Theme lecture: Active pollutants control and remediation of contaminated sites

Exposé sur le thème: Contrôle des polluants actifs et dépollution des sites contaminés

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1 INTRODUCTION

In recent years there has been increased awareness of the dangers to public health and safety from pollutants in the ground and the groundwater. Various technologies involving containment and/or physical, chemical and biological processes have been developed to control pollutants in the ground and to remediate contaminated sites. In many countries legislation to control pollutants in the ground and groundwater has been introduced in order to protect the public and the environment and this has provided a stimulus for the development of improved containment systems and remediation technologies.

2 ACTIVE AND PASSIVE CONTROL SYSTEMS

The question as to what is meant by an active pollution control system is discussed by Jefferis et al.(1997) in their paper to the Conference. They state that in the UK it is common practice to refer to barrier systems which impede the flow of groundwater as passive control systems while the term active control systems is used for those systems which reduce the contamination in the ground or immobilise the contaminants. However they state that these definitions are not universally accepted as, in the USA and Canada for example, the term active systems is often used to describe those systems where there is an energy input, such as in a pump and treat system, but not for those systems, such as reactive walls, which control pollution by removing contamination without any energy input. These different definitions reflect to some extent the relatively recent development of pollution control technologies. In this paper the UK meaning of the term active control is used and so the focus is on those technologies which involve some physical, chemical or biological process to control pollution by reducing the concentration of the contamination in the ground.

D. Daniel, in his Theme Lecture on 'Critical issues for waste containment in landfills and contaminated sites' to Session 6 of the Conference, focuses only on passive containment technology and recent developments in this technology to contain waste deposits and control pollution. In his lecture, he makes the disturbing statement that, despite the advances in containment technology in the past 15 years, failures and other problems with containment systems continue to occur at an undesirably high rate. Examples of failures and other problems with containment systems which he quotes include numerous instances of slides in landfill caps in the USA during the past 5 years, virtually all caused by excess pore water pressures, and chemical alteration of the bentonite in geosynthetic clay liners (GCLs) resulting in increases in their permeabilities. Daniel does not cover the broader subject of active pollutants control and remediation of contaminated sites, which was the particular topic of Session 6.2.

Active pollutants control and the remediation of contaminated ground by reducing the concentration of the contamination in the ground is an area that is still developing. There are still problems to be overcome and solutions to be found for dealing with some of the more difficult contaminants. Some of these problems and the possible solutions are described below.

3 SOURCE-PATH-TARGET METHODOLOGY

The source-path-target methodology provides a rational framework for assessing the risk due to contamination in the ground. It is also helpful in selecting the most appropriate technology for actively controlling pollutants or for remediating contaminated sites. In this methodology the effect of a toxic substance emitted from a contaminated site, i.e. a "source", on some sensitive point in the environment, i.e. a "target", is evaluated after it has travelled along some path, such as the groundwater connecting the source to the target. The objective in pollution control and remediation is to reduce the amount of contaminant reaching a particular target. As described by Jefferis et al.(1997) in their paper to this Session, the amount of contamination is given by the flux which is the product of the following four factors:

- the permeability
- the hydraulic gradient
- the flow area, and
- the contaminant concentration.

Controlling the contamination involves reducing the flux arriving at the target to an acceptable level by reducing one or more of these four factors. In a passive containment system, the flux is reduced by achieving a low permeability in the wall of the containment system. In active control systems the flux is reduced by either immobilising the contaminant at the source, for example by grouting, or by reducing the contaminant concentration along the path by some chemical, biological or physical method, such as by using a reactive wall.

4 REMEDIATION TECHNOLOGIES

Kovalik and Kingscott(1997) state that the Environmental Protection Agency(EPA) in the USA divides remediation technologies into two categories: established and innovative technologies. Established technologies are those for which there is sufficient information to support their routing use while innovative technologies are those that lack the cost and performance data necessary to support their routine use. The principal established remediation technologies are solidification/stabilisation and incineration, either on site or off site. The principal innovative remediation technologies are soil vapour extraction, thermal desorption, bioremediation and soil washing.

Remediation of solid wastes by in situ stabilisation/solidification with cement based grouts, which often contain lime as the stabilising additive, has been used particularly to treat metal-containing wastes. Indeed there are relatively few alternative technologies for use with metals. Stabilisation of wastes containing organic materials has been less successful because some organic compounds interfere with the setting of cement. Other additives have been added to overcome this problem. One of the main concerns with cement stabilisation is the long term performance of cement grouts and this is an important area for research. The paper by Al-Tabbaa and Evans(1997) allocated to Session 6.2 addresses this problem and describes some recent research to investigate the medium performance of stabilised/solidified soil-grout materials.

Remediation by in situ stabilisation/solidification is the subject of two of the papers allocated to Session 6.2. Corko et al (1997), in their paper, describe their experiences of jet grouting technology applied to the remediation of old dump sites, while Esnault and Deniau(1997), in their paper, describe landfill remediation by a deep mixing method of in situ stabilisation using the COLMIX system.

5 INNOVATIVE TECHNOLOGIES

Innovative technologies are the subject of the remaining three papers allocated to Session 6.2. Mazurkiewicz and Olanczuk-Neyman(1997), in their paper on contaminated harbour sediments, refer to the use of bioremediation to remediate this contaminated soil. The paper by Jefferis et al.(1997) is particularly interesting, setting out the basic concepts involved in the use of reactive treatment zones for the control of pollution migration. The authors distinguish active control through reactive treatment from passive containment with barriers and demonstrate the advantages of this method for contributing to the slow clean up of contamination from a source.

A very unexpected innovative technology for remediating a very unusual contamination problem is described in the paper by Kawamura and Hayashi(1997). In their paper the authors describe the problem of the reduction, due to contamination, in the number of beaches in Japan with musical sands. Musical sand is sand that gives a musical sound when hands are dragged through it or feet shuffled in it. To be musical these sands need to be clean and composed of grains with a narrow range of particle sizes. The Japanese musical sand is composed of quartz grains with a specific gravity, G_s of 2.66, an average particle size, D_{50} usually in the range 0.3 to 0.4 mm and a uniformity coefficient, U_c in the range 1.4 to 1.6 which corresponds to a poorly graded sand. These sands loose their musical property when they become contaminated by shell particles or by grains with a smaller particle size. The innovative technology that has been used to remediate these sands is to wash them in a rotating concrete mixer.

Musical sands are also found on some beaches in Ireland. At Brittas Bay, south of Dublin, blown dry sand on the beach close to the sea was found to be musical when it was walked on. This sand is composed of quartz particles and its aeolian origin gives it the rather uniform particle size which results in it being musical The properties of the Irish and Japanese musical sands are given in Table 1. These values show that the Irish and

Table 1. Properties of musical sands

Property	Japanese Sand	Irish Sand
G_s	2.66	2.66
D_{50} (mm)	0.3 - 0.4	0.26
γ_{dmin} (kN/m^3)	14.0 - 14.5	14.5
Quartz (%)	>60	80

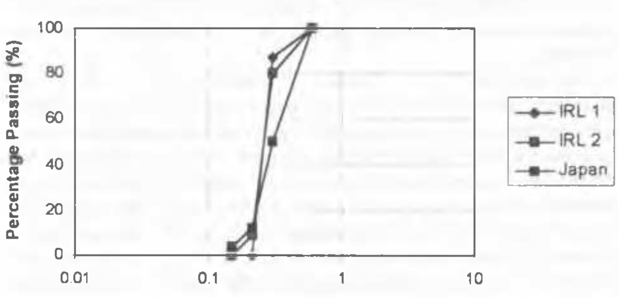

Figure 1. Particle size distribution curves for musical sands

Japanese musical sands have almost identical properties, both being composed of well-rounded quartz particles with an average particle size of about 0.3 mm.

The particle size distribution curves for two Irish musical sand samples, IRL1 and IRL2. and one Japanese musical sand are plotted in Figure 1. It can be seen that these curves are very similar

6 DISCUSSION

6.1 *Topics for Discussion*

The following topics were selected for consideration by the three Panellists, Prof. K. Rowe, Dr. J. Baumann and Dr. G. Grubb, and for the general discussion:

- Problems still to be resolved:
  - what are the most appropriate ground remediation methods?
  - what problems exist with the design and execution of the different remediation processes?
- What can geotechnics and geotechnical engineers contribute?
- What research is required?

6.2 *Panel Presentations*

K. Rowe, in his presentation, spoke about the often neglected importance of diffusion that occurs in the case of barrier walls used to contain contaminated sites. He pointed out that, even if a containment wall meets or exceeds its requirements regarding hydraulic conductivity, diffusion of contaminants through the wall has the potential to cause significant unacceptable impact on water quality. Diffusion needs to be controlled by appropriate design. The diffusion process depends on the contaminant potential inside the barrier wall and on the thickness and other diffusion related properties of the wall. Design of the wall for diffusion should take account of the potential for dilution of any contaminants that do diffuse through the wall.

J. Baumann addressed the problem of the failure of containment systems and posed three important questions:

- Is the diagnosis and remediation of DNAPL sites fact or fiction?
- Is in situ remediation by venting possible, and
- Do clay liners act as barriers to prevent groundwater pollution with, for example, pesticides?

In his presentation, entitled "Are European Landfills Safe" Baumann concentrated on the problems arising from fractures in the clay till in Denmark. In particular he explained that the fractures increase the permeability of the ground above that of the soil matrix and that contaminants flow along the fractures. Soil venting, one of the most common remediation techniques for volatile organic compounds(VOCs), works by the air picking up the VOCs in the unsaturated zone in the soil. Baumann stated that this method only works efficiently in the clay till if the fracture spacing is less than 0.1 m which is the case in the upper 2 m. The fractures in the clay till present a serious problem in the case of dense non-aqueous phase liquids(DNAPLs) which tend to settle in pools in the fractures. These pools cannot be located and, according to Baumann, even if they could be located, they could not be cleaned up. He said the solution was to consider containment or reactive barriers.

In the general discussion, Professor Mitchell, doubted Baumann's simplified point that it was not possible to clean up the DNAPLs. Baumann replied by stating that while 50-70% of DNAPLs may be removed by pumping and treating, the remaining part was the problem because of the extremely low criteria specified for drinking water. Furthermore drilling operations increase the risk of the spreading of DNAPL pools. Krebs Ovesen pointed out the significance of this for Denmark. Denmark depends on groundwater for virtually all of its water supply and this supply is threatened by contaminants seeping through the clay till from various sources, both industrial and agricultural.

D. Grubb, in his presentation, described an innovative procedure for remediating difficult contaminated sites. This procedure involves using ethanol to displace and remove NAPL contamination from the ground.

6.3 *Contribution of the Geotechnical Engineer*

What geotechnics and the geotechnical engineer can contribute in the area of active pollution control and remediation of contaminated sites was one of the points raised for discussion during this session. It appears that there is not much research being carried out at present by the geotechnical community in this area, judging by the numbers of papers on this topic submitted to the Conference. Out of the total of 505 papers submitted to the Conference, only 6 papers were submitted to Session 6.2 on active pollutants control and remediation of contaminated sites. Over twice as many papers, but still a small number, 15, were submitted to the session on pollution control via passive barriers. Forthcoming conferences in Lisbon and Melbourne, focusing on environmental geotechnics, should serve to stimulate more research in this area amongst the geotechnical community.

One of the reasons why geotechnical engineers are not making greater contributions in this area may be due to the engineering educational systems which tend to focus solely on the physical aspects of soil behaviour, such as strength, deformation and permeability. Geotechnical engineers generally receive little training in chemical and biological processes and hence are usually not familiar with the remediation technologies that are used for controlling and remediating polluted ground and groundwater. However, in many instances it is geotechnical engineers who become involved in designing and implementing the measures required to control pollution in the ground or to remediate polluted ground. For this reason Grubb stressed it is important for geotechnical engineers working in the area of environmental geotechnics to improve their knowledge and understanding of chemical and biological processes. Engineering courses will need to introduce more environmental geotechnics into their curricula. Also more research is needed to investigate the advantages and disadvantages of the existing active pollution control and remediation techniques, particularly the more innovative techniques, and to find methods for remediating those contaminated sites that cannot readily be remediated using the currently available techniques.

7 CONCLUSIONS

It appears that the topic of active pollutants control and remediation of contaminated ground is one in which not much research is being carried out generally by the geotechnical community. However, with the increasing redevelopment of inner cities and the re-use of brownfield sites, geotechnical engineers need to be able to design for these areas and need to have the appropriate knowledge and understanding of the different options for active pollutants control and the remediation of contaminated sites. This will require the introduction of more environmental geotechnics into engineering courses and more research into active pollutants control and remediation techniques.

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