

# SOLIDIFICATION/STABILIZATION OF CONTAMINATED SOILS AND WASTE MATERIALS

## G Quickfall

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## Introduction

“100% Pure New Zealand” The idea is an inspiration for the rest of the world but for New Zealand it is an aspiration. Behind our clean, green image is a land facing environmental problems, as urgent as anywhere else on earth.

Soil contamination is the result of various industrial processes and disposal of wastes either legally, in controlled waste facilities, or illegal dumping. Either way, the history of a site is crucial since previously acceptable industrial processes and methods of disposal of wastes have often left a legacy for this generation to clean up. Just like the rest of the world, New Zealand has inherited environmental problems from past generations.

These environmental problems require smarter methods of decontamination, disposal, land use and a shift from traditional ‘dig and dump’ philosophies.

Stabilization and Solidification (S/S) is an effective, cost efficient and environmentally responsible method of treating both contaminated soils and waste materials.

(S/S) involves the mixing of binding reagents into a contaminated media or waste resulting in a form that is less toxic and less available to the environment. The treatment protects both the environment and human health by immobilising the contaminants.

The term (S/S) refers to a general category of processes and, although these processes often occur concurrently, each is in fact a distinct technology. Stabilization changes contaminants by way of “... chemical reactions which convert the hazardous constituents into a less soluble, mobile or toxic form.” (Wilk 2004) Solidification is defined as “... a process which changes the physical properties of the waste. This involves an increase in compression strength, a decrease in permeability and the encapsulation of the waste to form a solid material, thus restricting contaminant migration.” (Wilk 2004)

This paper will outline the background history of (S/S) technologies worldwide. It will describe the (S/S) process itself in terms of design and methodology, including an explanation of the in-situ versus ex-situ methods.

Finally case histories from around the world and in NZ will demonstrate the various ways in which the (S/S) process has been used and tested in the past.

## **Background History**

Globally, (S/S) is a well established method for remediation of contaminated sites and the treatment of waste materials.

In the USA, the technology has been used for over 30 years and is regarded by the US Environmental Protection Agency (EPA) as "...one of the top five source control treatment technologies used..." in site remediation. (Ma 2000)

The best known remediation program in the USA is called the 'Superfund' program. This government initiative uses a tax collected from petroleum and chemical manufacturers and other potentially responsible parties, to remediate contaminated sites. "(S/S) is the most frequently selected treatment for controlling the sources of environmental contamination at Superfund remediation sites; 25% of selected remedies for Superfund sites include the use of (S/S)." (Wilk 2004)

The USA also leads the world in 'Brownfields' initiatives. These involve the remediation of previously used industrial and urban sites, to allow for redevelopment. In these cases (S/S) has the advantage that the process not only deals with the contamination but also allows the treated material to be reused in the site redevelopment. The result is significant cost savings and beneficial land reuse.

In the UK, disposal to landfill has been the traditional method of dealing with contaminated sites. But recently there is a growing awareness that "...this is merely transferring the problem to another place or another time." (Jones, Hills, Hopkins 2001).

Recent EU legislation has provided a catalyst for the UK to seek alternative methods for the disposal of its contaminated wastes. In particular the EU Landfill Directive (European Council Directive 1999) places severe restrictions or bans on a large number of wastes to landfill. (Al-Tabbaa A, Perera A.S.R 2002a)

With this in mind, in 2001, the UK Dept of Trade and Industry funded a study mission to the US to "Evaluate stabilisation and solidification (s/s) practices in the USA and to explore the potential for co-operation between the UK and the USA in the remediation of contaminated land using this technique." (Jones, Hills, Hopkins 2001) The mission concluded that "The science underpinning (s/s) technology is well established and cement-based stabilisation and solidification is used to treat a wide variety of process waste streams and contaminated soils around the world. The best practices observed in the USA can be incorporated into the guidance for (s/s) in the UK." (Jones, Hills, Hopkins 2001)

In the UK, innovative (S/S) applications are playing an important role in disposal methods. Field trials are underway to combine and stabilise sewerage sludge, coal shale and demolition waste to provide suitable engineering properties for building foundations.

In New Zealand, recent government legislation and guidelines point firmly in the direction of innovative solutions such as (S/S) but at the same time there is the potential for (S/S) to be overlooked if regulatory authorities take too cautious an approach.

In 2002 the Ministry for the Environment published the 'New Zealand Waste Strategy Report'. The report outlines the aim of government to move New Zealand towards

“zero waste” and “a sustainable New Zealand”. (Bradley et al 2002) By 2000 systematic investigations of potentially contaminated sites by councils had confirmed that 1,134 were contaminated. The report concluded that “Although some sites resulted from poor practices or unlawful disposal methods, many stemmed from previously acceptable practices now regarded as inappropriate.” (Bradley et al 2002)

The Ministry for the Environment has also developed “Landfill Waste Acceptance Criteria” guidelines which prohibit the disposal of untreated hazardous wastes to any landfill. Landfill legislation in NZ has seen the number of landfills reduced significantly, with landfills now being classified based on the level of natural and engineered containment. (Purchas C, 2004) This legislation aims to provide a higher level of landfill engineering. However longer cartage distances and increased landfill compliance costs are creating demand to look at alternative methods of treatment and disposal.

The (S/S) process is an ideal solution to the landfill problem. It can either be used to reduce contaminants to achieve complying landfill acceptance criteria levels, or the materials can be stabilised on site to eliminate the need for landfill altogether.

## **Design**

Since each site is unique, in its combination of contaminants, soil types, geotechnical properties, physical site properties and hydrogeology, the first step in the (S/S) process is to test and identify the background contaminant concentration levels. This information determines the exact combination of mixing reagents which will be incorporated at a particular site.

In the USA, common binder selection criteria has been developed in terms of specified properties or parameters and their target values. The UK has also adopted these broad targets bearing in mind that “...design criteria and target values should be selected to meet site-specific requirements, in terms of the required mechanical properties and acceptable levels of leaching.” (Al-Tabbaa A, Perera A.S.R 2002a)

Portland-cement is the most common base reagent used, providing cementitious reactions when combined with a wide variety of generic and proprietary binders.

Inorganic wastes, especially those containing heavy metals are ideally suited to cement-based stabilization. Organic contaminants have also been successfully treated by mixing the contaminated soil with organophilic clay prior to solidification with cement.

Sampling and validation testing of the stabilized waste, both during the implementation of the (S/S) process and at the end of the job, is the final stage in the process and is used to measure the effectiveness of the (S/S) technology.

“Commonly used design criteria and typical target values have included:

- (i) Unconfined compressive strength; >350kPa (soaked) at 28 days (USEPA, 1986)
- (ii) Leachate pH; 7 to 11 (Connor, 1993; Harris et al, 1995a)
- (iii) Leachability; using standard leaching tests such as the USEPA Toxicity Characteristic Leaching Procedure (TCLP test) (Federal Register, 1986), or the UK NRA leaching test (Lewin et al, 1994); acceptable limits are

usually quantified using a multiplier of drinking water standards, commonly 100 (Connor, 1993);

- (iv) Permeability; <math>10^{-9}</math>m/s (as for cut-off walls)
- (v) Freeze-Thaw and wet-dry durability; pass in the ASTM tests (ASTM, 1988;1990);
- (vi) Acid neutralisation capacity (ANC); using the Environment Canada test method (Stegeman and Cote, 1991). ANC is a measure of the stability of the chemical environment in the contaminated material, relating particularly to its ability to immobilise metals (Stegemann and Cote, 1990)”

(Al-Tabbaa A, Perera A.S.R 2002a)

## Methodology

The (S/S) process can be divided into two broad categories;

- (1) In-situ operations, in which the contaminated materials are mixed with the reagent directly within the ground.
- (2) Ex-situ operations, in which the contaminants are excavated then mixed either on or off-site. The immobilised material can then be returned to the original location or carted to another site. In some cases the stabilized material can even be used as aggregate in subsequent redevelopment of the site.

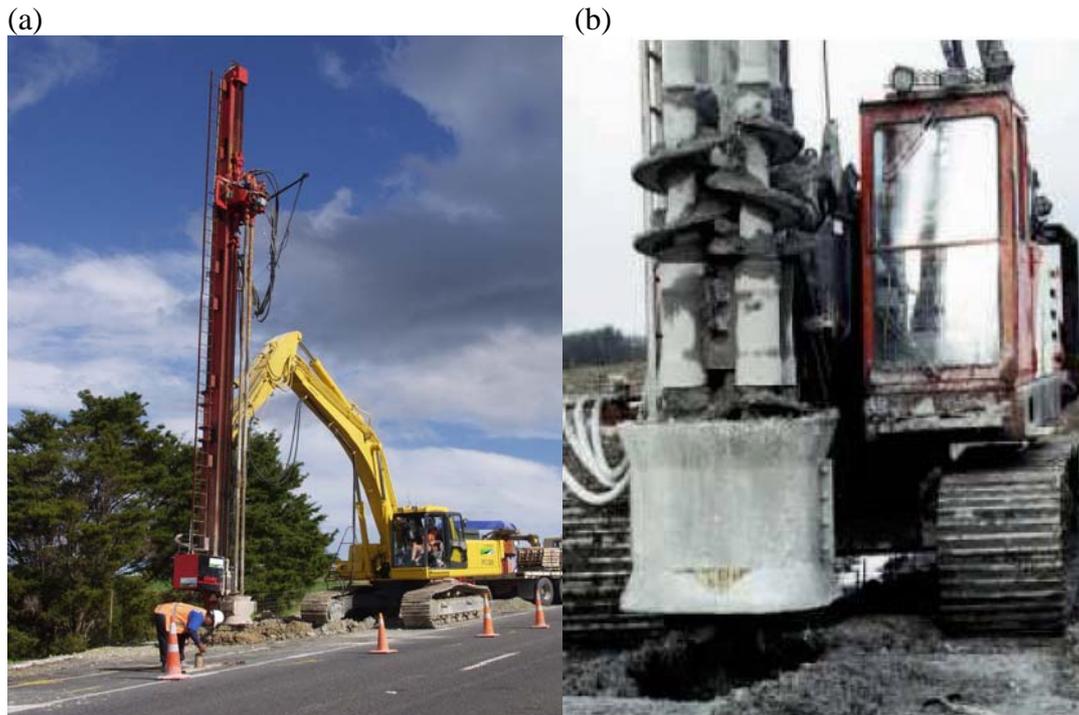
In-situ (S/S) processes generally use an auger or mixing tool system to introduce the binder and efficiently mix it into the contaminated soil.

The deep soil mixing “auger” system has been used on numerous sites in the New Zealand, USA, Europe and the UK. With this process the binder is injected through a hollow auger shaft, and blended with the contaminated soil, forming a monolithic column. Overlapping columns ensure complete treatment of the contaminated area or can be used to form a barrier wall around a contaminated site, as shown below.

(Al-Tabbaa A, Perera A.S.R 2002a)



**Fig 1. Examples of columns created using deep soil mixing augers: (a) overlapping configuration (photo SMW Seiko, 1997) and (b) barrier wall configuration (photo May Gurney Technical Services, 2001) (Al-Tabbaa A, Perera A.S.R 2002a)**



**Fig. 2. Examples of in-situ deep soil mixing equipment.**

(a) Colmix 1300 rig in use in Northland, NZ (photo Hiway Stabilizers Ltd, 2002)

(b) Soletanche Bachy Colmix rig, which was used at the Adeer landfill site. (Case Study 1) (photo Bachy, 1999)

Ex-situ (S/S) involves a portable plant which can be set up on-site or a fixed mixing plant at a purpose built facility. Typically these plants include pug-mills, hammer mills or specialist production mixers. Contaminated material is loaded into the plant and mechanically mixed with the binders. The resulting material is then disposed of off site or placed back in its original location, compacted and left to cure.

(Al-Tabbaa A, Perera A.S.R 2002a)



**Fig 3. Reterra mobile soil recycler in use at the NZ Navy Whangaparaoa firing range site. (Case study 5) (photo Hiway Stabilizers Environmental Ltd 2004)**

## **Case Studies**

### **1. Adeer Landfill Site, UK: In-situ (S/S)**

The client was ICI Explosives and the work was carried out winter/spring 1994/95. The Adeer landfill site, located 30 miles south west of Glasgow in Scotland, had been the repository for much of the waste from the chemical manufacturing operations on site for over 40 years. Adeer was the largest explosives manufacturing site in the world.

Site investigations revealed that the waste had a low pH combined with high ammonium and various heavy metals to a maximum depth of 5 metres. The work was carried out by Soletanche Bachy, a world leading geotechnical and environmental engineering company.

For this job a proprietary technique called Colmix was used to treat contaminated hotspots. Colmix involves the use of two or more overlapping and counter-rotating augers to break and homogenise the contaminated soil. A binder is injected, in slurry form, via the hollow augers and mixed with the soil. The resulting material is re-compacted to form a solid impermeable column.

In the case of the Adeer land fill, laboratory treatability studies led to the selection of an optimal cement-based grout mix consisting of cement mixed with lime, as a neutralising agent, and PFA, to improve the stability of the slurry and reduce leachability of the treated material. (Al-Tabbaa A, Perera A.S.R 2002b)

An initial trial was then followed by the full treatment in which 2047 augered columns were constructed down to 5m depth.

Assessment was carried out on samples of the freshly treated waste. The columns were tested for strength using a dynamic penetration system and groundwater monitoring wells were installed to allow for ongoing monitoring of groundwater.

### **2. Boston Brownfield Site, USA: Ex-situ (S/S)**

An old electric generating plant, this site was contaminated by petroleum and lead. It was planned to redevelop the site into an office, residential and retail campus.

In this case a portable (S/S) treatment plant was set up on site and approximately 2,100 cubic metres of material excavated. Over-sized material was screened off and the screened material conveyed, on a belt, to a pugmill. The computer controlled pugmill ensured that the proper amount of binder was mixed with the contaminated soil. The treated material was then able to be used as pavement base for a parking lot on-site.

Savings to the client were achieved in two ways, eliminating the need for off-site transportation and disposal costs and reuse of the material as pavement sub-base. (Wilk 2001)

### **3. Brest Ballast Pond, France: In-situ (S/S)**

The ballast pond behind the Moulin Rouge harbour in Brest, France was used to store waste from ships cleaning their ballast tanks when berthed quayside. In the late nineties it was decided to shut down the pond and reclaim the land for development as an industrial building site.

This project was carried out from September to November 2000 by the French company, Soletanche Bachy and their environmental division Inertec.

The technique adopted was as follows:

- A special double paddle mixing and injection system was developed and mounted on a long excavator boom.
- The pond was then treated in strips using a quick setting grout mix. Once each strip had set it could be used as a working platform to treat the next strip
- The whole pond was treated, in strips, in this manner.

More than 23,000cubic metres of soil were treated by this technique, in four months.

An active barrier was also placed around the pond perimeter. The barrier was fitted with filter gates to allow excess water from the site to escape free of any residual pollutants. (unknown author, [www.soletanchebachy.com](http://www.soletanchebachy.com) 2004)

### **4. West Drayton R&D Project, UK.**

In 1995 the University of Cambridge began a long term R&D project on an old chemical works site at West Drayton, near Heathrow airport. The site was contaminated with a wide range of heavy metals, inorganic and organic compounds. An in-situ method of (S/S) was used consisting of 23 overlapping columns, 600mm diameter and 2.3m deep and treating 14 cubic metres of soil.

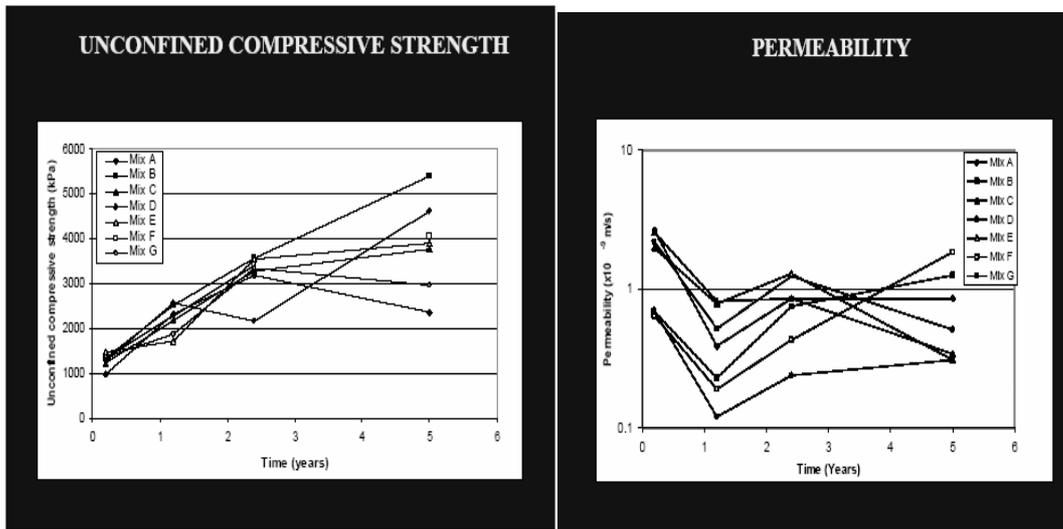
Core samples were then taken 2 months and 5 years after treatment. These were tested for strength, permeability, durability and leachability.

Results were very encouraging indicating that engineering properties such as strength and durability had increased with time, permeability had remained within acceptable levels and leachability of heavy metals was in concentrations much less than drinking water standards. (Al-Tabbaa A, Perera A.S.R 2002b)

The following tables show some of the results.

Table 1.

Table 2.



(Al-Tabbaa A 2002)

### 5. NZ Navy Site, Whangaparaoa: Ex-situ (S/S) of firing range soils.

In 2004, Hiway Stabilizers Environmental was awarded a contract to stabilise contaminated firing range soils at the NZ Navy’s Whangaparaoa training facility. These soils were contaminated by projectiles and posed an identified environmental risk. URS consultants were engaged by the client to investigate, design and supervise the remediation project.

Soils contained lead concentrations of up to 8470mg/kg dry weight were identified. Soils samples were mixed with three different binder types in the laboratory and tested for TCLP (Toxicity Characteristics Leaching Procedure) levels. The results indicated that 5 % cement binder achieved TCLP levels well below the levels required to meet landfill acceptance criteria for the Redvale landfill (a class A landfill).

A Reterra mobile soil recycler was used to incorporate binder and mix soils. Site verification testing was completed and the mixed soils then carted to landfill.

## Conclusion

Solidification/Stabilization is a tried and proven technology for the treatment of contaminated soils and waste materials. (S/S) involves the mixing of binders with contaminated waste resulting in a form which is less available to the environment. This is achieved either by solidification, which binds the contaminants into a solid impermeable form, or by stabilization which chemically changes the contaminants so they become less toxic or less mobile.

The technology has been successfully used in the USA for over 30 years. In many other countries, including NZ, recent environmental legislation has seen (S/S) technology emerge as an important alternative to carting wastes to landfill.

The (S/S) process can be divided into two broad categories: In-situ (S/S), in which the binders are mixed directly into the ground and ex-situ (S/S) where the ground is excavated and the mixing occurs within a mobile or fixed mixing unit. The resulting material can then be carted off-site or returned to its original location.

Various case studies outlined different ways in which (S/S) technologies have been used in the past, including its recent use on the Navy firing range site at Whangaparaoa, New Zealand. The West Drayton R&D Project in the UK illustrates the promising performance results over a 5 year testing period.

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