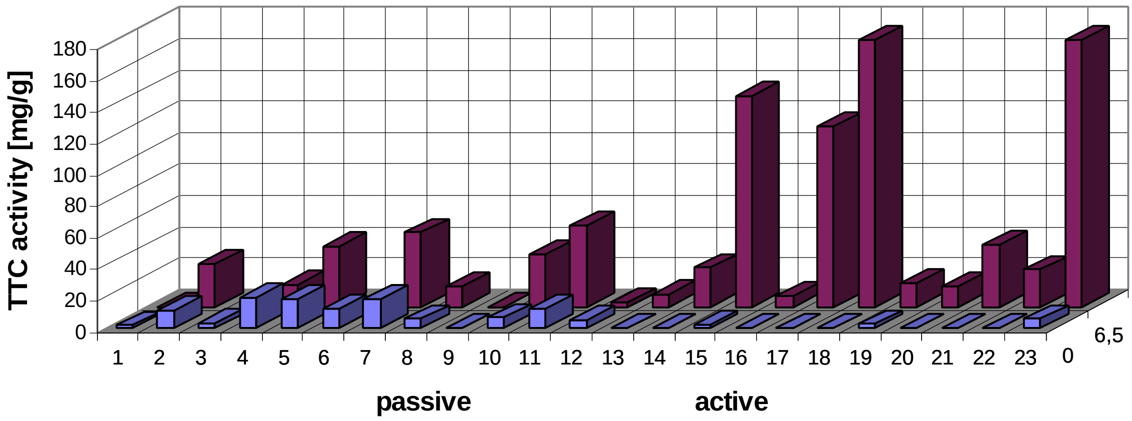
Water and soil samples are analyzed for polynuclear aromatic hydrocarbons, nutrients, inorganics, and microbiological activity. Water quality of the leachate is tested for pH, dissolved oxygen, specific conductance, temperature, and other chemical and physical parameters. The data gained from the monitoring program are used to calculate the biodegradation rates for total petroleum hydrocarbons (TPH). Four operating campaigns were planned (table 3.).

Table 3. Four Operating Campaigns

Duration	Main features
1. October'97 - January'98:	start up and mild aeration
2. February'98 - April'98:	intensive aeration
3. May'98 - June'98:	aeration, nutrients
4. July'98 - September'98:	aeration, nutrients, leachate recurculation

Results. Some results obtained during first three operating campaigns are shown below. Fig. 7. illustrates microbial activity in the biopile soil after 6.5 months of operation in comparison with the initial activity at each measuring point separately.

Fig. 7. Microbial activity, OC-2, deep



Despite of high heterogeneity of the biopile soil a general increase in the microbiological activity is rather evident. Changes in the average microbiolgical activity after each campaign are shown in Fig. 8. Dramatic decline in the activity is probably due to decrease in the availability of easily usable carbon or lack of nutrients like nitrogen or phosphorus. Results of the next operating campaign with leachate recirculation will throw more light on this problem.

Fig. 8. Microbial average activity

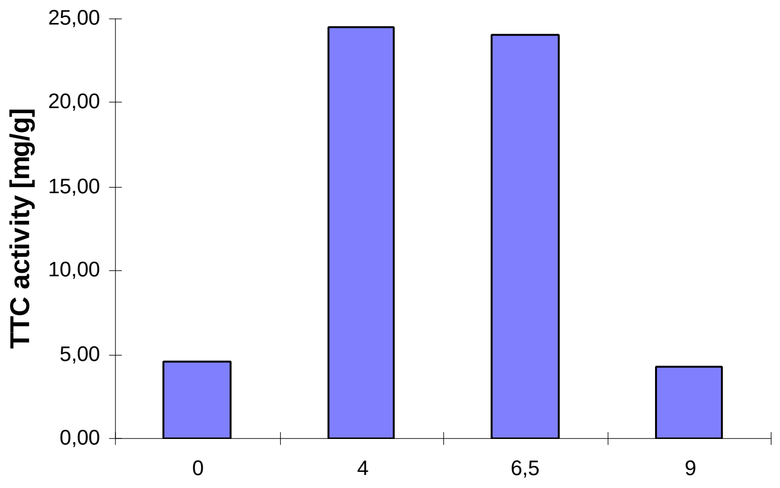
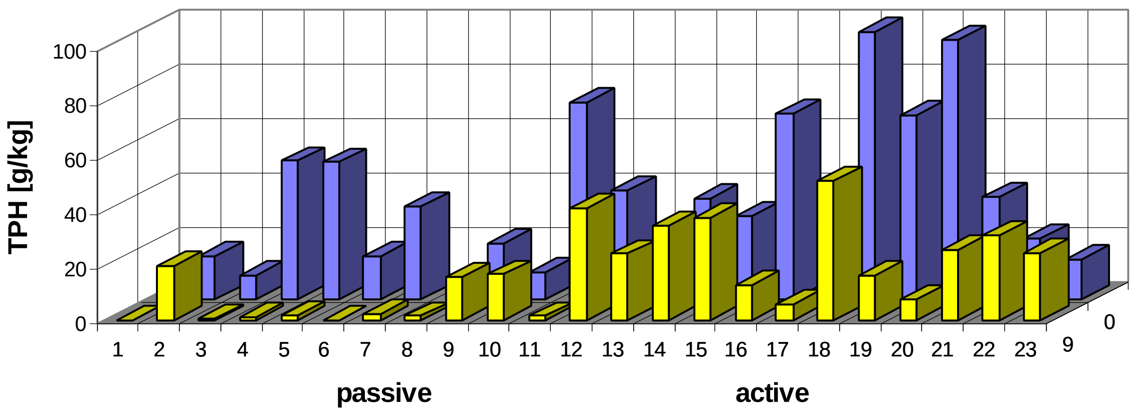


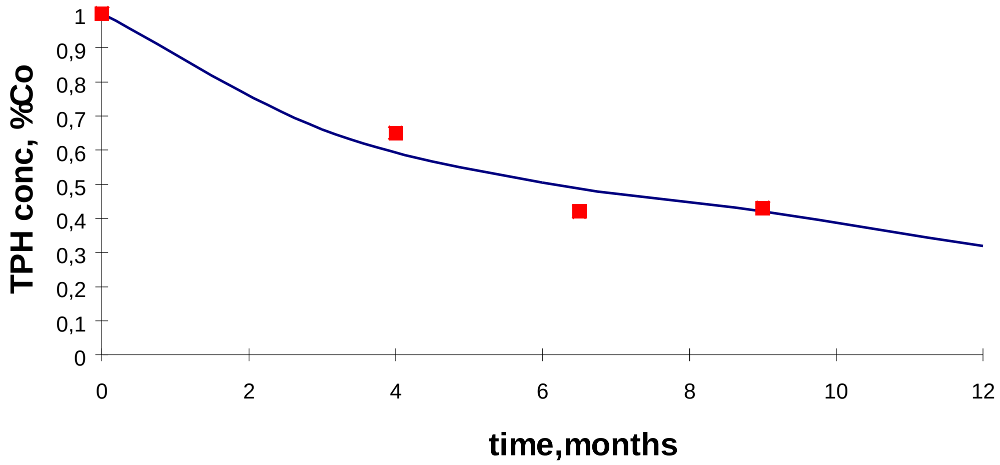
Fig. 9. shows distribution of TPH concentration in the biopile soil after the third operating campaign and contrasts it with initial concentrations. As before, a general decrease is distinct.

Fig. 9. TPH inventory, OC-3, deep



Changes in average concentration of TPH in the biopile soil are shown on Fig.10. Initial rapid decrease in TPH concentration during first two operating campaign is followed by a period of stagnation, which is in accordance with decrease in microbiological activity (see Fig. 8.)

Fig. 10. Average TPH inventory change



Basing on changes in TPH inventory in the biopile soil, contaminants biodegradation rates were estimated. Results are shown in Table 4.

Table 4. Average biodegradation rates (mg/kg/day)

Campaign	Average	Passive	Active
OC-1	80	44	119
OC-2	88	82	94
OC-3	< 0	33	~ 0

During 9 months of the operation totally more than 80 tons of TPH was removed from the biopile soil.

Conclusions. The biopiling proved to be a viable method for cleaning soil from weathered acid refining wastes at the Czechowice Refinery. TPH removal rates in active section occurred to a little higher than in passive one. Under circumstances, when there is no pressing on rapid closure of the site, a passive aeration can be taken under consideration as a cost effective alternative.

References

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