# Liquefaction silt: The Health Context

**Summary**

Liquefaction silt deposited on the heavily populated streets of Christchurch and Kaiapoi as a result of the 7.1 magnitude earthquake on the 4th September 2010 was unique in New Zealand's public health history. No parameters existed to enable discrimination between liquefaction-silt contaminated with wastewater and liquefaction silt with no such contact.

ESR provided advice on the nuisance and health impacts of the liquefaction silt as it dried out and the dust blew around the neighbourhoods. The *Guidelines for the Safe Application of Biosolids to Land in New Zealand* (NZWWA, 2003; the biosolids guidelines) was considered the most applicable guideline to assess whether pathogens in liquefaction silt may pose a risk to public health. The biosolids guidelines specify the concentration of indicator organisms below which the risk of infection is considered to be low, and Grade A biosolids carry the lowest risk to public health from infectious agents. Using the biosolids guidelines and a review of the literature, ESR's opinion was that while drying on surfaces may increase the persistence of some pathogens, especially those with a respiratory transmission route, the exposure of the liquefaction silts to sunlight and varying humidity was likely to inactivate most pathogens that may have contaminated the silt.

As a follow up to the advice given, 21 samples of undisturbed liquefaction silts from the Burwood residential and parkland area in Christchurch were obtained five weeks after the main earthquake, and tested for indicators of human faecal contamination (*Escherichia coli* and MS2 phage), and for the faecal pathogens rotavirus and enterovirus. Although it was not known whether the exact sites from which the liquefaction silts were obtained had been exposed to sewage, the immediate area had ongoing disruption to sewage infrastructure. Guideline values for Grade A biosolids were used as surrogate parameters to assess the potential risk to public health, however, none of the faecal indicators tested for were detected above the guideline values. ESR's scientific opinion was that the five-week old liquefaction silts from the sites tested represented a low risk of bacterial and viral infection to the public.

## Introduction

Liquefaction can occur when subsurface materials are transformed by an earthquake into a liquid-like matrix, and these can sometimes emerge on the soil surface. As the water component slowly drains away, fine sands and silt deposit on the soil surface. Significant liquefaction occurred throughout many suburbs in Christchurch and Kaiapoi as a result of the Canterbury earthquake on 4 September 2010. This, combined with earthquake damage to the sewerage infrastructure, led to concerns that some of the liquefaction silts may have been contaminated by sewage, representing a risk to public health.

Many liquefaction silt deposits were removed from affected sites during the first few weeks post-earthquake, especially where direct contamination by sewage was highly likely. As the remaining silts dried out over the weeks immediately after the earthquake, traffic and wind distributed the liquefaction silt dust more widely than the initial deposits. Hence, many homes became contaminated by dust from liquefaction silt and raised concerns about the risk to public health from the dust and pathogens associated with it.

Five weeks post-earthquake, some liquefaction silts remained relatively undisturbed in residential areas and local parks. Given that the silt piles could be attractive to children as play areas, or to adults who may decide to use the silts in their gardens, the question was raised whether these undisturbed silts were a likely ongoing source of infectious disease and a public health concern.

ESR provided advice on the potential for nuisance and health impacts from the liquefaction silt as it dried out and blew around, including what testing was appropriate. The physical properties of liquefaction silt dust and the potential for this dust to be associated with faecal pathogens were assessed.

## Health effects due to physical properties of liquefaction silt

The physical nature of the dust that was being generated from deposits of liquefaction silt may have potential to cause health effects, as fine particles can be easily inhaled and readily absorbed into the lungs. ‘Particulate matter’ (PM) describes very small solid or liquid particles in the air, such as dust, smoke or fog. Although $PM_{10}$ particles (less than 10 µm diameter) are considered an air pollutant of concern because they are linked to harmful health effects, it was likely that most of the liquefaction silt dust grain size would be above 10 µm, so the dust would not impact on health directly. However, fine silts can contain grains smaller than 10 µm, so the liquefaction silt dust could still contain some $PM_{10}$ particles and exposure to these fine particles needs to be managed. High concentrations of these fine dusts could cause nuisance and people with respiratory disorders could have experienced additional irritation of their symptoms.

ESR advised that to protect public health from the physical properties of liquefaction silt dust, the best option was silt removal. If this was not possible, measures should be implemented to prevent the fine dust becoming airborne, such as sheltering silts from wind and/or dampening the surface when windy.

Removal and dampening of liquefaction silt were underway soon after the earthquake, so the risk to public health from the physical nature of the liquefaction silt dust was considered to be low.

## Health effects of pathogens associated with liquefaction silt

There was concern about the potential health risk from pathogens if associated with the liquefaction silt dust due to contamination by raw wastewater.  While most liquefaction silt had probably not been exposed to sewage, by the time the silt was in the form of dust there was uncertainty about whether pathogens, if present, would still be infectious. ESR’s advice took two directions: 1) pathogens associated with current dust from liquefaction, and 2) the on-going risk from silt deposits that could become dust in the future.

The probable survival of pathogens in dust and parameters against which microbial concentrations in liquefaction silt or dust could be assessed were established. Several sets of guidelines were considered for appropriate parameters, and the *Guidelines for the Safe Application of Biosolids to Land in New Zealand* (NZWWA, 2003; the biosolids guidelines) was considered the most applicable. The biosolids guidelines specify the concentration of indicator organisms below which the risk of infection is considered to be low. Grade A biosolids carry the lowest risk to public health from infectious agents and are considered safe for people to handle and apply to land with minimal risk of disease. For Grade A biosolids, the guidelines indicate that material should contain less than 100 *E. coli* MPN $g^{-1}$ dry material and enteric viruses less than 1 PFU per 4 g dry material. As biosolids are made from treated and stabilised sewage sludge, it was reasoned that biosolids would represent the worse case scenario of material spread on land and to which people could be exposed.

Advice was provided on the potential health risks from liquefaction silt dust contaminated with sewage (from earthquake-disrupted sewerage infrastructure). No data are available on the survival of faecal indicators or faecal pathogens in liquefaction silt or its dust, and there are few data available on their survival associated with soil dust. The two main exposure routes to pathogens from dust, whether dust from soil, liquefaction silt or biosolids, are through direct contact and through inhalation.

**Exposure route – contact**. People may become exposed to pathogens through direct contact when handling soil, liquefaction silt or biosolids contaminated with pathogens or when touching surfaces with dust originating from contaminated matrices. Studies that used air-drying to store soil found that although enzyme activity of microorganisms declined rapidly during initial air drying, the activity stabilised in the following weeks and months and never approached zero even after years of dry storage (Dadenko et al., 2009; Liu et al., 2009). Similarly, the ability to continue to culture faecal indicator bacteria associated with beach sand persisted for longer than for bacteria in the water column (Craig et al., 2002; Zehms et al., 2008; Zhao et al., 2008; Boehm et al., 2009; Haller et al., 2009). This indicates that the microorganisms that survive air drying initially are stable within the soil/sand matrix, and, therefore, if dry soil or sand becomes disturbed and is transported as dust, the microorganisms could colonise new niches.

**Exposure route – inhalation.** People may be exposed to pathogens through inhalation of fine particles or droplets when handling soil, liquefaction silt or biosolids contaminated with faceal pathogens Few studies have been carried out that looked for faceal pathogens in aerosol from soil-dust where contamination may be expected; but where explicitly looked for, faecal pathogens have not been found (Teltsch et al., 1980; Linnermann et al., 1984; Brooks et al., 2004). Studies on biosolids applications did not find pathogens in the aerosols, even though the source material contained high numbers of potential pathogens and indicator bacteria (Teltsch et al., 1980; Linnermann et al., 1984; Brooks et al., 2004).

After an 8.0 magnitude earthquake in Sichuan, China in 2008, no evidence was found of respiratory pathogens in aerosol samples taken from around the sites of devastation (Yao *et al.*, 2009). No mention was made of liquefaction silt dust resulting from this earthquake.

Studies on dust from scarlet fever hospital wards during the 1940s suggest that once respiratory pathogens are dried within the hospital dust, they remain quite stable and represent a potential source of infective agents (Lidwell and Lowbury, 1950 b, a). However, natural sunlight, ultraviolet light and increases in humidity inactivated most of these pathogens (Lidwell and Lowbury, 1950b).

**Summary.** While drying on surfaces appears to increase the persistence of some pathogens, especially those of a respiratory transmission route, the exposure of the liquefaction silts to sunlight and varying humidity is likely to inactivate most pathogens that may have contaminated the liquefaction silt, especially the liquefaction silt dust.

### Suggested sampling plan

ESR advised that an initial assessment of liquefaction silt and silt dust for the presence of *E. coli* would provide an initial indication of faecal contamination. If liquefaction silt or dust was found to have potential human wastewater contamination, further analyses for additional indicators and pathogens could then be undertaken. ESR considered that if liquefaction silt was heavily contaminated with human wastewater, the methods described next would allow the risk to public health from exposure to liquefaction silt and silt dust to be assessed.

### Sampling considerations – see Section 9 of the biosolids guidelines (NZWWA, 2003)

A document detailing sampling considerations is available on request from Wendy Williamson at ESR: wendy.williamson@esr.cri.nz

**The testing regime** in the biosolids guidelines recommends 15 grab samples of biosolids for product verification. Therefore:

- for liquefaction silt ESR suggested analysing 16 samples: representative sampling of eight *different* liquefaction-silt deposits, with one sample for each deposit taken from the surface of the deposit and one sample taken from within the deposit. The 16 samples were to be tested for *E. coli* as described below. ESR suggested ~50 g liquefaction-silt per sample, which allowed testing for *E. coli*, dry weight determination and re-testing for pathogens, if required
- for liquefaction-silt dust ESR suggested representative sampling of about 12 households in the liquefaction zone and about three households outside the zone (controls for background contamination not associated with liquefaction). Dust from ledges and surfaces, **not** carpets, should be aseptically collected in one clean vacuum cleaner bag per home and tested for *E. coli* using the test method as described below. As the quantity of dust available was likely to be low, a composite sample from several sites around the home was to be taken to obtain as much material as possible, aiming for a minimum of 10 g, if possible.

The test method suggested for *E. coli* is based on the biosolids guidelines: Part 9221 F or Part 9223 B, Standard Methods for the Examination of Water and Wastewater (APHA, 1998). Instructions to the laboratory should ask them to retain the sample for potential follow-up microbial analyses.

In summary, the concentration of *E. coli* in liquefaction silt dust contaminated with human wastewater is unknown. Based on the biosolids guidelines, ESR suggested that if the concentration of *E. coli* is less than 100 MPN $g^{-1}$ liquefaction silt dust, the risk to public health was likely to be low. To a first approximation, analysing the liquefaction silt for *E. coli* would permit an estimate of whether the silt was likely to be a current and/or on-going source of dust containing potential pathogens.

### Sampling liquefaction silts five weeks after the Canterbury earthquake

**ESR's approach**. ESR sampled liquefaction silt deposits to determine whether silts were contaminated by sewage and to assess whether the silts were an ongoing health hazard; a very limited sampling of liquefaction silt was carried out along one street in Burwood, Christchurch. At the time of sampling, this area still had a disrupted sewerage system and *Port-a-Loos* were provided on the street, approximately one between two or three houses, for residents to use. A site survey indicated several locations where undisturbed liquefaction silt samples were still present, including a public park and in several residential properties along the one street. Samples were aseptically collected from four sites (the park and three residential properties) and returned to the laboratory for testing.

As a guide to the concentration of faecal organisms that may pose a risk to public health, ESR used the product pathogen standard for Grade A biosolids (*Guidelines for the safe application of biosolids to land in New Zealand*, 2003). Target organisms were *E. coli*, the pathogenic viruses rotavirus and enterovirus, and the bacterial phage MS2 (a faecal virus indicator). The biosolids guidelines indicate that Grade A biosolids material is "essentially free of pathogens" and is considered to represent a low risk of transmitting infectious organisms to people. An acceptable risk profile for Grade A biosolids is where *E. coli* is less than 100 MPN $g^{-1}$ dry material and enteric viruses are less than 1 PFU per 4 $g^{-1}$ dry material.

The silts were analysed for *E. coli* and MS2 phage using standard culture methods (Part 9221 F or Part 9223 B, Standard Methods for the Examination of Water and Wastewater (APHA, 1998)); 1 g silt per organism. For the faecal pathogens rotavirus and enterovirus, ESR used quantitative reverse transcription polymerase chain reaction (qRT-PCR) methods. PCR uses less sample material in assays and is faster than conventional culture methods, so 0.5 g silt was tested for rotavirus and enterovirus, rather than 4 g used in the biosolids guidelines. While PCR is more sensitive than culture for the detection of target organisms, it cannot discriminate between viable or non-viable organisms. As the intention of the analyses was to determine whether sewage had contaminated the liquefaction silts, checking the viability of PCR detected organisms was not planned, but was something that could be followed up using additional assays, if and when required.

## Results

| Site with liquefaction (sampled 12-10-10) | Site moisture (%) n = 4 per site | *E.coli* MPN per g dw* | MS2 phage Per g dw | Rotavirus Per 0.5 g dw | Enterovirus Per 0.5 g dw |
|---|---|---|---|---|---|
| Site 1 (n = 6) | 24 | 1 | Not detected | Not detected | Not detected |
| Site 2 (n = 6) | 8 | 1 | Not detected | Not detected | Not detected |
| Site 3 (n = 6) | 6 | 3 | Not detected | Not detected | Not detected |
| Site 4 (n = 3) | 7 | 8 | Not detected | Not detected | Not detected |

* dw; dry weight silt

**Conclusion.** For this very limited survey, there was no evidence of faecal contamination in any of the 21 samples of liquefaction silt analysed. Based on these results, the silts sampled were likely to represent a low risk of bacterial and viral infection to the public. This study has several limitations in addition to the low number of samples analysed. Considerable information could have been gained if samples had been collected immediately after the earthquake, and these results may have helped prioritise which sites to clean up first. Deliberate sampling of liquefaction silts that had overt evidence and odours consistent with sewage contamination would have permitted the utility of the proposed methods to have been tested and refined as necessary. Deliberate sampling would also have allowed follow-up work to assess the persistence of microorganisms on naturally contaminated liquefaction silt, which would have enabled risk management plans to be developed for populated areas with known liquefaction risks.

## References

A complete reference list is available on request from Wendy Williamson at ESR: wendy.williamson@esr.cri.nz.