LABORATORY – SCALE APPARATUS TO ASSESS FEASIBILITY OF SOIL VENTING PROJECTS

Application at the Jet-Fuel Polluted Air Base

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Abstract

The high numbers of unfinished soil remediation projects proved that new methodology to assess feasibility of soil venting projects must be obtained. The soil venting, (SVE) is rapid, efficient and rather low cost technique, which is usefully applied to remove volatile organic pollutants from the unsaturated zone of contaminated soil. Developed simple laboratory-scale testing apparatus uses a stainless steel commercial sampling tube to obtain unbroken column sample of real soil with defined dimension. Therefore, it is possible to study contaminant transport under well-defined laboratory conditions; important process parameters (pressure, air flow, etc.) can be controlled. The laboratory venting tests were applied on soil sample collected at former air base contaminated by jet-fuel. The soil characteristics were determined and mass balance of decontaminated amount was obtained. Thus the completed results can be directly applied in the field-scale.

Introduction

Many of soil remediation projects have been recently started in the Czech Republic, but only few of them have been finished until now. Most of these projects were parts of a privatization process and there was practically no time for feasibility studies. Companies apply for a remediation within common practice and have only limited knowledge of transport characteristics of contaminants in soil matrix. Without this knowledge, it is almost impossible to assess reliably the potential effectivity of the suggested remediation technique, time necessary for remediation and the costs.

Methods

Soil Vapors Extraction is (SVE, vacuum extraction, “air stripping”) is rapid, efficient and rather low cost remediation technology to remove volatile organic pollutants from the unsaturated zone of the contaminated soil. This method is usually set as in-situ, but the ex-situ application is possible. The high effectivity of SVE is in unsaturated zones only, for saturated zone other variation is used. The SVE uses the undepressure in wells in soil matrix, which causes the improvement for phase-to-phase transport. SVE is applied to reduce concentration of volatile hydrocarbon in soils-mostly chlorinated and petroleum ones, which are easily removed from soils with soil air by exhausting only. Exhausted vapors (1) are cleaned on Earth's surface (by sorption on activated carbon, catalytically burning) and clean gases are released to the atmosphere or impressed back to the wells (if allowed and required). Venting is generally applicable for volatile contaminants (VOC-Volatile Organic Compounds) and some Semi-Volatile Organic Compounds (SVOC) and its effectivity increases for lighter (more volatile) compounds.

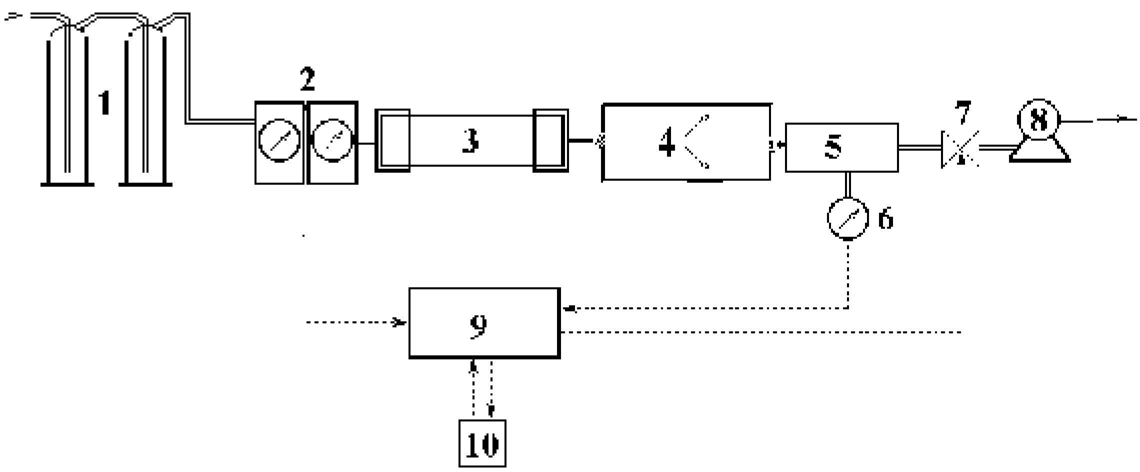
Laboratory tests include following steps: Sampling of unbroken soil sample, experiments in laboratory + analytical process, interpretation of tests. The methodology (2), (3) of laboratory venting tests is based on passing defined column of air through the real sample of soil collected on the contaminated locality. “Defined passing through” means process, when all important parameters (4) are precisely observed or controlled (e.g. when constant pressure gradient, flow mass is observed, or with constant flow mass the pressure gradient is measured). This “passing through” is arranged so the transport of contaminants in soil sample is two-dimensional.

One of the most important conditions for venting laboratory tests is the representative unbroken soil sample (5), (6). The expression “unbroken” is relative one only as any even smaller touch to soil causes broke. With all the possible technical means and experience the soil sampling must be performed to the lowest possible damage.

For soil sampling of unbroken soils a sampling set from Eijkelkamp was used. Sampling stainless steel column (length 24 cm, diameter 4 cm) is part of this set. Front side of this column is equipped with sharp edge to cut known-defined dimensioned soil sample. When sampled, soil was removed by hand-drill first until the contaminated soil depth was reached.

The schema of laboratory apparatus used for laboratory test is on following picture (Fig. 1), where is 1-washing containers, 2- flow sensors, 3-sampling column with soil, 4-sampled output, 5-air chamber, 6-manometer, 7-regulative valve, 8-pump, 9-operating unit, 10-computer

Fig. 1 The schema of laboratory venting apparatus



The basic element of apparatus is sampling stainless steel column mentioned above, filled with soil sample and closed by sampling fronts (Fig. 2). The pump creates the pressure gradient. Air passes through two washing/drying units and enters sampling column then. There are two measuring sensors with different range and bubbled flowmeter at the main inlet in case of any failure. Sampling unit is tt the output of column. These are the sorptive tubes or washing containers filled with methanol. Regular flow of gas through the column is provided by electronic valve. Back up system is represented by set of hand-operated valves. The pressure gradient is measured by manometer.

Fig. 2: Sampling columns filled by soil sample -(plugged) and closed by sampling fronts

The soil samples for following experiments were collected at the former air-base in the Czech Republic where jet-fuel pollution was detected in subsurface. Several types of soil samples were collected: soil samples in stainless steel columns for laboratory venting tests, soil samples for physical – chemical determination of soil characteristics, soil sample for soil characterization (soil particles distribution, etc.).

To determine soil particles distribution, soil sample was placed in the laboratory hood for 35 days to remove water and contamination. To obtain distribution of soil particles calibrated sieves were used (holes' size 4-0,0045 mm). The content of carbon, hydrogen, nitrogen was determined. The water content was determined by azeotropic distillation using the representative sample.

The collected soil sample was extracted by freon in Soxhlet apparatus to quantify the original contaminants' concentration. The content of jet-fuel was determined using Gas Chromatography - (GC) coupled with Flame Ionization Detector (FID). As jet-fuel could be separated in four fractions (- nC_{10}, C_{10} - nC_{11}, nC_{12} - nC_{13}, nC_{13}-) all fraction were determined.

The laboratory venting tests were performed in apparatus described above. After the laboratory venting test were finished the soil sample column was divided into several parts to determine one-dimension contaminant concentrated profile and moisture profile. The remaining concentration of contaminant and remaining content of moisture was obtained using identical analytical methods i.e. azeotropic distillation (moisture's content) and Soxhlet extraction (contaminant's content].

Results

Soil particles distribution was following: above 4 mm (1, 07 % ww), 4-2,8 mm (5,62 % ww), 2,8-2 mm (3,21 %), 2-1 mm (13,49 %), 1-0,5 mm (26,13 %), 0,5-0,4 mm (14,31 %), 0,4-0,315 mm (10,44 %), 0,315-0,25 mm (5,86 %), 0,25-0,2 (5,96 %), 0,2-0,1 mm (7,67 %), 0,1-0,08 mm (4,10 %), 0,08-0,063 mm (1,35 %), 0,063-0,05 mm (0,65 %), 0,05-0,045 mm (0,14 %), below 0,045 mm (0 %) which demonstrated that fraction 1-0,5 mm was highly represented.

The results of elementary analysis are shown in Table 1, which proved that soil had contained neither inorganic nor organic carbon, which had qualified the affiliation of contaminants to the soil surface only.

Table 1: The elementary analysis

sample	H [%]	N [%]	C total [%]	C inorg. [%]	C org [%]
01	0,09	0	0	0	0
02	0,23	0	0	0	0
03	0,09	0	0	0	0

The average water content was 9,28 % (w/w). This soil sample was collected at the same drill as the soil sample for laboratory venting tests. The original concentration of contaminants is shown in following table (Table 2).

Table 2: The concentration of contaminants

fraction/units	- nC_{10},	C_{10} - nC_{11}	nC_{12} - nC_{13}	nC_{13}-	jet fuel
mg. kg $^{-1}$	1731	1735	2769	263	6499

The result (Table 3) demonstrates the total mass balance of tested soil.

Table 3: Mass balance

fraction/ parameter	units	- nC_{10},	nC_{10} - nC_{11}	nC_{12} - nC_{13}	nC_{13}-
average concentration before experiment	mg. kg $^{-1}$	1731	1735	2769	263
amount before experiments	mg	762	764	1218	116
average concentration after experiment	mg. kg $^{-1}$	21	32	439	147
amount after experiments	mg	9	14	193	65
total removal	%	98,8	98,2	84,1	44,1
captured in washing containers	mg	747	650	769	27
removal by venting - provably	%	98,0	85,1	63,1	23,3
losses	mg	6	99	257	24
losses	%	0,8	13	21,1	20,4

The reduced value of flow through gas (i.e. $\frac{flow\ through\ gas}{pore\ volume}$) was 300 000, which is higher than for in situ applications.

Discussion

The Table 3 confirms that light fraction of jet-fuel could be entirely removed from soils using SVE. The heavier fraction above nC13- was not considerably removed. The mass losses could be caused by following possibilities: losses of contaminant during soil manipulation, losses of contaminant during its trap into the solvent, biodegradation during samples storage and during venting tests or by other factors. Therefore the table includes the parameter of provable removal by venting which calculation includes the amount trapped in washing containers only.

Conclussion

The claim of these experiments was to observe application of laboratory scale apparatus to assess the feasibility of venting projects. The hypothesis of unbroken soil sample was necessary and was performed by application stainless steel column as a sampling container. The laboratory apparatus was developed and applied to the real soil samples collected at former air base polluted by jet-fuel. The application of apparatus proved that only contamination of lighter fractions of jet-fuel would be entirely removed from soils. This apparatus and method are capable to help in assessment of minimal remediation process time and economically achievable residual concentration of pollutants in soil remediated by venting methods.

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