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Development of a geophysical method for quantitative risk assessment Innovative methods for the quantification of industrial by-products in roads

Martijn van Houten (3), dr. Rod Eddies (2), and dr. Ronald Koomans (1)

(3) Witteveen+Bos, the Netherlands (m.vhouten@witteveenbos.nl), (2) Fugro Aperio, United Kingdom (R.Eddies@fugro-aperio.com), (1) Medusa Explorations, the Netherlands (koomans@medusa-online.com)

1 Introduction

Risk assessment of polluted sites requires objective and quantitative methods for site investigation. Small sites are often mapped by coring, sampling and laboratory analysis used for the assessment of chemical pollutants. For larger sites, sampling is expensive whilst geophysical mapping systems up until now could only give a general image of pollution, insufficient for a quantitative risk assessment.

By using a unique combination of radiometric methods, electromagnetic (EM) and ground penetrating radar (GPR), we have developed a strategy for reliable, spatially-detailed mapping of zinc concentrations originating from zinc slag distributed over approximately 1,150 km road network in an area of 2,600 km^2 in the Kempen region of the Netherlands.

2 Approach

An interactive approach with a combination of geophysical methods was used to survey the suspect roads. Targeted samples were used to calibrate the results of the geophysical survey, which in turn were used to map the suspect roads. The results were screened for anomalies and used to ‘zone’ the roads in areas with similar characteristics. The results of the survey made it possible to calculate risks related to public health and to leaching of metals into groundwater. As a result the various sites could be ranked in terms of priority for remediation.

3 Geophysical technologies

The three techniques: radiometrics, EM and GPR were complementary depending on the situation (deep target, shallow target, paved/unpaved surface). The combination of the techniques proved to be the key to the reliability of the overall survey.

The concentration of radio nuclides was recorded with the Medusa sensor mounted on the front of a survey vehicle. Fugro-Aperio GPR antennae were mounted on each side underneath the vehicle and the Fugro EM device on a specially constructed non-metallic trailer behind the vehicle. Laboratory samples were subject to radiometric measurement analogous to the field acquisition method.

This allowed for setting up a physical model relating radiometry and other material properties (texture, chemical properties) in the laboratory. This model was used to calibrate the radiometric measurements in the field. Predictive maps of zinc slag and zinc concentration could be made by using non-invasive field measurements and a geochemical model relating radiation and pollution.

4 Setting up a database and validation

Data from the geophysical sensors provided information on the presence and on the concentration of zinc slag at individual data points or sections of road.

Together with additional information on pavement type, classification of verges, photographs of the road and other GIS based information, details of the road sections were fed into a GIS database. Each section of road was ranked on its accuracy by the number of geophysical sensors that pointed to the presence of zinc slag. A total of 1,472 cores were taken and 8,697 samples were tested for zinc by means of hand-held XRF systems. Laboratory results were used to validate the geophysics results.

5 Using the database for quantitative risk assessment

All information from geophysics and field inspection was fed into a database that combined other geographically distributed information such as soil type, distance from natural reservation areas, distance from urban areas. A multi-variate approach made it possible to rank road sections on their potential risks. The costs of remediation were calculated. This risk-based approach brought the problem of remediation into perspective.

The ultimate goal of this investigation was determine potential risk for leaching for each section of road containing zinc slag. Based on the risks for leaching, a model to determine the site-specific remediation depth was derived.

The project was successful in combining quantitative, spatially detailed information from the source of zinc (the amount of zinc slag measured by geophysical methods) with spatially detailed information of soil properties (e.g. acidity of soil) in an area-specific model. It would not have been possible to calculate the remediation-depths on a detailed scale without the use of geophysical methods.