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Waste Materials in Construction: Putting Theory into Practice

INVESTIGATION STRATEGIES FOR CONTAMINATED SOILS IN FINLAND

Hanna-Liisa Järvinen
Geological Survey of Finland
Espoo, Finland

ABSTRACT

Geological Survey of Finland has completed a project, the objective of which was to find reliable investigation strategies and methods for contaminated soils. The applicability of the ISO-standard Draft, the Dutch prestandard and U.S. EPA recommendations to Finnish geological and hydrogeological environment was studied. During the preliminary assessment, standard drafts turned out to be complicated and expensive to carry out in practice. However, the basic principles in drafts were found applicable also in Finland. During the project a new Finnish practice was created.

Investigations on contaminated sites are divided into three phases: preliminary survey, field investigation and additional investigations. Based on the preliminary survey the site is whether "probably uncontaminated" or "potentially contaminated". The distribution of the contaminants is always supposed to be heterogeneous in Finnish geological environment. Quality control samples reveal the quality of sampling and analyzes. The local baselines (background values) must always be verified in any assessment of contaminated sites. The sampling pattern is determined after the preliminary survey and it is designed primarily case-by-case. The sampling intensity is recommended for both probably uncontaminated or potentially contaminated sites.

1 INTRODUCTION

This research project was carried out by Geological Survey of Finland and Technical Research Centre of Finland. It was partially financed by The National Environmental Geotehnics Program (organized by The Technology Development Centre of Finland). The objective of this project was to recommend reliable investigation strategies and methods for contaminated sites as well as provide quality specifications for various remediation methods. In the final project report the recommendations are given for a number of soil and water samples, their type and locations, quality control, analytical methods etc. The report includes a short review of geophysical methods, which are an increasing field of investigation. The recommendations are based on the experiences gathered from investigation projects made by Geological Survey of Finland and Finnish consultant companies.

So far, widely differing approaches and research intensities have been used in the completed remediation projects. Investigations have generally been insufficient. Usually remediation decisions are based limited risk assessment if any, which may lead to unnecessarily intensive measures. The aim of this project was to unify research procedures to improve risk assessment and remediation solutions. The applicability of the ISO-standard Draft (ISO 10381-5 Version 6, draft) Ref.1., the Dutch prestandard (NVN 5740) Ref.2. and U.S. EPA recommendations Ref.3. to Finnish geological and hydrogeological environment was studied. However, they turned out to be complicated and expensive. Thus, the project published a new Finnish practice Ref. 4.

2 RESEARCH PHASES

Investigations in contaminated sites are divided into three phases like in ISO-standard Draft Ref.1.: preliminary survey, field investigation and additional investigations. During the preliminary survey, information on the past and present activities on the site as well as basic information on the soil stratification and hydrogeology is gathered. The hypothesis of the situation at the site is formulated like in ISO-standard Draft Ref.1. and the Dutch prestandard Ref 2. The site is whether "probably uncontaminated" or "potentially contaminated". However, the distribution of the contaminants is always supposed to be heterogeneous in Finnish geological environment.

Soil and groundwater sampling is carried out during the field investigation phase. The chemical analyzes of samples will reveal if the site is contaminated. Additional investigations are applied if needed. The objectives of additional investigations are the following: to provide detailed information on the geological condition of the site and its impact on surrounding area, to give detailed information on contamination (3D) for risk assessment as well as for remediation design, cost estimate and performance. The intensity of additional investigations depends on geological and hydrogeological conditions, the reliability of earlier investigations, the future activity on the site and considered remediation technologies.

After investigations the risk assessment is carried out to evaluate the hazards on the site and in the surrounding areas. Health risk and ecological risk assessment provide information to decision makers as the consequences of possible actions.

3 SUBSTANCES FOR CHEMICAL ANALYZES

When potentially contaminated sites are investigated, soil and groundwater samples should be analyzed for the contaminants that are probable according to the preliminary survey. In addition, a small number of samples should be analyzed for a wider spectrum of substances. The most common contaminants should be analyzed when probably uncontaminated sites are in question. Ref.1.

Typically in Finland soil has been contaminated by the following inorganics in industrial or other activities: arsenic, chromium, copper and mercury in wood-processing industry; copper, nickel, zinc and cyanides at mines, metal smelters and shooting ranges; zinc and chromium in surface treatment; mercury and chromium in leather and fur industry. The typical organic contaminants are creosote oil, chlorinated phenols, dioxines and furans at wood preserving facilities; PCBs in chemical wood-processing industry; oils, solvents, dioxines and furans in chemical, textile, metal and machine building industry as well as at waste management facilities; oils, solvents, and gasoline at gas stations. Ref.5.

4 QUALITY CONTROL SAMPLES AND BASELINE SAMPLES

Quality control (QC) samples are taken near to the point from which the original soil samples were taken. QC samples are divided into two parts which both are analyzed. The differences between an original sample and a QC sample reveal the quality of sampling. The differences between QC subsamples reveal the quality of analyzes. The recommended number of QC samples is 10% of the number of original samples. At least two QC samples should always be taken.

To get more reliable information on contamination in groundwater, samples can be taken from several groundwater pipes/wells and several times.

Geochemical baseline samples give the natural concentrations of elements at the region. Natural concentrations of several elements exceed the guide values designated for contaminated soils in many areas in Finland. The local baselines (background values) must always be verified in any assessment of contaminated sites. Ref. 6. The baseline samples have to be taken near the site of concern, from the same kind of geological environment that is not contaminated.

5 SAMPLING PATTERN

Samples should be taken from both probably uncontaminated sites and potentially contaminated sites. Sampling pattern is determined after the preliminary survey. It is designed primarily case-by-case. The locations of sampling points and sampling intensity are based upon the knowledge of site conditions, such as geological variabilit, the area of the site, contaminant concentrations and migration directions. Also systematic or random sampling can be used if there is a specific reason for the applicability.

Groundwater monitoring pipes/wells should be located upgradient and downgradient of the site as well as at the contaminated site.

6 SAMPLING INTENSITY

The number of samples to be taken depends on the area of the site, topography and geological conditions. Every other sampling point is extended deeper -- in other words at every other point both topsample and subsample are taken. Topsamples are taken from the topsoil layer which existed when contamination occurred. Topsamples are taken from the surface to one meter deep (0 - 1 m). Subsamples are taken at the level where human activities have not extended (natural soil layers). If there is a soil layer with very low permeability (clay, clay rich in organic material or silty till) it is recommended to take subsamples from the surface of this layer or from the soil layer above bedrock. It needs to be very careful not to penetrate soil layers with low permeability. In addition, the possibility of perched groundwater needs to be considered. Drilling holes can be filled up with bentonite slurry to avoid migration. It is economical to take several samples at the same time, although all of them would not be analyzed.

During the field investigation primarily individual samples are analyzed. Mixed samples may be useful in same cases, but their applicability has to be considered carefully. In practice, it is possible to mix at the most five individual samples. Groundwater samples are always analyzed individually. Table 1 shows the recommended sampling practice when the site is probably uncontaminated.

When the site is probably uncontaminated, groundwater samples are taken from the nearest groundwater wells. Surfacewater samples are taken toward the flowing direction from a ditch, lake, pond or river.

Table 1. Recommended sampling practice for probably uncontaminated sites.

Area	Soil samples				
(ha)	Sampling grid in horizontal plane e.g. m x m	Number sampling points	Number of analyzed top-samples	Number of analyzed sub-samples	Number of QC samples
< 1	-	3	3	2	2
1	50 x 50	4 - 9	4 - 9	2 - 4	2
2	60 x 60	6 - 13	6 - 13	3 - 6	2
3	65 x 65	7 - 16	7 - 16	3 - 8	2
4	70 x 70	8 - 18	8 - 18	4 - 9	2
5	75 x 75	9 - 20	9 - 20	4 - 10	2
6	75 x 75	10 - 22	10 - 22	5 - 11	3
7	80 x 80	11 - 24	11 - 24	5 - 12	3
8	80 x 80	12 - 25	12 - 25	6 - 12	4
9	90 x 90	13 - 27	13 - 27	6 - 13	4
> 9	100 x 100				

If the hypothesis of the site is potentially contaminated the investigations have to ensure the contamination of different subsites and strata. In addition, it is necessary to find the distance from where on no contaminants are detected or their concentration is lower than the trigger concentration. In the table 2 is shown the recommended sampling practice for potentially contaminated sites.

Table 2. Recommended sampling practice for potentially contaminated sites.

Area	Soil samples					Ground-water samples
(ha)	Sampling grid in horizontal plane e.g. m x m	Number of sampling points	Number of analyzed top-samples	Number of analyzed sub-samples	Number of QC samples	Number of monitoring pipes/wells
≤1	25 x 25	16 - 25	16 - 25	8 - 12	2	3 - 4
2	30 x 30	25 - 36	25 - 36	12 - 18	4	3 - 4
3	35 x 35	28 - 43	28 - 43	14 - 21	4	3 - 4
4	35 x 35	32 - 50	32 - 50	16 - 25	5	4 - 6
5	40 x 40	36 - 56	36 - 56	18 - 28	5	4 - 6
6	40 x 40	39 - 61	39 - 61	19 - 30	6	4 - 6
7	40 x 40	42 - 66	42 - 66	21 - 33	6	4 - 6
8	45 x 45	45 - 71	45 - 71	22 - 35	7	4 - 6
9	45 x 45	48 - 75	48 - 75	24 - 37	7	4 - 6
> 9	50 x 50					≥ 6

Near "hot-spots" smaller grids are recommended, e.g. 10 m x 10 m. "Hot-spots" are usually located at the places where the polluting agents are used: near the cylinder and sink at wood impregnation plant, around oil tanks etc. When the site is very large, it is economical to use large grids at first. In addition, geophysical methods can be useful before locating sampling points. The geological conditions have to be considered carefully when deciding number and location of groundwater wells.

7 CROSS-CONTAMINATION DURING SAMPLING

Cross-contamination is a severe problem during sampling process. Sampling should be started from the cleaner part of the site and then proceeded to more contaminated parts.

To avoid contamination the sampling equipment can be cleaned mechanically or chemically. Usually mechanical cleaning (drying, brushing, blowing, rinsing) is adequate. When contaminants are not water soluble, special cleaning agents or solvents can be used. Organic contaminants can be cleaned with such chemicals as methanol, acetone, hexane or isopropanol. Chemical cleaning is recommended before a new sampling project is started. Usually mechanical cleaning is sufficient between the sampling points. Ref. 7.

8 DISCUSSION

Even though it is difficult, almost impossible to give general instructions for investigations some guidelines have to be established. In the beginning there is a strong tendency to underestimate the need of detailed data. Later, during remediation the deficiencies turn out to be expensive. The applicability of these recommendations is reevaluated in future when more experience is gathered. Currently the Geological Survey of Finland is working on research project including intensive sampling on contaminated wood impregnation plants.

9 REFERENCES

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