Production – scale bioreactor for petroleum contaminated soils.

A.Worsztynowicz[1], D. Rzychon[1], M. Adamski[1], S. Iwaszenko[1], D. Altman[2], M. Kuperberg[3]

Abstract: A small, mobile bioreactor, intended for use in remediating limited volumes of contaminated soils, was designed and constructed by the IETU in cooperation with WSRC. The bioreactor was built as a continuous airflow, packed bed reactor. A modified, 6m^3 capacity standard container for waste collection and transport was used as a vessel where contaminated soil was to be bioremediated. It was equipped with a false floor to provide leachate collection and uniform aeration of remediated soil, as well as pumps and sprinklers to recycle the leachate through the system. Supplementary equipment was used to control the bioremediation process and provide on-line monitoring of basic bioreactor working parameters. This includes blowers to force air through the soil layer, the leachate recirculation system (provides a mechanism for the uniform distribution of fertilizer or other amendments), a set of soil gases sensors for measuring CO_2, O_2 and CH_4 concentrations along with soil temperature. The data acquisition process is fully controlled by IETU developed software (BioReDaq) working in the Advantech VisiDaq environment. Once the bioreactor was built, a soil cleanup test was carried out. Approximately 3.2 tons of petroleum contaminated soil from the Czechowice Refinery (Poland) was used for treatment. During the bioreactor operation (97 days) data was collected continuously from solid state sensors. The data was confirmed by periodic sampling with GEM 500 Landtec device. The test results show that both TPH and PAH were reduced to ~50% of initial average concentrations. The bioreactor equipped with the data monitoring/control system seems to be a very useful tool to bioremediate limited amounts of petroleum contaminated soil.

Petroleum contaminated soils, on one scale or another, are common to all DOE sites as well as those of other government agencies and commercial locations worldwide. While large areas of contaminated soils justify dedicated remedial operations, smaller areas could be addressed with on-site, batch, ex-situ remediation. Bioremediation is a promising technology for removing organic contaminants from soil. It is a process that mineralizes or transforms hydrocarbons (both xenobiotic and naturally occurring) introduced into the environment to less toxic or innocuous forms (Atlas, 1984). Indigenous microorganisms in the soil and groundwater can degrade large quantities of petroleum hydrocarbons if they are provided sufficient amounts of water, oxygen, and other limiting nutrients, usually nitrogen and phosphorus. Soil bioventing conducted in a batch reactor (bioreactor) appears to be a proper means to perform hydrocarbon contaminated soil bioremediation in well–controlled environment, allowing process optimization and technology development. Bioreactors are most frequently mobile treatment units, which makes them easily moved into and out of the site when necessary. The bioreactors clean-up time is relatively short, with times ranging

[1] Institute for Ecology of Industrial Areas, 6 Kossutha St., 40-833 Katowice, Poland, Ph (48-32) 254-60-31, Fx (48-32) 254-17-17, worsz@ietu.katowice.pl
[2] Westinghouse Savannah River Company, Savannah River Technology Center, Environmental Biotechnology Section, Building 704-8T, Aiken, S.C. 29808, U.S.A., Ph 803-557-7238, Fx 803-557-7223
[3] Instiute for International Cooperative Environmental Research, Florida State University, 226 Morgan Building, 2035 East Paul Dirac Drive, Tallahassee, FL 32310-3700, Ph (850) 644-5516, Fx (850) 574-6704, mkupe@mailer.fsu.edu

between 2 and 24 months. During treatment, personnel are not required to be on site full time thus limiting their exposure and cost. Finally, the use of bioreactors is rather inexpensive compared to other types of possible remediation processes as the system is reusable.

The proposed treatment method consists of a small, mobile bioreactor, designed as continuous airflow, packed bed reactor. The system consists of:

- Bioreactor vessel,
- aeration system,
- leachate circulation system,
- monitoring system.

The bioreactor (Fig. 1) is designed as a continuous airflow, packed bed reactor. An adapted regular waste container (a "skid pan") with a nominal volume of 6 m^3 (3.50 m. long, 1.73 m. wide and 1.00 m. deep) was used as a vessel where contaminated soil was bioremediated.

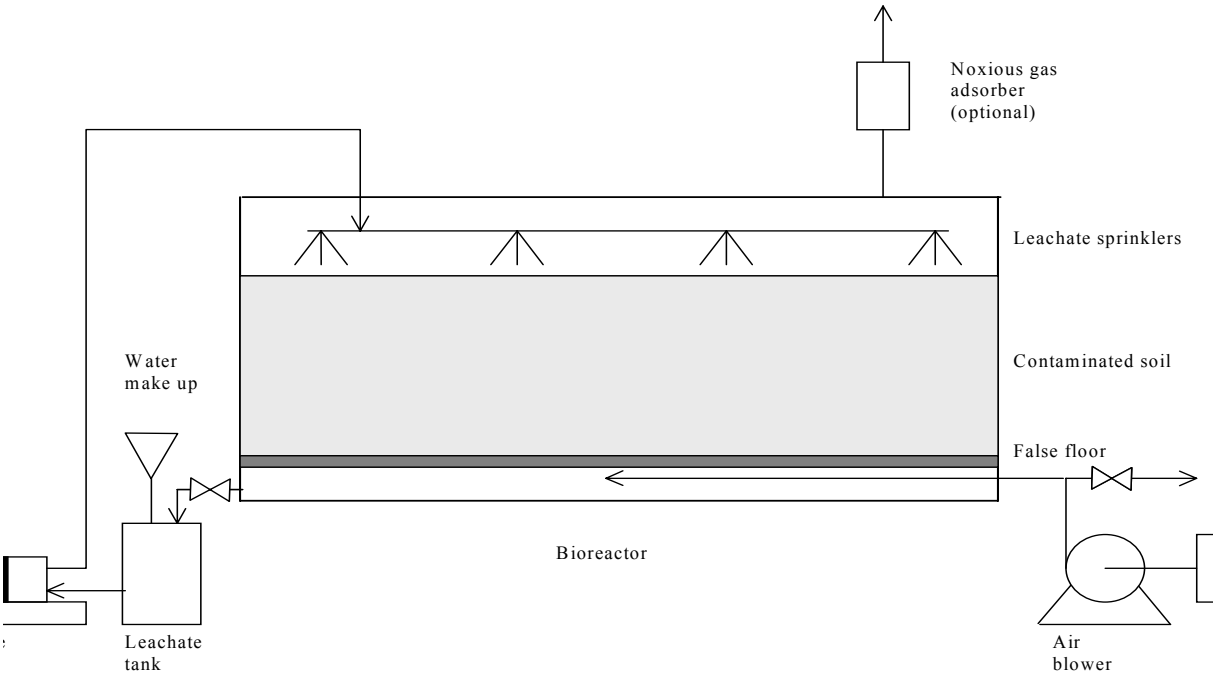

Fig. 1 Bioreactor aeration and leachate circulation system.

The aeration system consists of an air blower equipped with an inlet air filter, a by-pass pipe equipped with a control valve, an inlet air nozzle, and (optionally) a noxious gases adsorber at the bioreactor gas outlet. The leachate circulation system includes a drain equipped with a valve, a small tank vessel, a pump and a system of sprinklers. The whole system has been equipped with the necessary devices placed in several sampling ports for monitoring the main parameters of the bioremediation process.

A process monitoring system was designed to control the bioreactor's working parameters and to evaluate the rate of bioremediaton. To control the mass balance during the bioreactor operation, the following parameters were measured:

- inlet and outlet gas parameters (e.g. gas composition, temperature, pressure, flow rate, etc),
- soil temperature and moisture content,
- soil gas composition.

Six sampling points (SP 0 to 5) have been placed in the soil bed. At these points O_2, and hydrocarbons concentrations, temperature and soil humidity were measured. Additionally, concentration of CO_2 was measured in SP 2 and SP 3. One sampling point was placed in vessel above soil bed – SP 7. At this point the concentration of O_2, hydrocarbons and CO_2 are measured. Inlet and outlet gas temperature and humidity and inlet pressure were measured outside the vessel in the vicinity of the gas flow meters because these parameters were used to recalculate gas flow into normal conditions and should be measured as close as possible to the corresponding gas flow measurement points.

The system is equipped with a data collection system for continuous monitoring and collection of soil gas composition, soil temperature and moisture content in the bioreactor bed. The data acquisition process is fully controlled by IETU developed software (BioReDaq) working in the Advantech VisiDaq environment. The software allows observation of raw sensor signals, signals converted to natural units (e.g., % of volume, m^3/h, etc.) and input parameters (assigned individually for each sensor) used for the conversion of raw signal to natural units. BioReDaq schedules the data logging process e.g., sampling intervals, sensor warm up times, and number of samples used to calculate average values. All data are logged in ASCI text files, and, after converting to MS Access, can be used for further calculations and presentation.

A sample (approximately 3.2 tons) of petroleum contaminated soil from Czechowice Refinery was transported to IETU. Soil was sieved and mixed with about 300 L of oak and pine chips, as well as with fertilizers - 100 kg of Saletrzak (main component: ammonium nitrate) and 50 kg of Poldap (mostly monoammonium phosphate and diammonium phosphate). Prior to adding amendments, approximately 60 kg of sieved soil was separated to serve as a reference sample. The sample points were inserted in a both-ends-opened plexiglass cylinder in the bioreactor soil bed. Thus, the bioremediation conditions for both amended and unamended soil samples should be similar and comparisons possible. During the operational test, both TPH and PAH were reduced to ~50% of initial average concentrations. The test results show that the combined bioreactor and the data monitoring/control system should provide a useful tool to bioremediate limited amounts of petroleum contaminated soil. PAH concentrations in soil, measured during the start–up bioremediation process, are presented in Figure 2.

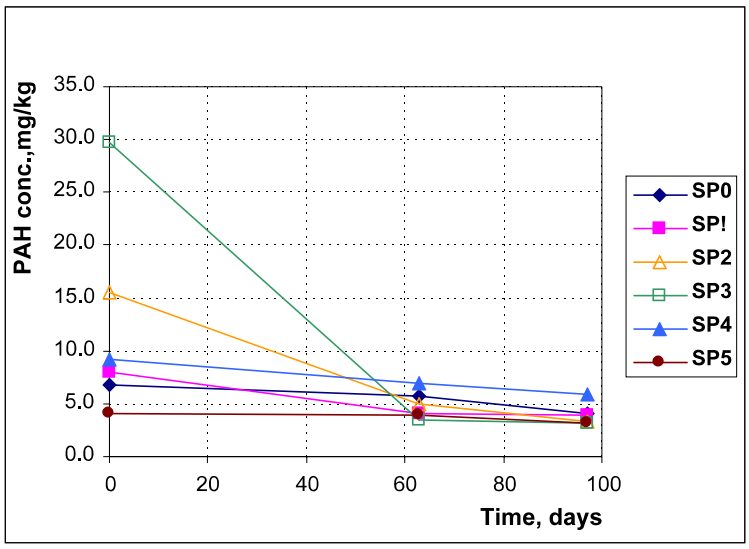

Fig 2. PAH Concentrations in soil bed.