THE MISMATCH BETWEEN (IN-SITU) SOIL SITE INVESTIGATION AND (EX-SITU) EXCAVATED SOIL QUALITY

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ABSTRACT

Based on the statistical analysis of an extensive database, the mismatch between in-situ and ex-situ qualified soil stockpiles from remediation sites was determined. On average, the environmental quality of the excavated soil stockpile is better than the in-situ qualified soil, independent of the destination of the soil. For soil opted for treatment, approximately 20 % could be directly reused. For soil opted for landfilling, approximately 30 % could be directly reused whilst 15 % could be thermally treated. From an environmental point of view, the additional ex-situ qualification of soil is beneficial. However, additional ex-situ qualification results in additional costs. Therefore an economic assessment of the impact of incorporating an ex-situ qualification step in the remediation process was made. It was concluded that on a national level, the financial effect is approximately cost-neutral. Since the national policy is aimed to maximise reuse and to minimise landfilling, it was decided that all disposable soil should be ex-situ qualified prior to landfilling. This measure became effective in November 2001. In addition, the Dutch organisation of soil treatment facilities have adopted a code of conduct, which strongly promotes the identification of reusable soil lots prior to treatment.

1. INTRODUCTION

In The Netherlands the first step in the investigation of (potentially) contaminated sites is based on the NEN 5740 site sampling protocol [1]. When contamination is present and can potentially be considered as dangerous, more elaborate protocols [7, 8] are employed to determine the in-situ soil quality. Upon these investigations, the site remediation plan is based. Essential aspects of this plan are the contamination contour map and consequently the destination of the excavated soil lots. Depending on soil chemical and physical quality, the excavated soil stockpiles are qualified to be:

1. Reused according to the standards set by the Dutch Building Materials Decree [2].
2. Treated. Either thermally, biologically or by soil washing.
3. Disposed off in a landfill.

Although the quality of the soil determines its destination, there is a policy preference to reuse as much as possible and to landfill as little as possible. The three potential destinations are therefore listed in a preferential order.

In The Netherlands, it is common practice that – based on the in-situ investigation **only** - excavated soil lots are directly landfilled, treated or reused. We decided to verify whether or not this procedure yields the correct results. Therefore an additional step was incorporated into the overall process. All excavated soil lots qualified to be treated, were additionally stockpiled and ex-situ sampled and chemically analysed with a validated protocol for soil stockpiles [3]. This is depicted in Figure 1.

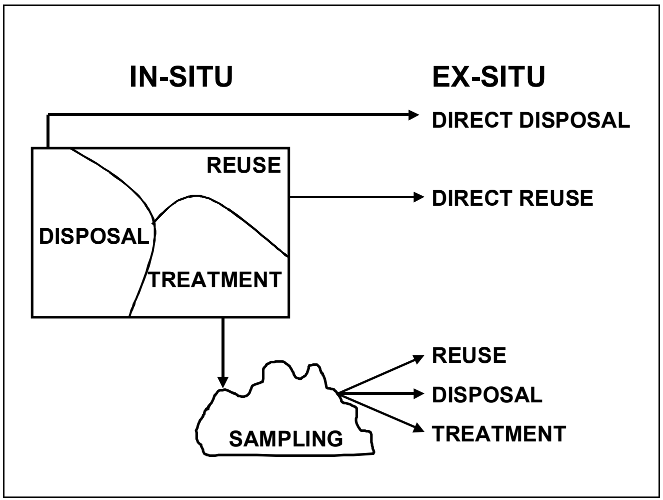

FIGURE 1 – Alternative sampling scheme.

From a comparison between the in-situ and ex-situ data for soil that was in-situ qualified as treatable, the mismatch in soil qualification is deduced [4].

For soil lots qualified for disposal, only in-situ data was available. By using the in/ex-situ correlation factors - derived from the statistical analysis of the database for treatable soil – we were also able to estimate the mismatch in qualification for disposable soil [5].

Since, for both treatable and disposable soil, the observed mismatch in qualification was significant, a economic analysis was performed to assess the costs and benefits of incorporating an additional ex-situ sampling and qualification step prior to disposal and treatment [6].

2. STATISTICAL ANALYSIS OF THE IN-SITU AND EX-SITU QUALIFICATION FOR TREATABLE SOIL

Over a period of approximately 5 years a large database, incorporating the chemical and physical properties of approximately 450.000 tons of treatable soil, was generated (see Table 1). Treatability was derived from the in-situ chemical and physical characteristics of the soil. Depending on these characteristics [9], the soil can be treated either thermally, biologically or by soil washing.

Feature	Number
Remediation projects	119
Number of in-situ (pre)qualified soil lots	189
Number of ex-situ qualified soil stockpiles	506
Tons of in-situ qualified soil lots	439 kton
Tons of ex-situ qualified soil stockpiles	468 kton

Table 1 – Basic features of the in/ex-situ database for treatable soil.

The protocols [7,8] used for the in-situ investigation of soil are mainly aimed to identify hot-spots and to draw contamination contours maps. After excavation, but **prior** to treatment, the corresponding excavated soil lots were (ex-situ) stockpiled and sampled with a validated protocol [3]. This protocol yields the mean contaminant concentration in the stockpile. The resulting 189 sets of in-situ and ex-situ data, comprising 8 heavy metals (As, Cd, Cu, Cr, Hg, Ni, Pb, Zn), mineral oil, sum-PAH's and extractable halogenated organics (EOX) were statistically analysed. Examples of the correlation between in-situ and ex-situ data for lead and sum-PAH's are shown in Figure 2. From the full analysis of all compounds investigated, two striking observations were made:

- The mean contaminant concentrations in the (ex-situ) stockpiles are on **average** lower than in the in-situ soil lots. This is clearly demonstrated in Figure 2.
- Per remediation project, a significant spread in the in-situ and ex-situ data exists.

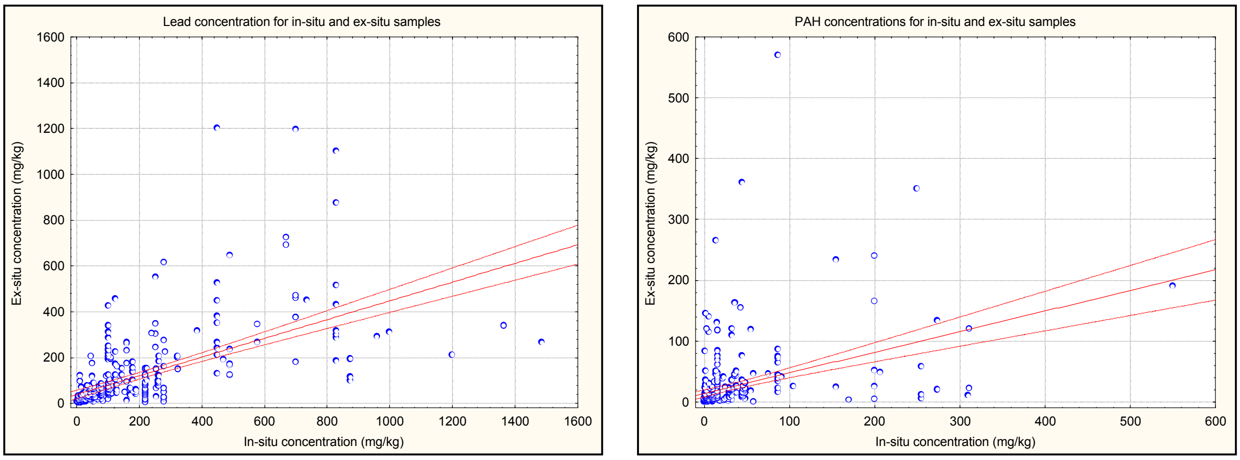

FIGURE 2 – **Mean concentration of sum-PAH's (10 VROM) and lead derived from in-situ and ex-situ sampling (correlation line and 95% confidence limits for the mean values are shown).**

The main reasons for the observed discrepancies are:

- The dilution effect. For the total of the 119 remediation projects, 10 % more soil has been excavated than was anticipated on the basis of the in-situ data and the site remediation plan. However, per remediation project large differences occur.
- The difference between the objective of in-situ and ex-situ investigations. The in-situ investigation is aimed at identifying hot-spots, whilst the ex-situ investigation is aimed at determining the mean contaminant concentration in the stockpile.

Additionally, other explanations for the discrepancy were identified, but it was demonstrated that these had only a minor effect on the observed differences in soil quality. Since the soil chemical and physical quality determines the (final) destination of the soil, permutations do occur. For thermal treatment and soil washing these permutations are depicted in Figure 3.

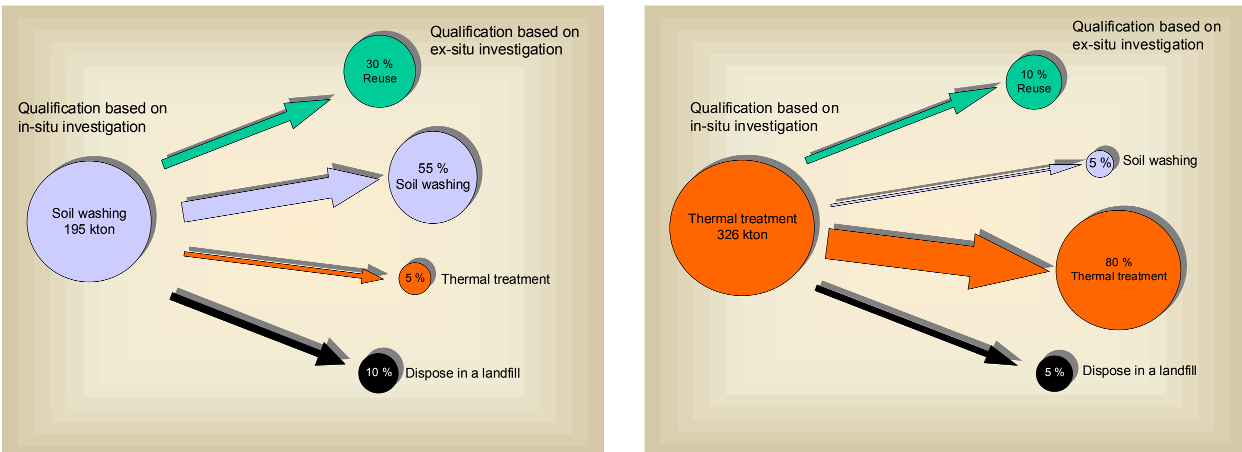

FIGURE 3 – **Mismatch between in-situ and ex-situ soil qualification for soil washing and thermal treatment.**

From Figure 3 it can be seen that permutations amongst the preferred treatment technologies occur. But most importantly, significant proportions of the soil lots opted for treatment can be directly reused. Since the costs for reuse (2 – 7 Euro/ton) are significantly lower than for treatment (35 – 55 Euro/ton) - as reported by A. Honders et al. [9] – large cost savings can be achieved. A comparison between in-situ and ex-situ qualification of the soil lots for the total of the 119 remediation projects is shown in Figure 4. It should be noted that given a specific soil lot, treatment with different technologies is

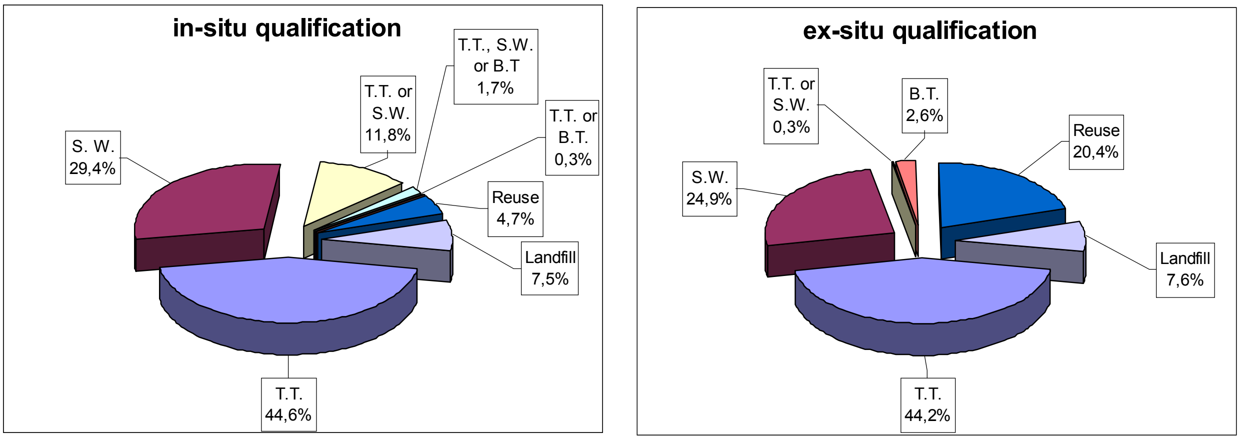

FIGURE 4 – Differences in qualification based on in-situ and ex-situ soil investigations (T.T. = Thermal Treatment, S.W. = Soil Washing, B.T. = Biological Treatment).

sometimes possible. From Figure 4 it is inferred that approximately 20 % of the soil lots opted for treatment, can be directly reused. As a result of these findings, the Dutch organisation of soil treatment facilities have adopted a code of conduct, which strongly promotes the identification of reusable soil lots prior to treatment.

3. STATISTICAL ANALYSIS OF THE IN-SITU AND EX-SITU QUALIFICATION FOR DISPOSABLE SOIL

Over an extended period of time, the (in-situ) chemical and physical properties of landfilled soil lots were gathered. The number of soil lots and the total landfilled tonnage as a function of time are depicted in Figure 5.

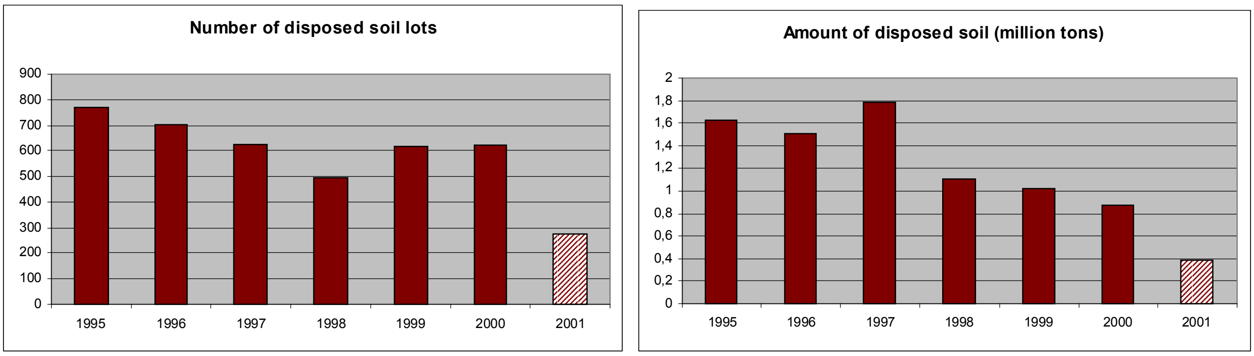

FIGURE 5 – Number of soil lots and the total landfilled tonnage of soil per year (the results for 2001 refer to the first half year only).

For the landfilled soil, no additional ex-situ characterisation of stockpiles was performed as was done for the soil opted for treatment. Only the in-situ properties for landfilled soil were available. In order to estimate the differences in soil characteristics for the landfilled soil, the expected ex-situ properties were estimated. This was carried out in a two-step exercise:

- First, the soil containing asbestos and residues from soil washing [9] were subtracted from the database, because for these soils disposal is per definition obligatory. On a ton basis this represents, respectively, 8.4 % and 23.9 % of the total data.
- Secondly, from the statistical analysis of the database for treatable soil, for all contaminants, the in/ex-situ correlation factors were derived (See for example Figure 2 where the correlation is shown between in-situ and ex-situ sampling and chemical analysis).

Thus, the expected ex-situ data for disposable soil were calculated from the in-situ data. In terms of soil qualification, the results are depicted in Figure 6. Because the ex-situ quality of the disposable soil is estimated, the data in Figure 6 should be regarded as indicative, rather than exact. However, it can be concluded that the estimated mismatch for disposable soil is large and statistically significant.

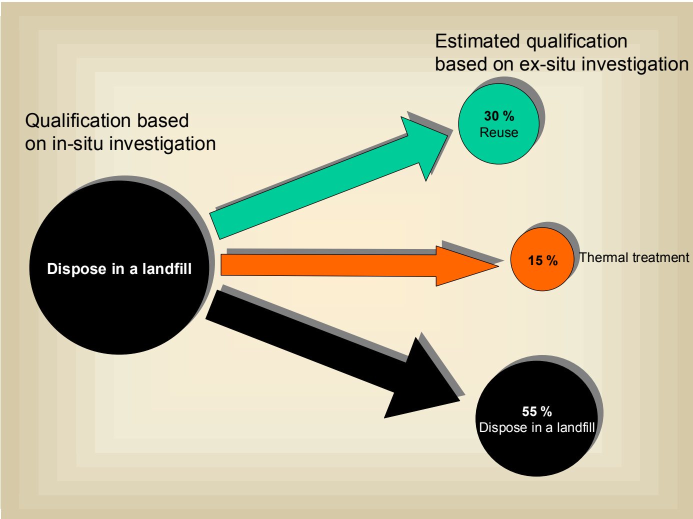

FIGURE 6 – Estimated mismatch between in-situ and ex-situ soil qualification for landfilled soil (on a ton basis).

Two conclusions were drawn by the responsible authorities and policy makers:

- It is economically undesirable to landfill soil for a tariff of 40 – 70 Euro/ton, while it can be directly reused for a tariff of 2 – 7 Euro/ton.
- It is politically unacceptable to landfill soil, which can be either reused or (thermally) treated.

Two actions were therefore decided upon:

- Prior to landfilling, soil lots from remediation sites and residues from soil washing should be ex-situ sampled and qualified.
- This process is monitored in the sense that the data thus gathered will be subjected to a second statistical analysis to determine the true mismatch for disposable soil.

These two measures have been fully implemented in November 2001. All processes are carried out under audited quality control and assurance schemes.

Since ex-situ sampling and qualification of both (in-situ) treatable and disposable soil lots could possibly yield savings on the national budget for site remediation, an extensive economic assessment was carried out. The main features of this exercise are reported in the next paragraph.

4. ECONOMIC ASSESSMENT

From the analyses in the previous paragraphs it is inferred that by incorporation of an additional sampling and analysis step - prior to treatment and landfilling - the destination of excavated soil lots from remediation sites can drastically change. It was also concluded that more cost-effective options – such as reuse – become available. Based upon the premise that all soil lots from remediation sites are additionally qualified, an economic assessment of the impact of such a measure was made for The Netherlands. The benefits mainly derive from lower costs for reuse and treatment as compared to landfilling (see Table 2).

PROCES	COSTS [Euro/ton]
Reuse	2-7
Thermal treatment	55
Soil washing	35
Biological treatment	20
Landfilling	40-70

Table 2 – Market tariffs for soil treatment, landfilling and reuse.

Additional costs factors are: sampling and analysis, storage and handling, transport and logistics. The following elements were assembled into a mathematical model:

- Mismatch for treatable and disposable soil (i.e. Figures 4 and 6).
- Throughputs for treatment and landfilling over the period 1995 – 2002 (e.g. Figure 5).
- Bandwidths for tariffs for all the relevant unit operations, such as treatment, reuse, landfilling, transport, etc.

The results for disposable and treatable soil are depicted in Figures 7 and 8, respectively. Three scenarios are displayed, an optimistic scenario, a realistic scenario and a pessimistic scenario. The type of scenario results form the assumptions made for the above-mentioned parameters. The large differences between the scenarios clearly indicate the uncertainty in the economic effects. This a prime motivator for the the monitoring programme for the next years.

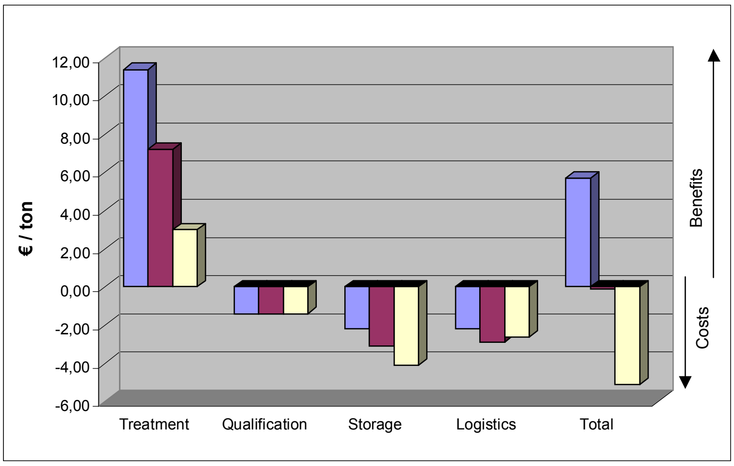

Figure 7 – Costs and benefits resulting from ex-situ qualification of disposable soil.

From these Figures it is concluded that, assuming that the realistic scenario is indeed correct, incorporation of an additional (ex-situ) qualification step, has only marginal effects for the national budget for site remediation. For individual remediation projects, effects might either be positive or negative. This largely depends on additional logistics (e.g. transport distances) and regional tariffs for the various unit operations.

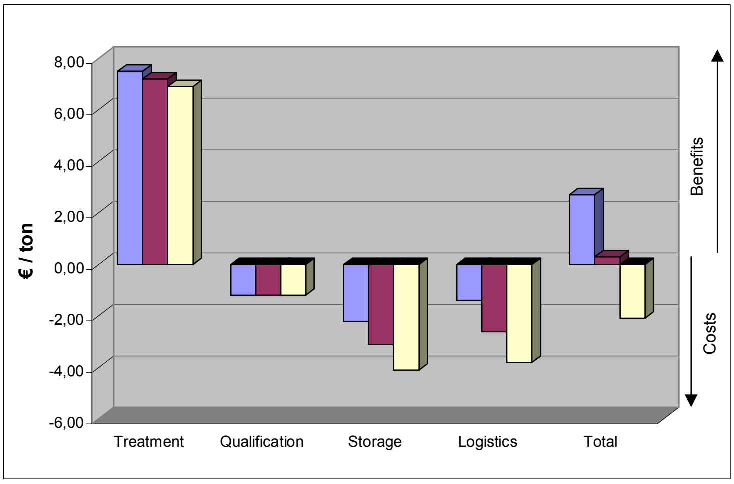

Figure 8 – Costs and benefits resulting from ex-situ qualification of treatable soil.

5. EPILOGUE

In this paper the mismatch between in-situ and ex-situ quality of treatable and disposable soil from remediation sites was determined and estimated, respectively. On average, the environmental quality of the excavated soil stockpile is better than of the in-situ qualified soil lot. Thus, more cost-effective treatment and reuse options become available. An economic assessment indicates that incorporation of an additional (ex-situ) qualification step would be approximately cost-neutral for the national remediation budget. However, since the national policy is aimed to maximise reuse and to minimise landfilling, it was decided that all disposable soil should be ex-situ qualified prior to landfilling. This measure became effective in November 2001. In addition, the Dutch organisation of soil treatment facilities have adopted a code of conduct, which strongly promotes the identification of reusable soil lots prior to treatment.

6. REFERENCES

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