Bulgarian Journal of Agricultural Science, 21 (No 5) 2015, 935-939
Agricultural Academy

TECHNOLOGY FOR THE REMEDIATION OF SOIL

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Abstract

KETIN, S., M. IMAMOVIC, D. NIKOLIC and R. BIOCANIN, 2015 Technology for the remediation of soil, *Bulg. J. Agric. Sci.*, 21: 935–939

This paper presents the importance of soil remediation technology in large process systems (oil and petrochemical industry, electricity production). Various types of technology have been compared and presented with all their advantages and shortcomings. Some solutions for specific examples when the soil remediation is required are suggested. The examples are used to present all the problems and their solutions when a contaminated soil requires remediation.

Key words: remediation, soil, technology

Introduction

There was not a single legal regulation to deal fully with the issues of groundwater pollution and soil pollution; therefore, such issues required the implementationof some internationally accepted approaches to the matter. The regulations are binding and they demand for the polluters to control all the emissions of contaminating substances, which are emitted into the air and all of the wastewaters, which are released into the waterways, soil and groundwater. They are also required to act environmental friendly. Recently, a regulation called "The Regulation on the Program of Systematic Monitoring of Soil Quality, Soil Degradation Risk Assessment Indicatorsand the Methodology for the Remediation Projects 88/2010" has been passed, and it has proved to be a domestic regulation in accordance with the international environment protecting demands. Since this country until recently had no regulations on protecting groundwater and soil, it also lacked the criterion which would be the basis for determining the obligation for soil and groundwater remediation hence international standards were commonly applied. The internationally accepted approach, especially appreciated in Europe, is presented in the national standard of Holland (DBO/1999226863/ The Nederlands Ministry of Housing, Spatial Planningand Environment Circular on target values and intervention values for soil remediation, February 4th, 2000). According to this standard the contents of mineral oil in unsaturated soil is up to 50 mg/kg, and the soil with the contents of mineral oil over 5000 mg/kg should be considered polluted so some of the remediation technology should be used on it.

Only after excavation of the polluted soil could the excavated soil be considered a waste, and the Regulation on Waste Categories, Examination and Classification (`Public Herald RS`, no. 56/2010) is applied. Prior to the remediation the waste is classified according to the Waste Catalogue in 17 05 and after the remediation in 19 13, according to the List of Waste Categories in Q15, according to the Y list in Y23 and finally according to the disposal method in D1.

In the Waste Catalogue, each waste marked with an asterisk is considered a dangerous waste. In Appendix 7 of the Regulation (following the Border values of the concentration of hazardous components of the waste which are used as the basis for determining the waste characteristics), is stipulated that for the waste such as oil contaminated soil, soil with other types of contamination, waste soil, waste excavated soil and other, a border value of concentration of overall carbon hydrates 50 mg/kg of dry mass, is used.

Soil is considered a dangerous waste if the content of mineral oils exceeds 20 g/kg according to the Basel Convention (UNEP/CHW.7/11/ Add. 3, 22.07.2004.-Interin guidelines

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on hazardcharacteristic H13 of Annex III to the Basel Convention). According to the European Directive (EC Council Decision of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC), the materials cannot be disposed at landfills should the content of mineral oils exceed the border value relevant to the disposal of the inert waste at the landfills (500 mg/kg).

Materials and Methods

Soil remediation technology

There are many developed and applied remediation (decontamination) technologies in the world. They are used for decontamination of the polluted objects and new ones are frequently developed whilst the old ones are upgraded. They differ relative to the medium on which they could be applied, to the contaminating substances they remove, to their efficiency and expenses per polluted medium unit and to the duration of the remediation. They are most commonly divided to those that could be applied to the solid mediums (soil, sediments, silt and solid waste) and those that could be applied to water (groundwater, surface water, filtered water and waste water) – Table 1.

The remediation technology, itself, could be the source of further pollution spreading or of polluting other mediums. All preventive steps should be taken in order to prevent such events. The presence of contaminating substances in the polluted area, the nature and the location of the polluted area dictate the use of several technological options.

The remediation technology could be in situ, which is implemented on the polluted area and ex situ, which requires removal of the polluted material to be processed away from the polluted area. Many scientists can separate the technology options according to the medium to which they are applied, or according to the types of the contaminating substances, because different substances have different characteristics and different reactions hence they need to be treated differently in order to be removed.

The types of remediation technology which remediate soil, silt, sediments and solid waste polluted with evaporative and semi-evaporative organic compounds, oil and oil productsas well as with inorganic substances are all presented in the Table 1. The table presents the status of technology, availability, implementation, remediation time and overall expenses. Data presented regarding the status, availability and the expenses are relevant to the USA situation in 1995.

The interpretation of the table items:

- The status of technology: relates to the level of technology development (is it developed to be commercially applied or is it in pilot project phase)
- Availability: implies the number of the specialized companies that are able to perform the necessary planning and do the remediation (+ unsatisfactory - only 2 companies at the most can perform the job, ++ average- 2-4 companies can perform the job, +++ satisfactory - there are more than 4 companies specialized to use the technology in question)
- Implementation: refers to the matter whether the technology is self-applied □ or it has to be combined with other types of technology in order to obtain satisfactory results (◊)
- Contaminating substances: present the evaluation of the applicability of certain technology types when dealing with specific contaminating substances (+ unsatisfactory, ++ average, +++ satisfactory)
- Remediation time: it is the time required to achieve certain standards for soil via remediation (+ unsatisfactory- over 3 years for the soil using in situ remediation, over a year for the soil using ex situ remediation, over 10 years for water; ++ average - 1-3 years for the soil using remediation in situ, 0.5-1 year for the soil using remediation ex situ, 3-10 years for water, +++ satisfactory- less than a year for the soil using remediation in situ, less than half of a year for soil using remediation ex situ, less than 3 years for water)
- Overall expenses include the expenses for designing and development of the technology required as well as the expenses for the implementation of remediation esteemed separately for each technology type used (+ unsatisfactory- over 330 $\$/t$ of soil, over 2.64 $\$/m^3$ of groundwater or over 11.33 $\$/kg$ of gaseous contaminating substances; ++ average - 110-330 $\$/t$ of soil, 0.75-2.64 $\$/m^3$ of groundwater and 3.17-11.33 $\$/kg$ of gaseous contaminating substances; +++ satisfactory-less than 110 $\$/t$ of soil, less than 0.79 $\$/m^3$ of groundwater and less than 3.17 $\$/kg$ of gaseous contaminating substances)

Technology types for remediation of soil ex situ

Some twenty years ago, excavation of the polluted soil, its illegal deposition on a public landfill with other waste and covering the hole that remains after excavation with clean material was the commonest way of performing the remediation of the polluted soil. The limitations of such procedure were:

- An emission of gaseous contaminating substances
- The distance of the polluted area from the landfill
- The necessity of transport through populated areas
- The depth and contents of the polluted soil

The development of the environment protection turned the procedure, described above, into the first phase in implementation of technology for processing polluted soil ex situ.

Table 1
Soil, Sediments and Silt Remediation Technology

The status of technology	Status of technology	Availability	Application in combination	Pollutants				Remediation time	Residue	Overall expenses
				VOC	SVOC	Fuel	Inorganic sub-stances			
Biologic processes ex situ										
Biologic processing of the polluted soil	®	†††	□	†††	††	†††	†	†	no	†††
Composting	®	†††	□	†††	††	†††	†	††	no	†††
Controlled biologic processing of the polluted soil	®	†††	□	†††	††	†††	†	††	no	†††
Biologic processing of the polluted soil in slurry state	®	††	□	†††	††	†††	†	††	no	††
Physical and chemical processes ex situ										
Chemical reduction/oxidation	®	†††	◊	††	††	††	†††	†††	solid	††
Halogen removal	®	†	□	††	†††	††	†	◻	gas	◻
Halogen removal	®	††	□	††	†††	†	†	††††		†
Soil washing	®	††	◊	††	†††	†††	†††	†††		††
Soil vapor extraction ex situ	®	†††	□	†††	†††	††	†	††		†††
Solidification/stabilization	®	†††	□	†	††	†	†††	†††		†††
Solvent extraction	®	††	◊	††	†††	††	†	†††		†
Supercritical fluid oxidation	®	•	•	•	•	•	•	•		•
Supercritical fluid extraction	•	•	•	•	•	•	•	•		•
Thermal processes ex situ										
High temperature thermal desorption	®	†††	◊	††	†††	††	†	†††		††
Low temperature thermal desorption	®	†††	◊	†††	††	†††	†	†††		†††
Incineration	®	†††	□	††	†††	†††	†	†††		†
Pyrolisis	®	†	□	††	†††	††	†	†††		†
Vitrification	®	††	□	††	††	††	†††	††		†
Technology (plasma)	•	◻	□	†††	†††	†††	†††	◻		
Biologic processes in situ										
In situ biodegradation	®	†††	□	†††	†††	†††	†	†		††
In situ bioventing	®	†††	□	†††	†††	†††	†	††		†††
Natural attenuation	•	†††	□	†††	†††	†††	†	†		†††
Phytoremediation										
Physical and chemical processes in situ										
Creating cracks in the layers (Fracturing)	o	††	◊	††	††	††	††	•		†††
Soil flushing	o	†††	□	†††	††	††	†††	†		◻
Soil Vapor Extraction - SVE (Vacuum extraction)	®	†††	□	†††	††	†††	†	††		†††
In situ solidification/stabilization	®	†††	□	†	††	†	†††	†††		†††
Thermal processes in situ										
Enhanced vacuum vapor extraction	®	††	□	††	†††	††	†	†††		††
Vitrification	o	†	□	††	††	††	†††	†††		†

Legend:®- completely developed technology, o- pilot facility level of developed technology, • - there is no data, † - unsatisfactory, †† - average, ††† - satisfactory, □ - self-applied technology, ◊ - technology is applied in combination with other subsequent technologies, ◻ - inadequate data, voc - evaporative organic compounds, svoc, semi-evaporative organic compounds

All ex situ technology types commence with the excavation of polluted soil, which may last from several hours to several months depending on the issues that may occur in the excavation process and on the quantity of the polluted soil. The excavation could be accompanied with uncontrolled emissions of contaminating gaseous substances and air pollution. When excavation is performed in close vicinity of residential buildings, electric lines, water supply pipes or sewerage system, then the process demands additional caution and conditions that may significantly slow the technology down and the expenses of the process may rise. Polluted soil could be a dangerous waste, which would demand special conditions for processing on a specific location according to the legal regulation. Some special work conditions are also required for the workers on the excavation site and in transport of the polluted materials for there is a possibility of polluting 'the transport route'. The excavated soil should be replaced with clean materials, whichcorresponds the excavated material or purified material excavated from the same location. That process may prolong the time of remediation.

Once excavated, the polluted material-soil, undergoes the ex situ remediation process, biological, physical, chemical and thermal processes. The ex situ techniques may be faster, easier to control, usable for multitude of contents and various contaminating substances and adequate for various types of soil.

Many limitations, side effects and large expenses of soil remediation have stimulated the development of the unconventional, alternative methods, especially regarding the carbon hydrates when microorganisms are used to degrade them.

The ex situ processes have some advantages over the in situ processes and they are as follows:

- Simplified control over the reactions of reactants - contaminating substances and remediation by- products
- Modification of the excavated soil adding the alimentary substances and substances which increase the permeability of the polluted soil
- The improvement of control may comprehend the gaseous products which are collected by placing the coverings i.e. leachate water and by placing a collecting pipe system
- It requires less samples and analyses in order tomonitor the process and to verify its efficiency.

The remediation can be improved as follows:

- Using aeration of the polluted materials with injecting the air or extracting the vapor after treating the polluted materials by adding the materials that increase permeability
- Maintaining the humidity at the optimal level of 50-85% of material capacity
- Using balanced distribution of alimentary substances in the pile and the reactor

and

- Modifying the texture of polluted soil and mixing it with the unpolluted soil

Biologic processes for soil processing

- Biologic processing of the polluted soil (land treatment/ land farming)
- Composting
- Controlled biologic processing of the polluted soil (biopiles)
- Biologic processing of the polluted soil in slurry state (slurry-phase bioremediation)

Physical and chemical processes for soil processing

- Chemical reduction/oxidation
- Halogen removal
- Soil washing
- Soil vapor extraction ex situ
- Solidification/stabilization
- Solvent extraction
- Supercritical fluid oxidation
- Supercritical fluid extraction

Thermal processes for soil processing

- High temperature thermal desorption
- Low temperature thermal desorption
- Incineration
- Pyrolisis
- Vitrification ex situ

Technology types for remediation of soil in situ

In situ technology for soil remediation and removal of the contaminating substances is performing the processing on site without removing polluted soil or water. Microorganisms and various chemicals could be introduced into the system, but polluted material, during the processing, remains at the location where it was found when pollution was detected. The technology may be biologic, physical, chemical, thermal and some others.

Biologic processes for soil processing (in situ) - bioremediation

- In situ biodegradation
- In situ bioventing
- Natural attenuation
- Phytoremediation

Physical and chemical processes for soil processing in situ

- Creating cracks in the layers (Fracturing)
- Soil flushing
- Soil Vapor Extraction - SVE (Vacuum extraction)
- In situ solidification/stabilization
- In situ chemical reduction/oxidation

Thermal processes for soil processing in situ
• Vitrification
• Enhanced vacuum vapor extraction

An example

The recovery of soil polluted due to the spilling of oiled liquid from the oil pit using bioremediation.

A certain amount of oiled liquid was spilled probably due to the strong impact of the high groundwater on that location, which was particularly high at the time. Measures were taken to prevent spreading of the oiled liquid and to remediate the consequences of the spilling. The samples of the water from the oil pit and the bordering channel were taken and analyzed as well as the samples of the soil in close vicinity of the pit and of the contaminated soil, and the same procedure was practiced for the samples of the liquid in the channel. The soil close to the TS was also sampled. It was visually determined that there had previously been a spilling of oil substances at the location.

The common procedure for solving problem such as this is a closed system, which means that there is no gas emission, no emissions in wastewater or in the soil. The treatment of contaminated soil by method of remediation is to be performed on the location using 'ex situ' method in the following way: the basis for bioremediation of the oiled soil is to be prepared, contaminated soil, which is mixed with the nutrient, is to be excavated and transported, the soil is to be transferred to the prepared basis, contaminated soil is to be sampled, the entire excavated soil is to be covered with foils, temperature and humidity levels are to be constantly monitored. The process lasts until the satisfactory result is acquired from the sample and after the bioremediation; the sampling is performed by the certified laboratory.

Conclusion

This paper has presented modern types of technology for remediation of soil, silt, sediments and solid waste polluted with evaporative and semi-evaporative organic compounds, oil and oil products and with inorganic substances. The technology status, availability, implementation, remediation time and overall expenses have been analyzed in great detail. The types of technology that could be used relevant to the situation have been suggested. The example of implementation of bioremediation technology for recovery of polluted soil next to the power substation was presented.

References

Beškoski, V. P., G. Đ. Gojgić-Cvijović , J. S. Milić , M. V. Ilić, S. B. Miletić, B. S. Jovančićević and M. M. Vrvić, 2012. Bioremediation of soil polluted with crude oil and its derivatives: microorganisms, degradation pathways, technologies. *Hem. Ind.***, 66** (2): 275-289. doi:10.2298/HEMIND110824084B

Rajicevic, **V.** Microorganisms in soil and water bioremediation, Faculty of Agriculture Zemun UDC:631.461.1.001.7:628.353.1=861. http://www.sitzam.org.rs/zm/2007/No2/ZM_48_2_49.pdf

Rasulic, **G.**, 2007. Oil and the environment, protection, and pollution remediation, Petroleum Industry NIS, Serbia, ISBN 978-86-910643-0-3

Sokolovic, **S.**, Modern methods of soil remediation, Faculty of Technical Science, Novi Sad, 2007

US EPA, 1990. Engineering Bulletin, Slurry Biodegradation, Sept, 1990, *EPA,* 540 2 90 016.

US EPA, 1994. Engineering Buletin, In Situ Bioremedation Treatment, April, 1994, *EPA,* 540 S 94 502.

US EPA, 1994. Remedation Technologies Screening Matrix and Reference Guide, Federal Remediation Technologies Roundtable, Prepared by DOD Environmental Technology Transfer Comminite, October, 1994, *EPA*, 542 B 94 013, NTISD PB 95 104782.

US EPA, 1996. A Citizens Guide to Bioremedation, April 1996, *EPA,* 542 F 96 007.

US EPA, 1998. Innovative Site Remedation Technology, Design and Application, Vol [10] l.1., Bioremedation, May, 1998, *EPA,* 542 B 97 004.

US EPA, 2001. A Citizens Guide to Bioremedation, April, 2001, *EPA,* 542 F 01 001.

Received March, 17, 2015; accepted for printing August, 14, 2015