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Quality Control and Remediation of Contaminated Soils in Urban Areas – Some Examples from Romania

Rotaru Ancuța

Department of Roads and Foundations, Faculty of Civil Engineering, "Gheorghe Asachi" Technical University Blvd. Dimitrie Mangeron 43A, 700050, Iasi, Romania.

Abstract: In the last years the control of contaminated soil in urban areas has been an area of research and the remediation an important goal. The implementation and evaluation of developed technologies are now the first priority. As remediation progresses, attention to soil protection, to prevent new contamination, will increase. At the same time long term remediation processes, like natural attenuation, will increase attention on soil monitoring and quality management. In the mid future the focus of research will be on soil quality management and sustainable soil use related to the development of urban areas. One goal of soil quality research is to manage soil in a way that improves soil properties. Soil quality is an assessment of how well soil performs its properties now and how those functions are being preserved for the future. Soil quality cannot be measured directly, so we evaluate indicators. Indicators (physical, chemical, and biological properties, processes, or characteristics of soils) are measurable properties of soil that provide information about how the soil can function. Soil has both inherent and dynamic qualities. Inherent soil quality is soil's natural ability to function. Soils respond differently to management depending on its inherent properties and on the surrounding landscape. Dynamic soil quality is how soil changes depending on how it is managed. In the paper some techniques of contaminated soil treatment in urban areas will be analyzed and some rules of how a soil can support human habitations will be plotted, having into account that buildings need stable soil for support. In Romania, conservation measures reduced soil erosion rates by 55-90%. But still numerous industrial landfills are located close to human settlements and affect the environment. Several studies conducted in areas most polluted by metal smelters (Copsa Mica, Baia Mare, and Zlatna) have shown significant levels of population exposure to toxic metals (Cd, Pb), and confirmed adverse impacts of the exposure on health. The exposure is not only related to waste management, but also to the entire process of production not considering prevention of environmental pollution at all its stages. Exposure to hazardous substances at the work place is quite common in Romania and causes substantial morbidity.

Key words: soil quality control, contaminated soils, chemical soil pollution, bioremediation, soil stabilization, capping and covers, cut-off walls, soil incineration

INTRODUCTION

The soil quality is the capacity of a soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal, maintain water and air quality, and support human health and habitation.

From the civil engineer point of view, soil quality is providing a stable foundation for structures. Soil stability means compacted subsoil under buildings and roads, and healthy soil and vegetation next to structures to prevent sliding and erosion. It's obvious that the ideal soil parameters for supporting roads and houses are different than the ideal parameters for plant growth and hydrology.

Soil has both inherent and dynamic qualities. Inherent soil quality is soil's natural ability to function. For example, sandy soil drains faster than clayey soil. Deep soil has more space for roots than soils with bedrock near the surface. These characteristics do not change easily.

This implies that soil quality has two parts: an intrinsic soil part which covers the soil's inherent capacity and a dynamic part influenced by the soil manager.

Inherent quality represents intrinsic properties of soil, as determined by the soil formation. The inherent quality of soil is used to compare the capabilities of a soil against another, and to evaluate the suitability of soil for specific uses.

Corresponding Author: Rotaru Ancuța, Department of Roads and Foundations, Faculty of Civil Engineering, "Gheorghe Asachi" Technical University Blvd. Dimitrie Mangeron 43A, 700050, Iasi, Romania.

Soil responds different to management, depending on it inherent properties and on the surrounding landscape.

Dynamic quality is determined by the soil properties influenced by human use and management decisions. These properties are use-dependent and may be temporal (dynamic). Bulk density near the surface and organic matter content are two such properties.

Dynamic soil quality is how soil changes depending on how it is managed. Management choices affect soil structure, soil depth, the amount of soil organic matter, water and nutrient holding capacity (Brady, N.C. and Weil R., 1999). One goal of soil quality research is to manage soil in a way that improves soil function.

Some Rules of How a Soil Can Support Human Habitations:

To build in urban areas can lead to contaminated soil or groundwater. Excavations for linear construction (such as pipelines) in an urban area may be adjacent to sites capable of contaminating soil and groundwater at the construction site. A building may occupy a site that was the former location of a contaminated area.

Contaminated soils may be considered less hazardous than contaminated air or water. However, soils can present serious environmental and public health hazards in situations where contaminants levels are high and exposures (direct or indirect) are likely. In most cases the potential of the contaminated soil to serve as source of contaminant release to another media (air or groundwater) creates the need to consider remedial action.

If new construction requires excavation of soil or dewatering, an environmental investigation is necessary where it is reason to believe that contamination exists.

When contaminated soil is encountered either during the pre-construction investigation or during construction, their management requires consideration of multiple important issues that include, together with geotechnical concerns: (a) legal issues regarding responsibility for the cost of remediation; (b) regulatory issues, addressed before initiating remedial actions, that may involve requirements concerning contaminated soil excavation, remediation and disposal; (c) options available for managing the contaminated soil and the effects of implementation of such options on the proposed project; and (d) the cost and time schedule required for soil clean-up.

Most construction projects will require excavation, transportation and disposal of some volume of soil. Excavation of contaminated soil will require a health and safety plan and training for all workers potentially exposed to contaminants. The level of protection must be comparable with the level of risk. The more hazardous the greater the level of protection required and, consequently, the greater the cost (and duration) of excavating the soil.

Most Contaminated Soils in Urban Area:

Soil contamination is the presence of man-made chemicals or other alteration in the natural soil environment.

The most common contaminated soils in urban area are: soils contaminated by petroleum fuel products and soils contaminated by hazardous wastes.

Romania suffers from great problems with industrial wastes. Only 10% of waste deposits abide by proper technical provisions. Industrial facilities have resulted in extreme contamination in several metropolitan areas. About half of Romania's population live more or less in the vicinity of waste sites that do not conform to the contemporary heath standards. Landfills frequently burn and there are problems with the smoke as well as the smell (Cucu M., *et al.,* 1994).

There is little effort to separate hazardous from municipal waste in Romania and even disposal of municipal waste is inadequate in many areas (Carpenter D.O., *et al.,* 1996).

In Romania, chemical soil pollution affects about 0.9 million ha, of which 0.2 million ha excessively polluted (pollution with heavy metals, acid rains, etc.). The main negative effects of pollution with heavy metals and acid rains consist in soil chemical composition alternation due to the accumulation of emission elements, soil acidification with 1–3 pH units, leaching of exchangeable bases, mobilization of high amounts of exchangeable Al with a toxic effect on plants, severe decrease of nutrients, especially mobile phosphorus, leading to poor plant fruiting, deregulation of microbiological activity decrease of bacteria population and dehydrogenase activity, increase of fungi population and index of colonization with micromycetes) leading to the decrease of humification rhythm of organic matter, excessive heavy metal accumulation in plants, etc. This type of pollution is present on important land areas in the zones of Baia Mare, Copsa Mica, Zlatna, etc. The total area affected by pollution in the Copsa Mica region covers approximately 180,750 ha, of which 31,285 ha forest and 149,465 ha agricultural lands. The severely polluted area, where at least one pollutant exceeds the maximum allowable limit) covers 21,875 ha, of which 3,249 ha forest and 18,630 ha agricultural lands.

In Zlatna area, in the middle of Romania, the acid deposition totally destroyed the vegetation on more then 2,000 ha, which caused very intense processes of erosion and landslide. Other 3,000 ha are subjected to degradation processes and heavy metals pollution has a moderated intensity on other 15,000 ha.

Soil Contaminated by Petroleum Fuel Products:

The requirements for the management of the contaminated soil by petroleum fuel products alone are less important than for soil contamination by other hazardous materials, because subsurface contamination by such fuels has a lower health-risk, a relatively high biodegradation potential, and limited migration potential in groundwater systems. Oil or oil components can migrate through the soil matrix in two ways. First is bulk flow of an oil phase which infiltrates the soil under the influence of gravity and capillary forces. Second, the oil components can dissolve in air or water and migrate in these phases by diffusion or bulk flow. Soil contaminated only by petroleum fuel products from underground storage tanks require a limited site investigation (consisting of sampling soil from several shallow borings in the vicinity of the tank). When the soil contaminated by petroleum fuels is identified, the remediation requires tank removal, removal of free product, remediation of contaminated soil in the immediate vicinity of the site, and possible groundwater contamination assessment (Hoeppel R.E., *et al.,* 1991). Thus, excavated soil from construction sites with petroleum product contamination below minimum levels of contamination and in absence of methyl tertiary butyl ether (MTBE) may be allowed to be used as fill or replaced *in situ* with no or minimal treatment. For example, from a gas station localized in a mountainous region, along the valley of an important river and between a highway and a railway, at Lunca de Jos, Harghita County, Romania, disappeared 500 l of fuel. From the site were taken samples of polluted soil and water. Due to the proximity of the river, the existence of a relatively intense underground water flow underneath the old river branch, where the railway was built, is assumed. In an abandoned well, about 20m away from the assumed underground water flow, was noticed the presence of oil products. After digging out of tank, the presence in the underground water of a bitumen layer was noticed. The tank was not provided with double walls. The oil products affected the tank, dissolving the protective layer; the tank walls were corroded and, finally, perforated. The effect of the fuel loss on the water and soil occurred periodically and passed unnoticed.

The effects of the accident:

- four wells, representing the water source for their owners, were unusable for six months;
- expenses derived from the obligation to decontaminate the soil and the underground water of the affected area;
- a part of the gas station capacity was set out of use;
- the affected area was connected to the water supply network.

Soil Contaminated by Hazardous Wastes:

A contaminated soil will be managed as a hazardous waste if is based on the following risk-characteristics: (a) toxicity; (b) reactivity; (c) ignitability; or (d) corrosivity, or it contains hazardous waste from a specific source. The management of soil that is contaminated by constituents other than or in addition to petroleum fuels is often subject to more rigorous requirements, the level of stringency being associated with the quantity of hazardous waste contained in soil or with hazardous waste constituents. In Romania, the total generated waste is about 200 million tones/ year. This amount includes urban, industrial and hazardous waste. The total generated industrial waste in Romania is about 200 thousand tones /year. The most common method used in Romania to eliminate the wastes is by landfilling them. In 2000, the Tisa pollution caused by a cyanide spill following a damburst of a tailings pond in Baia Mare, Romania, increased public awareness of the environmental and safety hazards of mining activities in Romania. The World Heritage Committee analyzed the damage caused by a mine owned jointly by the Romanian government and Esmeralda Explorations, Ltd. of Australia - the Baia Mare gold recovery project in northwestern Romania. In January 2000, breach of a tailings dam spilled cyanide tainted water into eastern European rivers wiping out all aquatic life from the mine to the Black Sea (Szanto Zs, *et al.,*).

The assessment of waste generation showed that in Romania, as well as in Czech Republic, Estonia, Bulgaria, Poland, Slovakia, the waste produced during the extraction and processing of the mineral resources ranks both in quantity and creating environmental problems. The International Commission for the Protection of the Danube River and Zinke Environment Consulting (ICPD, 2000) made a regional inventory of potential accidental risk spots in the Tisa Catchment, on the territories of Romania (ICPDR, 2000).

Table 1: Some remediation technologies for contaminated soils

Technology			
Soil vapour extraction			
Bioremediation	*In situ* bioremediation	Anaerobic bioremediation	Bioventing
			Injection of hydrogen peroxide
		Aerobic bioremediation	
	Ex situ bioremediation	Slurry phase bioremediation	
		Solid-phase bioremediation	
Stabilization			
Capping and covers			
Cut-off walls			
Incineration			
Other *ex situ* treatment technologies			

Methods and Goals to Improve the Contaminated Soils in Urban Areas:

The excavation, transport or treatment of contaminated soil requires definition of project's methodologies and goals. There are certain technologies for the management and recycling a large amount of generated wastes and for using them in other technological processes (Table 1). *In situ* techniques do not require excavation of the contaminated soils so may be less expensive, create less dust, and cause less release of contaminants than *ex situ* techniques. Also, it is possible to treat a large volume of soil at once. *In situ* techniques, however, may be slower than *ex situ* techniques, may be difficult to manage, and are most effective at sites with permeable (sandy or non-compacted) soil (Smyth D.J.A., *et al.,* 2001). The methods of *in situ* treatment of contaminated soil are dependent on project-specific conditions (the planned uses of the site or surrounding neighbourhood), soil and groundwater conditions, and whether the contaminated soil was discovered in advance of the project, or during the initial phases of construction. *In situ* methods are most feasible at sites that are sufficiently large, and particularly at locations where schools, hospitals, houses, childcare centres are relatively distant (Lucia P.C., *et al.,* 2001). In the cases where contamination is more extensive than expected, was discovered during construction or the space for treatment is limited, it is necessary to quickly export material from the site and the management of the contaminated soil will be realized at an appropriate *ex situ* location. *Ex situ* techniques can be faster, easier to control, and used to treat a wider range of contaminants and soil types than *in situ* techniques. However, they require excavation and treatment of the contaminated soil before and, sometimes, after the actual bioremediation step (US Environmental Protection Agency (EPA), 1996). When selecting a method of *ex situ* remediation, we have to consider the nature of the soil contamination, the physical limitations of the contaminated site and the limitations of any other site selected for remediation. Soil contaminated with the following is excluded from *ex situ* remediation:

- Chlorinated solvents, organic acids or other hazardous waste;
- Tars and asphalt;
- Petroleum refinery sludge;
- Spray irrigation from municipal or industrial wastewater treatment systems;
- Industrial sludge, fly ash or other unapproved non-petroleum substances.

The advantages and disadvantages of both *in situ* and *ex situ* techniques must be carefully weighed for each particular situation.

Soil Vapour Extraction:

Soil vapour extraction is an *in situ* technology that removes volatile contaminants (organic compounds) from the soil through the use of vapour extraction wells, sometimes combined with air or oxygen injection wells, to strip and flush volatile contaminants up through the groundwater into the air stream. The entire system acts as an *in situ* air stripper. Stripped or volatilized contaminants will be removed through soil vapour extraction wells and usually require further treatment. In chemical terms, organic compounds are those that contain carbon and hydrogen atoms. Vapour extraction is mot applicable when the contaminants consist of solvents with a high vapour pressure. This process may require months to years to reduce contaminant concentrations. Therefore, it is most useful when the contaminated soil has been discovered during the pre-construction investigation. The method can remove a large fraction of volatile organic compounds from the soil, but cannot remove all contaminants because the rate of removal decreases as residual concentration of volatile organic compounds in the soil decreases.

Bioremediation:

Bioremediation can be performed as a clean-up method for contaminated soil and water. Bioremediation is a treatment process that uses naturally occurring microorganismss (yeast, fungi, or bacteria) to break down, or degrade, hazardous substances into less toxic or non-toxic substances. Microorganisms eat and digest organic substances for nutrients and energy. Certain microorganismss can digest organic substances such as fuels or solvents that are hazardous to humans. The microorganisms break down the organic contaminants into harmless products - mainly carbon dioxide and water. Once the contaminants degraded, the microorganisms' population is reduced because they have used their entire food source. Dead microorganisms or small populations in the absence of food pose no contamination risk. Microorganisms must be active and healthy that bioremediation takes place.

Bioremediation Applications Can Be Done in Situ or ex situ:

Romania is a country situated in an area where the bioremediation can not be so successfully used, because the bacteria used in the remediation process can be efficiently used at temperatures of over 18 ºC, for a period of minimum 6 consecutive months in a year. Unfortunately, in Romania we do not constantly have temperatures above 18 ºC for a period of 6 consecutive months. The long and cold winters are the reason for which the bioremediation, even if it is a viable process for other regions of the world, can't be used with the same success in Romania (Ilie D., 2005).

In Situ Bioremediation:

In applications of this technology an air or oxygen source and sometimes nutrients are pumped under pressure into the soil through wells, or they are spread on the surface for infiltration into the contaminated material. The main advantage of this method is that it's realized in the place where the contaminant soil exists. The primary disadvantage of *in situ* bioremediation is that this process requires time to reduce the concentrations of contaminants to appropriate levels. The second disadvantage is that the method doesn't realize a complete detoxification of contaminants. *In situ* remediation often requires years to reach clean-up goals, depending mainly on how biodegradable specific contaminants are and is not the preferred method if the goal is to reduce contaminants to non-detectable levels. This technique is used at sites where the soil conditions are proper for air and fluids transport, with great hydraulic conductivity, 25-85% moisture content, and not extreme pH values. Monitoring is made by taking soil-samples and measuring contaminant concentrations (Fig. 1).

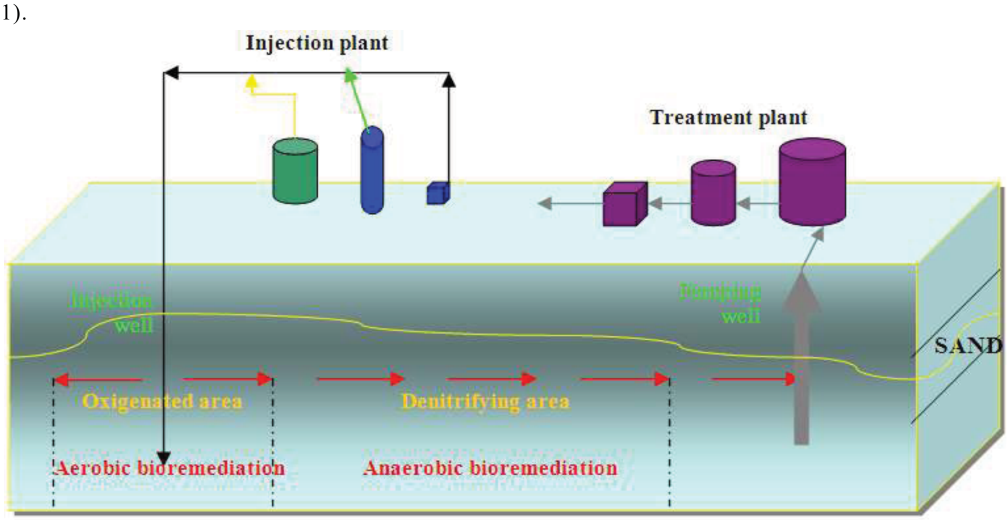

Fig. 1: Schematic in situ bioremediation

In situ bioremediation may not work well in clays or in highly layered subsurface environments because oxygen cannot be proper distributed throughout the treatment area (US Environmental Protection Agency (EPA), 1996). This method may not be feasible in the case where the contamination is discovered after construction has begun. In Romania, some in situ bioremediation studies were conducted at Potlogi Oil Field, Dambovita County (in the Southern part of the country). The experiment was carried out over a 2-year period, starting in 1996, on parcels. Each parcel was filled with oily sludge from Potlogi oil reservoirs (with 24.66%

residual hydrocarbon content) and other materials. The degradation percentages increased gradually over the 2 year-period, with slightly higher rates in the first and the last 6 months. At the end of the 2-year experimental period, good residual hydrocarbon degradation efficiencies (exceeding 90%) were observed, being associated with rich microbial populations in the soils of all parcels (Petrisor I.G., *et al.,* 2001).

Aerobic Bioremediation:

Aerobic bioremediation consists of inducing conditions (moisture, oxygen and nutrients) that foster the growth and reproduction of carbon-consuming aerobic bacteria within the contaminated area, degrading the organic contaminants. Water is usually added to the soil during the bioremediation process. The goal of aerobic *in situ* bioremediation in saturates areas is to supply oxygen and nutrients to the microorganisms in the soil.

This method is appropriate for petroleum hydrocarbons and benzene, toluene, ethyl-benzene and xylene compounds, and improper for chlorinated solvents, phenols, pesticides, dioxins and other organic compounds. Aerobic *in situ* techniques can vary in the way they supply oxygen to the organisms that degrade the contaminants. Two such methods are bioventing (combines soil vapour extraction methods with bioremediation) and injection of hydrogen peroxide (US Environmental Protection Agency (EPA), 1996).

Bioventing:

When subsurface movement of vapours is determined to present a hazard, such vapours can be effectively controlled through use of soil venting. Bioventing is the technology that combines soil vapour extraction methods with bioremediation. It uses vapour extraction wells (placed in the ground where the contamination exists) that induce air flow from atmosphere in the soil above the water table through air injection or through the use of a vacuum. The number, location, and depth of the wells depend on many geological factors and engineering considerations. An air blower may be used to push or pull air into the soil through the injection wells. Air flows through the soil and the oxygen in it is used by the microorganisms. Nutrients may be pumped into the soil through the injection wells. Nitrogen and phosphorous may be added to increase the growth rate of the microorganisms.

Contaminant reduction is the result from two processes:

- The volatile organic compounds are volatilized and flow through the pore spaces to the wells, where they are carried to the surface for final treatment by combustion, sorption or catalytic decomposition.
- The increased air flow stimulates the growth of soil bacteria here present, which consume volatile organic compounds. The vapour extraction system is augmented by use of passive soil vent, heating of the soil, and air sparging.

Soil venting is efficient for vapour control, for removal of volatile hydrocarbons and reducing their concentration in soil. Bioventing can be effective in remediation releases of petroleum products. In general, the process of removing residual petroleum products from the soil will take a relative short time, and a relatively small mass of liquid will be vented to the atmosphere. So, there will be only a short-lived environmental impact during the site restoration process. The risks from this technique must be compared to the risks and costs posed by other practical remediation alternatives.

Injection of Hydrogen Peroxide:

The injection of hydrogen peroxide method delivers oxygen to stimulate the activity of naturally occurring microorganisms by circulating hydrogen peroxide through contaminated soils to speed the bioremediation of organic contaminants. A system of pipes or a sprinkler system is used to deliver hydrogen peroxide to shallow contaminated soils. Since it involves putting a chemical (hydrogen peroxide) into the ground (which may seep into the groundwater), this process is used only at sites where the groundwater is already contaminated. Injection wells are used for deeper contaminated soils (US Environmental Protection Agency (EPA), 1996).

Anaerobic Bioremediation:

Anaerobic bacteria are able to metabolize hydrocarbon compounds, but 10-100 times slower than aerobic bacteria. Thus, anaerobic degradation is not an economic technique.

Ex Situ Bioremediation:

In many urban areas, construction of basements or subsurface parking levels requires that soil be exported from the site to create space underground, taking into account: (a) cost of treatment versus the cost of disposing of untreated soil, (b) availability of *ex situ* treatment facilities, and (c) regulatory requirements. This technology uses microorganisms to degrade organic contaminants in excavated soil removed from the site. The microorganisms break down contaminants by using them as a food source. The end products are carbon dioxide and water.

Ex situ bioremediation requires excavation of the contaminated soil. The treated soil may be replaced into the ground as compacted fill or disposed off-site. *Ex situ* bioremediation offers the advantage of relatively rapid processing compared to *in situ* bioremediation, ease of monitoring, and it can be used where the site configuration and soil types are not capable to efficient *in situ* bioremediation.

Ex situ bioremediation is used when the contamination occurs in highly cohesive clayey soils. In this case, it isn't possible to drive oxygen moisture and nutrients into the situ pore-spaces inducing growth of aerobic bacteria. The process is more efficient if the soil is porous and if the hydrocarbons are light, sort-chain molecules such as fuels or solvents. As the soil is removed from the site, the soil fabric can be disrupted and more exposed, such that bioremediation becomes possible.

The method can be used on heavier, long-chain hydrocarbons by using longer treatment periods or by adding enzyme admixtures to facilitate the degrading of heavy hydrocarbons.

Ex situ bioremediation is monitored by periodic sampling of the soil and by testing bacterial density, to confirm mitigation of contaminant concentrations. It is necessary to analyze the soil beneath the treatment area to be clean. *Ex situ* bioremediation includes slurry phase bioremediation and solid-phase bioremediation.

Slurry Phase Bioremediation:

In the case of slurry-phase bioremediation, contaminated soil is combined with water and other additives (to form slurry) in a large tank (bioreactor) and mixed to keep the microorganisms (already present in the soil) in contact with the contaminants in the soil. Nutrients and oxygen are added, and conditions in the bioreactor are controlled to create the optimum environment for the microorganisms to degrade the contaminants. Upon completion of the treatment, the water is removed from the solids, which are treated further if they still contain pollutants (Sasikumar S. and Papinazath T., 2003). The process can be monitored and performed regardless of season.

Slurry-phase biological treatment is a relatively rapid technique compared to other biological treatment processes, particularly for contaminated clays. The success of the process is dependent on the soil's properties and chemical properties of the contaminated material. This technology is useful especially where rapid remediation is high priority.

Solid-phase Bioremediation:

In the case of solid-phase bioremediation, the soils are placed in a cell or building and tilled with added water and nutrients. Land-farming and composting are types of solid-phase bioremediation.

Land-farming bioremediation is a temperature-sensitive method, applied to warm-weather sites where bioremediation is realized over several seasons. In the land-farming technique, soil is removed from the ground, placed in sallow lifts, and water, nutrients and bacteria (if necessary) are applied by injection pipes. The soil is tilled periodically to introduce air to the pore-spaces. The process is continued for a period (days, months) until contaminant concentrations have reduced to a wanted level.

Stabilization:

Stabilization is a treatment technology for contaminated soils, for remediation alone or as part of redevelopment. Stabilization increases the compressive strength, decreases the permeability, encapsulates toxic element and converts hazardous elements into less soluble, mobile or toxic forms.

In situ or *ex situ* stabilization reduces the mobility of contaminants in the environment through both physical and chemical means. Unlike other remedial technologies, stabilization method trap or immobilize contaminants within the soil, or building materials that contain them, instead of removing them through chemical or physical treatment. Leachability testing is used to measure the immobilization of contaminants.

In situ stabilization techniques use auger/caisson systems and injector head systems to apply stabilization agents to the soils.

In situ stabilization can be accomplished by various means, including: (a) conventional or chemical grouting to reduce hydraulic conductivity or fix contaminants; and (b) thermal stabilization, ranging from steam or air injection at low temperatures to strip volatiles to high temperature *in situ* vitrification (1,600 ºC), where soil electrodes are used to melt the soil mass into an inert, glassy mass.

Ex situ stabilization is done excavating the contaminant soil, stockpiled, processed and then re-used as backfill or disposed off-site. Treatments can be designed to mitigate a range of contaminant characteristics, including: reduction of the solubility of metals; reduction of the mobility or toxicity of heavy organics; and removal of petroleum hydrocarbons or volatile organic compounds.

Ex situ stabilization requires disposal of the resulting materials. Portland cement, often augmented with other materials (fly ash, lime kiln dust, cement kiln dust, and lime), is used as a binding reagent in stabilization because of its ability to solidify (change the physical properties) and stabilize (change the chemical properties) a wide range of hazardous materials. Mixing the right combination of binding reagents into contaminated soils allows them to be either excavated and disposed of in a landfill, or re-used on site to support redevelopment.

Capping and Covers:

Capping is a process used to cover contaminated soils to prevent the migration (movement) of the pollutants. This migration can be caused by rainwater or surface water moving over or vertically through the site, or by the wind blowing over the site. Where contamination is shallow or not mobile, capping may prevent human or environmental contact and provide acceptable levels of protection.The cover must be designed to minimize infiltration and direct surface flows away from the cover surface.

Caps are made of composite synthetic materials with low permeability (fibres, heavy clays, sometimes concrete) and they are designed to accomplish several goals:

- Must provide efficient draining of surface water from the site to prevent the occurrence of standing water.
- Must prevent the vertical movement of water through the contaminated soil.
- Must be resistant to damage caused by the consolidation of soils and other adverse conditions (heat, cold, UV radiation) and easily maintained.
- Must be capable to eliminate as much water as the underlying filter or soils are capable of handling.

A cover may be an option when the following conditions exist: (a) the contaminants are not mobile in the soil, (b) groundwater is located at a distance from the contaminants, and (c) the long-term integrity of the cap is assured.

Problems using this method:

- Is messy and not a long-term solution.
- Is expensive (requires significant long-term funding).
- Requires heavy trucking and noisy equipment.
- Capping material could add pollution and could destroy wildlife habitat and quality-of-life.
- Future uses would be prohibited.
- Caps require periodic inspection for settling of the overlying soils, standing water, erosion, or disturbance by deep-rooted plants.
- The groundwater wells, usually associated with caps, need to be sampled periodically and maintained.

The decision to use a cover should evaluate the possibilities of the cap to reduce the mobility of the contaminants, and the potential risk to human health and environment (Bonaparte R. & Yanful E.K., 2001).

Cut-off Walls:

Physical barriers are vertical features in the ground that provide mitigation of contaminants in soil.

The most commonly physical barriers used in geotechnical and environmental remediation methods are: soil-bentonite, cement-bentonite, bipolymer drain, deep mixing, jet grouting, grout curtain, sheet piling, and geochemical barrier. They are formed using a variety of materials.

The oldest and most commonly used types of physical barriers are cut-off walls. Vertical cut-off walls have been used to control the movement of contaminants and contaminated groundwater since the remediation of contaminated sites began by forming a physical impediment to groundwater flow.

The results of the cut-off wall are function of its continuity, its resistance degradation by contaminants and its resistance to physical degradation.Hydraulic conductivity is a useful measure of soil compatibility, but permeability tests alone cannot assure the long-term stability of a cut-off wall (Day S.R., 1994).

There are significant hydraulic conductivity differences between soil-bentonite, cement-bentonite, plastic concrete, and *in situ* mixed cut-off walls.Indicator tests are used where the leachate and the proposed materials are combined and tested in immersion, desiccation, sedimentation, and other modes. Each indicator test attempts to model a different scenario of the cut-off wall installation and operation.

The results of laboratory and field studies show the influence of material properties, confining stress, permeameter type, water table position, and state of stress, on the hydraulic conductivity of vertical cut-offs. The results of these studies show the range of hydraulic conductivity expected for each of the cut-off wall types (Evans J.C., 1994).

Because of their exceptional physical, structural and chemical properties, bentonites are offering manifold possibilities to protect the environment against the negative effects of dumping grounds (Koch D., 2002).

Construction of a soil-bentonite slurry wall consists of installing mixture of soil (or other material) and bentonite clay into a vertical trench to form a very low permeability, vertical barrier to groundwater flow. The result is function of: (a) the environment of the wall; (b) the percentage of bentonite clay used in the soil-bentonite mix; (c) the type of soil used; (d) the quality of wall construction.

Increasing confining stress decreases the hydraulic conductivity of soil-bentonite and has a reduced impact on stronger backfill materials. In soil-bentonite cut-off walls the stress at depth is less than predicted using the effective weight of the overlying materials, as a result of soil-bentonite materials hanging-up on the side walls of the trench. Thus, applying the effective stress calculated from the effective weight of the overlying backfill overestimates the stress to be used in the laboratory tests and results in unconservative measures of hydraulic conductivity. Field data also reveals that, with time, the hydraulic conductivity of soil-bentonite above the water table may increase substantially. Further, the hydraulic conductivity does not significantly decrease upon re-saturation (Evans J.C., 1994).

In the last years, in Romania the Tisa river basin has come to the forefront of international attention due to a series of major flood events and environmental disasters.

The permanent pollution of the River Tisa originates on the one hand from industrial activities, where mainly inorganic micro-contaminants are released to the water. On the other hand, it derives from agricultural activities and municipal sewage discharges. The use of fertilizers and pesticides in agriculture may contribute to a significant nutrient and chemical load in the Tisa and its tributaries.

The following options were determined as possible to mitigate the pollution of the territory (Szanto Zs, *et al.,*):

- Reconstruction of cap system (clay cap);
- Backfilling of the vaults (reduction of cap settlements and water ingress to the wastes);
- Groundwater cut-off wall;
- Partial/full recovery of spent sources;
- Compaction and repackaging of other waste; and
- Improvement of record keeping and installation of markers.

Incineration:

As a waste-disposal technology, incineration has been used for about 500,000 years, since *Homo erectus* discovered the fire. For millennia, incineration was a proper solution to turn big piles of hazardous waste into air emissions, smaller piles of ash, and sometimes energy. But incineration has drawbacks. When hazardous waste goes into an incinerator, it comes out as potentially harmful air emissions, although these emissions are strictly controlled.

High temperatures, 870 to 1,200 °C are used to volatilize and combust halogenated and other organics in hazardous wastes. Auxiliary fuels are used to initiate and sustain combustion. Incinerator designs are function of different waste streams and different end products, and operating temperatures vary with the different designs.

Incineration is the most expansive option for management of contaminated soil. It is a proper method only when the contaminated soil contains chemicals of very high toxicity and potential persistence in the environment. The advantage of this method is that the contaminants are destroyed.

Both *in situ* and *ex situ* incineration use high temperatures to volatize and combust (in the presence of oxygen) halogenated and other organics in hazardous wastes. The destruction and removal efficiency for properly operated incinerators exceeds the 99.99 percent requirement for hazardous waste and can be operated to meet the 99.9999 percent requirement for Polychlorinated biphenyls (PCBs) and dioxins.

In November 2004, in Constanta Harbour, Romania, was practised a project for cleaning and removing of waste from oil tanks and soil, in order to obtain oil by incineration of the contaminated soil with oil products and using of the obtained heat in the production processes.

Other ex situ treatment technologiesDependent on the waste characteristics, other *ex situ* management options are available for contaminated soils:

- recycling of contaminated soils for use as road base, limited to mildly soils and efficient only when the project site is no too far from the recycling soil, and
- use as fill on construction sites, restricted to soils that are not highly contaminated.

Conclusion:

The management of contaminated soil may lead to a decision on whether the proposed project can move forward or whether the project may not be feasible. The engineer must manage with the contaminated soil with respect to the legal and regulatory environment of the project, the cost efficiency and schedule goals of the client.

REFERENCES

Bonaparte, R. and E.K. Yanful, 2001. "Covers for waste" In: R.Kerry Row (ed.), *Geotechnical and Geoenvironmental Engineering Handbook,* pp.825-876. Berlin: Springer Berlin / Heidelberg

Brady, N.C. and R. Weil, 1999. The Nature and Properties of Soils. 12th ed. Prentice Hall. Upper Saddle River, NJ.

Carpenter, D.O., A. Suk, K. Blaha and M. Cikrt, 1996. "Hazardous Wastes in Eastern and Central Europe" In: Environmental Health Perspectives, 104(3): (Mar., 1996), 244-248, Publish by: The National Institute of Environmental Health Sciences (NIEHS).

Cucu, M., M. Ionescu Lupeanu, M. Nicorici, L. Ionescu and S. Sandu, 1994. "The dangerous wastes and health risk in Romania: national report. Cen Eur J Public Health (Suppl), 2: 41-43.

Day, S.R., 1994. "The Compatibility of Slurry Cutoff Wall Materials with Contaminated Groundwater", ASTM Digital Library, Published: Jan 1994.

Evans J.C., 1994. "Hydraulic Conductivity of Vertical Cutoff Walls", ASTM Digital Library, Published: Jan 1994.

Hoeppel R.E., R.E. Hinchee and M.F. Arthur, 1991. "Bioventing soils contaminated with petroleum hydrocarbons" Journal of Industrial Microbiology and Biotechnology, Springer Berlin / Heidelberg, 8(3): 141-146.

ICPDR, 2000. "Regional Inventory of Potential Accidental Risk Spots in the Tisa catchment area of Romania, Hungary, Ukraine & Slovakia". Prepared by the Permanent Secretariat of the ICPDR in cooperation with Zinke Environment Consulting for Central and Eastern Europe, Vienna, August 2000 (http://www.zinke.at).

Ilie, D., 2005. "An Alternative to Bio-remediation" In: The Romanian Journal of Oil, Gas and Energy, No. 9(75)/2005.

Koch, D., 2002. "Bentonites as a basic material for technical base liners and site encapsulation cut-off walls", Applied clay science, Publisher: Elsevier Science, Amsterdam, 21(1-2): 1-11.

Lucia, P.C., G. Fod and H.A. Tuchfeld, 2001. "Management of Contaminated Soil in Engineering Construction", In: R.Kerry Row (ed.), Geotechnical and Geoenvironmental Engineering Handbook, pp: 947-966. Berlin: Springer Berlin / Heidelberg.

Petrisor I.G., Dobrota S., Lazar I., Voicu A., Stefanescu M., Kuperberg M. and Teaf C., 2001. "Field Deployment of Oily Sludge Bioremediation in Romania", Proceedings of International Containment & Remediation Technology Conference and Exhibition, June 2001, Orlando, Florida.

Sasikumar S. and T. Papinazath, 2003. "Environmental Management - Bioremediation of Polluted Environment" in Martin J. Bunch, V. Madha Suresh and T. Vasantha Kumaran, eds., Proceedings of the Third International Conference on Environment and Health, Chennai, India, 15-17 December, 2003. Chennai: Department of Geography, University of Madras and Faculty of Environmental Studies, York University, pp: 465-469.

Smyth D.J.A., R.W. Gillham, D.W. Blowes and J.A. Cherry, 2001. "In situ Containment and Treatment of Contaminated Soil and Groundwater" In: R.Kerry Row (ed.), Geotechnical and Geoenvironmental Engineering Handbook, pp.921-946. Berlin: Springer Berlin / Heidelberg.

Szanto Zs, Svingor E., S.A. Nagy, I. Futo, L. Palcsu, A. Elek, D. Furj, M. Molnar and L. Rinyu, "The Tisza-project - challenges and perspectives".

US Environmental Protection Agency (EPA), 1996. "A Citizen's Guide to Bioremediation".