EX-SITU TREATMENT OF CONTAMINATED SOIL – THE DUTCH EXPERIENCE

A. Honders, Th. Maas and J.M. Gadella
Centre for Soil Treatment
P.O. Box 19 – 3990 DA Houten – The Netherlands
aho@scg.nl

ABSTRACT

This paper reviews the development of ex-situ soil treatment technologies over the last 20 years, against the background of developing legislation and market forces.

Legislation along the lines of site remediation, soil treatment, landfilling and reuse was developed and improved in the eighties and nineties. In addition, substantial budgets were made available by the national government to tackle the remediation of contaminated sites. This stirred the development of soil treatment technologies. As a result of an intensive learning process, the market is now considered to be mature. The more relevant aspects of the soil market (in 2001) are gathered in the table below.

TECHNOLOGY	THROUGHPUT [kton/year]	COSTS [Euro/ton]	FACILITIES [number]
Thermal treatment	725	35-60	3
Biological treatment	265	20-40	24
Soil washing	855	20-45	25
Immobilisation	150-250	40-45	12
Landfilling	550	40-70	40
Reuse untreated soil	9000	2-7	20
Reuse treated soil	1500	0-3	-

Presently, both public and private players are heavily focused on quality control and assurance. In concert, certification schemes for processes (e.g. treatment, remediation) and products (e.g. reusable soil) are being developed and implemented. Regular, independent auditing of these certification schemes yields enhanced customer confidence and improved compliance with legislation.

1. INTRODUCTION

The conception of the contaminated land issue in The Netherlands occurred in 1980 with the discovery of a housing project (Lekkerkerk) situated on a chemical waste disposal site. This stirred the development of national policies and legistion regarding site remediation, soil treatment, reuse and landfilling. Consequently, a host of technologies emerged. This paper reviews the development of ex-situ soil treatment technologies over the last 20 years against the background of developing legislation and market forces. In Figure 1 the interactions between the various aspects of legislation, technology and market are schematically depicted.

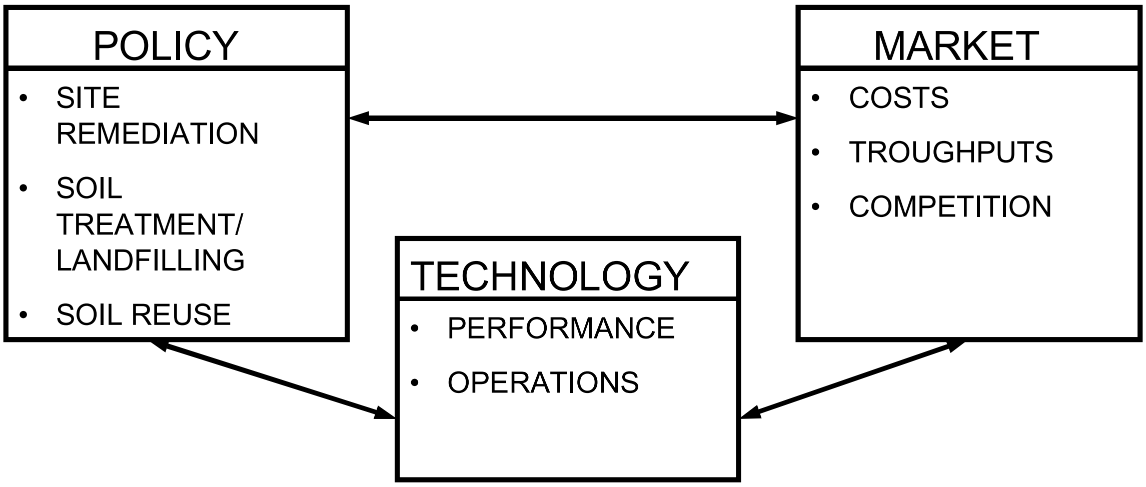

FIGURE 1 – Schematised interactions between policy, technology and market.

In subsequent order, the following aspects are dealt with:

- A broad, descriptive outline of policy development;
- A description of operational technology performance;
- Market development in terms of costs, throughputs and competing technologies.

2. POLICY DEVELOPMENT

Site remediation

With the conception of the contaminated land issue, an interim policy was developed in the early eighties [1]. All contaminated sites had to be fully excavated and remediated to the level of the reference values (natural contaminant concentrations in soil), to allow for various ways of land-use. This so-called concept of “multifunctionality” was based upon the perception that the total national remediation costs would be in the order of 0.5 billion Euro. Remediation funds were largely provided by the national government. Removal of contamination, resulting from activities after 1975, was to be paid by the polluter. Based upon a large-scale evaluation, the magnitude of the Dutch contaminated land issue became abundantly clear at the end of the eighties. Total remediation costs were now estimated to be in the order of 50 billion Euro. Also, it became apparent that the majority of the urban areas in the country were mildly contaminated, whilst the majority of industrial sites were heavily contaminated. These findings stirred a national debate on the remediation policy in general and on the concept of “multifunctionality” in particular. This spelled the conception of the Soil Protection Act [2], which leans more on a risk-based approach towards site remediation. The concept of “multifunctionality” was replaced by the concept of “functionality”. The site to be remediated needs to fulfill the required standards for anticipated future use, ranging from kindergarten to industrial sites. This development spelled the integration of site remediation and spatial planning in the late nineties. Nowadays it is becoming increasingly popular to develop brownfield sites (e.g. in city centers) within the framework of a public-private partnership.

Soil treatment and disposal
At the end of the eighties the largest part of contaminated soil was landfilled as a result of high treatment costs and the absence of a reuse policy. This stirred the discussion on prevention and reuse of waste materials. In the mid-nineties legislation on landfilling was adopted [3,4]. Landfilling of treatable soil was prohibited. Soil treatability was formalised in an assessment scheme, incorporating the following technical and economic elements:

- Soil treatment yields a clean or reusable product;
- Maximum treatment costs of 40 Euro/ton are allowed for treatment schemes yielding less than 80 % reusable product;
- For treatment schemes yielding more than 80 % reusable product, treatment costs of 45 Euro/ton for mildly contaminated soil and 75 Euro/ton for heavily contaminated soil are allowed for.

Compliance with these regulations is enforced by the Cente for Soil Treatment (SCG). Since 1995 approximately 19 million ton of contaminated soil has been assessed. Approximately 67 % of the soil appeared to be non-treatable, and was correctly disposed off in a landfill.

Soil reuse
In the eighties no formal policy towards the reuse of soil was defined. Basically, untreated soil was (re)used upon local insights. For treated soil more stringent rules applied. In general, only fully treated (clean) soil was accepted for reuse in f.i. road construction. The beginning of the nineties saw the advent of reuse policies on the provincial level. Essentially, these policies were precursors for the Building Materials Decree [5]. For both inorganic and organic contaminants, concentration ranges were defined for clean and reusable soil. Although contaminant leachability was a parameter in the provincial reuse policies, in practice the defined rules were not strictly adhered to. Local reuse policies were replaced by national legislation. The Building Materials Decree, which became fully effective in mid 1999, strictly defines soil quality assessment procedures, such as sampling, chemical analysis and leaching. In addition, the environmental soil quality standards, in terms of contaminant concentration and leachability, are unambiguously defined. Recently, the effectiveness of the Building Materials Decree has been evaluated. Based on new insights and practical data, legislation will be amended to enhance practical use within the boundaries of formulated policies.

3. STATE OF THE ART OF SOIL TREATMENT TECHNOLOGIES

The performance of operational soil treatment technologies has been extensively described and validated in 1998 [6]. This paragraph reviews operational and performance aspects of thermal and biological treatment and soil washing.

Thermal treatment
A process flow scheme is depicted in Figure 2. Prior to treatment, large debris is removed

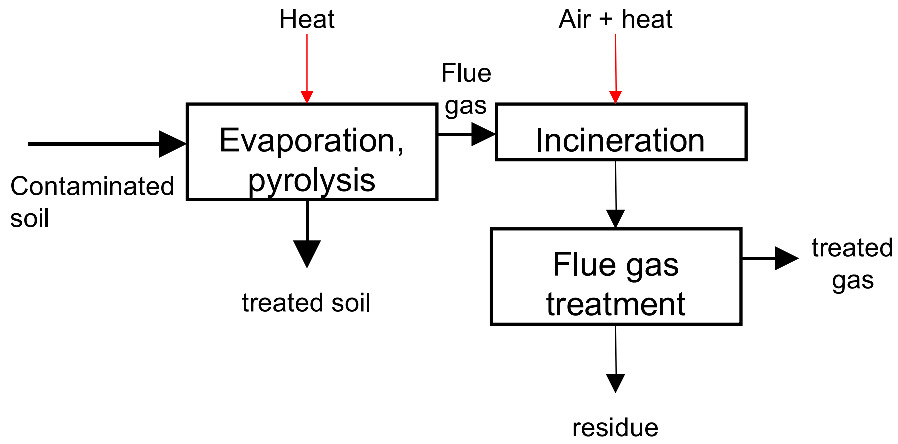

FIGURE 2 - Schematised process flow scheme for thermal treatment.

from the input soil by sieving and magnetic separation. Soil treatment occurs in a rotary kiln at temperatures in the range 550 - 650 °C. Thus, (partially) oxidised and pyrolysed organic contaminants evaporate from the soil, which is subsequently cooled by addition of water. Flue gas treatment involves incineration (1000 – 1100 °C) and dedusting. Thermal treatment is suitable for all organic contaminants (see Table 1). Heavy metal concentrations are bounded by the reuse standards. At present, 3 thermal treatment plants are operational in The Netherlands. Typical throughputs are in the 20 - 35 ton/hour range.

Treatment technology =>	Thermal	Soil washing	Biological
Maximum values physical parameters			
Water [% m/m]	60	-	-
Organic matter [% d.s]	25		5
Fraction < 63 µm [% m/m]	-	20	25
Debris 2-32 mm [% d.s.]	5		5
Chemical parameters			
	Removal efficiency [%]		Maximum input [mg/kg d.s.]
Cd, Cr, Cu, Pb, Zn	0	80 – 95	Reuse value
As, Hg, Ni	0	50 - 80	Reuse value
CN	99.99	80 – 95	Reuse value
BTEX	99.99	90 – 98	200 – 2000
Naftalene	99.99	90 – 98	10
PAH's [10 VROM]	99.99	80 – 98	Reuse value
EOX	99.99	80 – 95	1
VOX	99.99	90 – 98	Reuse value
Mineral oil C10-C14	99.99		7500
Mineral oil C14-C27	99.99	90 – 99	2500
Mineral oil C27-C40	99.99		1500

TABLE 1 - Typical removal efficiencies for thermal treatment and soil washing. For biological treatment the maximum input concentrations are given. EOX = extractable halogenated organics. VOX = volatile halogenated organics.

Biological treatment

Various modes of operation of biological treatment exist. In the extensive mode, the contaminated soil is merely stockpiled in layers of 1 – 2 m. Occasionally, ploughing is performed. Depending on soil type (i.e. sand fraction) and contaminant type (e.g. mineral oil), treatment times range from 0.5 to 2 years. In the intensive mode, biodegradation is stimulated by a range of actions. Generally, pH, water content and nutrient levels are adjusted, while air and heat are supplied to enhance contaminant biodegradation. Thus, treatment times of 3 – 6 months can be achieved. Maximum contaminant input concentrations, which allow for intensive biological treatment are gathered in Table 1. Heavy metal concentrations are bounded by the reuse standards. At present, 25 biological treatment facilities (5 intensive mode) are operational in the Netherlands.

Soil washing
A process flow scheme is depicted in Figure 3.

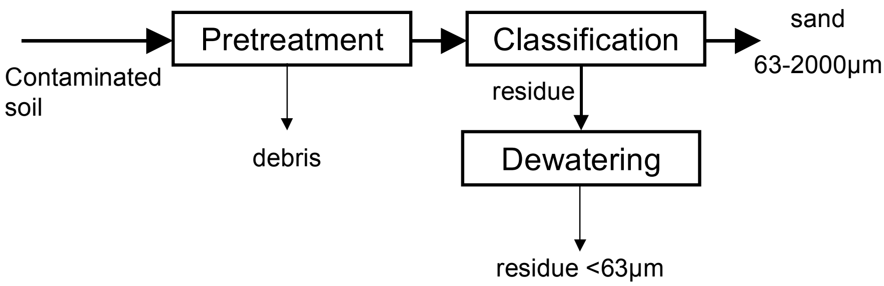

FIGURE 3 - Schematised process flow scheme for soil washing.

Prior to treatment, large debris is removed from the input soil by sieving and magnetic separation. Subsequently the soil is slurryfied, scrubbed and subjected to host of classifiers such as hydrocylones, upstream columns, spirals and flotation cells. Thus, a reusable sand product is obtained. The residue – which typically contains the < 63 µm minerals fraction and the organic matter – is dewatered by flocculant-assisted thickening and filter pressing. The residue, which contains the bulk of the input contaminants, is disposed off in a landfill. In general terms, soil washing is economically feasible for soils containing up to
20 – 40 % (m/m) silt and organic matter. Soil washing is a technology suitable for removal of both organic and inorganic contaminants. Contaminant removal efficiencies are gathered in Table 1. At present 21 stationary and 4 mobile plants are operational in The Netherlands. Plant troughputs range from 20 to 50 ton/hour. Since, to a certain extent, soil washing is more an art than a science, an expert system was developed to predict output soil quality and process costs based upon the chemical and physical characteristics of the input soil. This expert system is available from website:

http://www.ta.tudelft.nl/GK/local/VanHoek/HoekIndex.htm.

In addition, special (laboratory) tests have been developed to assess soil treatability by washing technologies [7].

Immobilisation
Sintering and smelting of soil and sediment residues (ex sand separation) - yielding gravel and basalt-type products – have been succesfully attempted on a pilot scale in the nineties. At present, no full scale sintering or smelting plants are operational. On a project basis, cold (cement-based) immobilisation of contaminated soil is practised in The Netherlands. It is estimated that 150 – 250 kton/year of soil is immobilised to yield a product for stabilising road constructions. Approximately 6 stationary and 6 mobile facilities are operational. Unknown, but limited quantities of off-spec (i.e. non-reusable) sand from soil washing operations are used in bitumen. Formally, soil treatment is preferred over immobilisation. Therefore immobilisation presents no competion for thermal and biological treatment and soil washing. At present this policy is under debate.

In-situ site remediation
A large stimulus for in-situ site remediation was derived from a public-private sponsored R&D programme, which ran in the second half of the nineties. At present, in-situ remediation is primarily employed for plume abatement, in cases where excavation and ex-situ treatment are not feasible. Therefore, in-situ technologies are not competing with ex-situ technologies. The yearly “throughputs” of in-situ treated soil are unknown.

4. MARKET DEVELOPMENT

Eighties
In the eighties, the ex-situ treatment technologies were still in their infancy. The situation was characterised as “misery of scale”:

- Trial and error treatment;
- Small scale facilities, low throughput;
- Little supply, high prices.

As a result, the bulk of the contaminated soil was landfilled. According to national policy, treatment is preferred over landfilling. It was therefore decided by the provincial and national authorities to establish an organisation, with a mandate to solve these problems. In 1989 the Centre for Soil Treatment (SCG) was established.

Nineties
The SCG became fully operational in 1990. One of its tasks was to centrally subcontract the treatment of contaminated soil originating from remediations financed with public money. This served three purposes:

- Treatment facilities were guaranteed a steady supply of soil. This enabled them to optimise their technologies and thus lower costs;
- Subcontracting procedures were harmonised and large amounts of soil became available for treatment. Thus, higher plant throughputs induced lower operational (treatment) costs;
- Soil quality prior to and after treatment were accurately measured. This significantly enhanced the acceptance of decontaminated (i.e. treated) soil as a reusable product in f.i. road construction.

The effects of this measure are depicted in Figure 4, where the total amount of treated soil and the centrally subcontracted amount (by SCG) are shown. Clearly, in the first half of the nineties the SCG was a major player in the treatment market. In 1995, legislation (i.e. landfll tax) was adopted, which prohibited disposal of treatable soil (see Section 2). This again resulted in an additional supply of soil for treatment. In 1999 it was decided that SCG had achieved its mission to promote the treatment market. At present, subcontracting of soil treatment by SCG is performed as A mere convenience for customers, such as provinces and large municipalities.

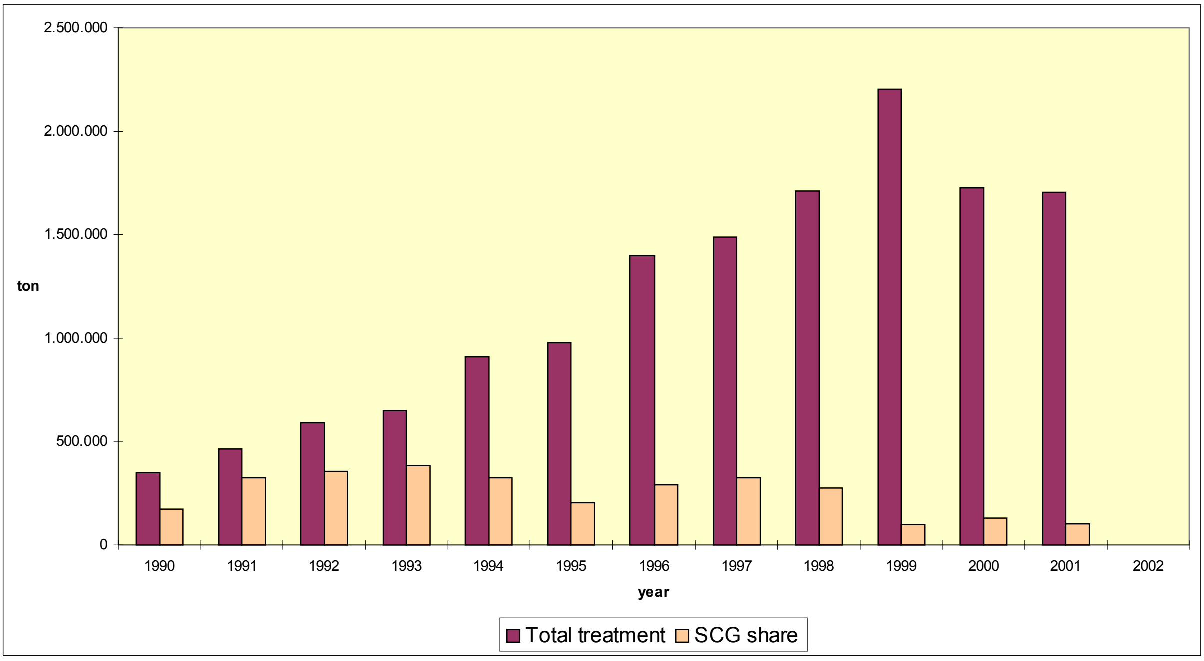

FIGURE 4 - **Centrally subcontracted soil treatment (by SCG) and total treated soil.**

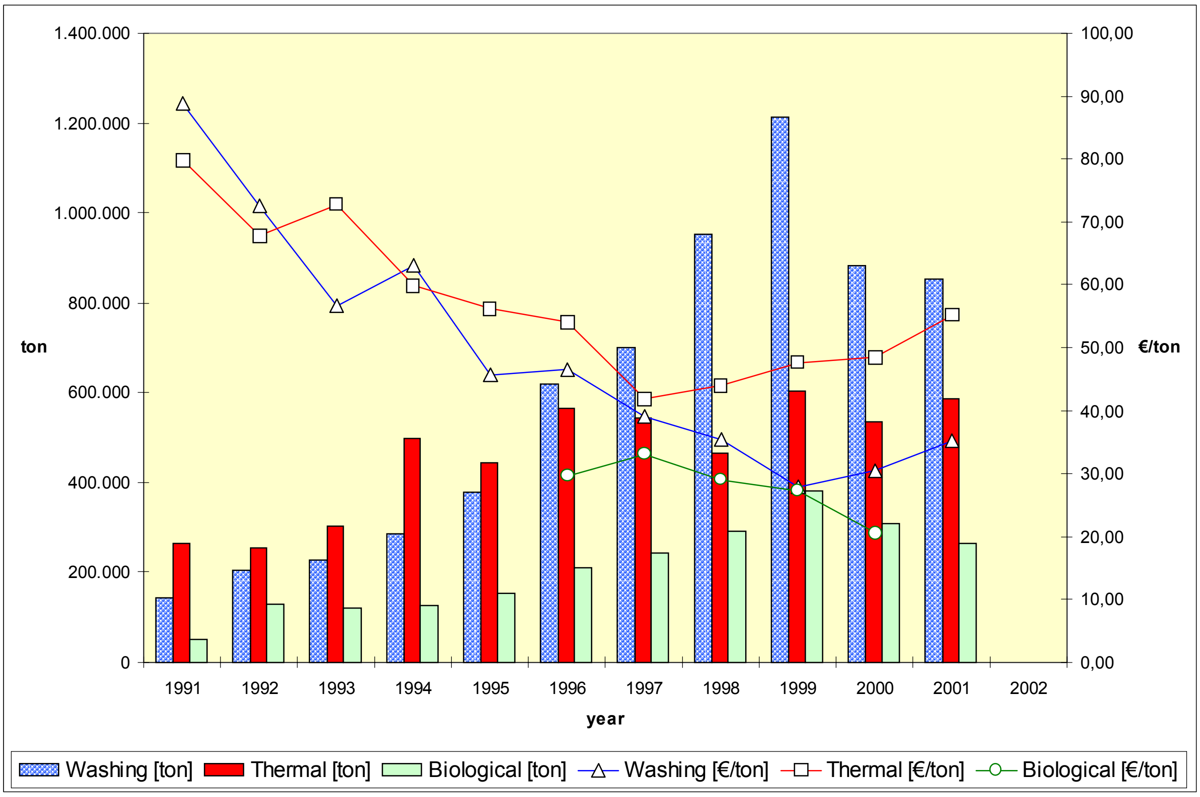

FIGURE 5 - **Yearly throughputs and costs of operational technologies.**

In Figure 5 are shown the yearly throughputs and average treatment costs for the three operational technologies. Total yearly throughput has increased steadily for four reasons:

- Improved legislation regarding site remediation [2];
- Increased national budgets for site remediation and soil treatment;
- Introduction of legislation prohibiting the disposal of treatable soil [3,4];
- Improved reuse policies [5] and the acceptance of treated soil as an applicable product.

Because of higher throughputs and improved technologies (i.e. operational skills), treatment costs have come down significantly over the years. In addition, the limiting contaminant concentrations for reuse were eased. In the beginning of the decade only clean soil was accepted for reuse. At the end of the nineties the standards of the Building Materials Decree [5] became applicable. Technology performance could be reduced. Thus lowering treatment costs.

The relative high throughputs for soil washing – as compared with thermal and biological treatment – derive from the fact that a significant part of soils is contaminated with a cocktail of organic and inorganic contaminants. The relative low throughputs for biological treatment – as compared with thermal treatment – derive form the fact that a significant part of contaminated soils is clayey. For these soils, biological treatment is less effective than thermal treatment.

2000's
In terms of throughputs, costs and technology development, the market for ex-situ soil treatment has leveled out. Depending on the size of the (national) remediation budget contaminated soils will either be in-situ or ex-situ treated, landfilled or immobilised. Estimates for costs and throughputs, over the year 2001, are gathered in Table 2.

TECHNOLOGY	THROUGHPUT [kton/year]	COSTS [Euro/ton]
In-situ treatment	?	?
Thermal treatment	725	35-60
Biological treatment	265	20-40
Soil washing	855	20-45
Immobilisation	150-250	40-45
Landfilling	550	40-70
Reuse untreated soil	9000	2-7
Reuse treated soil	1500	0-3

TABLE 2 – Soil treatment, landfilling and reuse – costs and throughputs (2001).

Summarising: the intricate interplay between policy development, technology development and market forces over the last two decades has resulted in:

- A diversity of (competing) soil treatment facilities;
- Minimalisation of landfilling;
- Maximalisation of reuse.

against acceptable costs in a mature market.

5. NEW DEVELOPMENTS

Quality control and assurance
To enhance customer confidence and to improve compliance with existing legislation, the 2000's saw the advent of increased and formalised attention for quality control and assurance. A central organisation (SIKB) shaped as a public-private partnership was established in 2001. One of its tasks is to define certification schemes for the multitude of unit operations in the "remediation => treatment => reuse chain". Certification schemes for sampling, chemical analysis and leaching are effective since 1999 [8-10]. Procedures for the qualification and application of reusable soil have also been converted into a certification scheme [11,12]. Numerous market players - such as environmental

consultants, laboratories, civil engineering contractors and soil distribution facilities – carry out their processes and/or deliver their products according to the agreed certification schemes. Auditing is performed on a regular basis by independent and specialised companies. A certification scheme for soil treatment processes is in preparation [13].

Leachability
Previously the leaching of the standard heavy metals (As, Cd, Cr, Cu, Hg, Pb, Ni, Zn) has been described by A. Honders at al. [14]. From an extensive database (ca. 1000 soil lots), a decison support system, to predict leaching behaviour for both treated (different technologies) and untreated soils was derived. Recently, it became apparent that more exotic parameters – such as Sb, Mo, V, Ba and fluoride – exhibit alarmingly high leachabilities. In the coming years, the actual presence of these parameters in various soils and their leaching behaviour will be the subject of an intensive research program.

Other waste materials
At present, it is common practice for soil washing plants to treat significant amounts of other waste streams such as sieve sands, demolition waste and the sandy residue of sewarage systems. As of January 1st, 2002, a tax on disposal of aquatic sediments containing in excess of 60 % sand became effective. It is expected that increasing quantities of sandy sediments will be treated in soil washing facilities.

6. EPILOGUE

Over the last two decades the market for ex-situ soil treatment has become mature. Essential factors promoting the learning process are:

- The presence of relevant and practically applicable legislation regarding site remediation, soil treatability/landfilling and soil reuse;
- Sufficient funds;
- Centralised subcontracting of sufficiently large amounts of soil.

Attention is now focused on quality control and assurance to further optimise processes and thus achieve cost-effectiveness.

7. REFERENCES

1. Interim Wet Bodemsanering, 01.04.83.
2. Wet bodembescherming, 01.01.95.
3. Besluit stortplaatsen en stortverboden afvalstoffen, 01.01.96.
4. Wet belastingen op milieugrondslag, 01.01.95.
5. Building Materials Decree, Staatscourant (20), 1998 – translation available.
6. Handboek bodemsaneringstechnieken, Sdu Uitgeverij, Dutch only (English version in due time).
7. R. van Soest, A.C.J. Pronk, A. Honders, J. Rienks, R.H.P. Ringeling – Projectboek natte deeltjesscheiding T-2000 – Novem, (2002), Dutch only.
8. SIKB BRL 1000 – Beoordelingsrichtlijn monsternemingen voor partijkeuringen Bouwstoffenbesluit – (since 1999, update 2002), Dutch only.
9. SIKB protocol 1018 – Monsterneming grond ten behoeve van partijkeuringen – (since 1999, update 2002), Dutch only.
10. AP04 – Accreditatieprogramma Bouwstoffenbesluit – (since 1998, update 2002), Dutch only.
11. A. Honders, J.M. Gadella, A.J. Orbons, E. Bosscher, P. Leenders - Development and application of a quality control and assurance scheme for reusable soil, this conference.
12. SIKB BRL9308 – Grond voor toepassing in werken (since 1999, update 2003), Dutch only.
13. SIKB protocol 7010 – Procesmatige ex-situ reiniging van grond en baggerspecie (in preparation), Dutch only.
14. T. Honders, M. Gadella, P. de Wilde, C. Zevenbergen – Leaching of heavy metals from soils – an analysis – Conference proceedings WASCON 2000, pp. 707-716.