A method for the verification and quantification of zinc slag in roads

R. L. Koomans[1], P. van der Wal[2] & T.P.J. Kamsma[3]
[1]Medusa Explorations BV, 30/05/2009
[2] Tauw BV
[3] Actief Bodembeheer de Kempen

This paper will be presented at the Eage congress *Near Surface 2009* in Dublin

Medusa Explorations BV
P.O. box 623
9700 AP, Groningen
The Netherlands

Web: www.medusa-online.com
Email: info@medusa-online.com
Tel: +31 (0)50 5770280

This study was commissioned by ABDK, in cooperation with the provinces of Noord-Brabant and Limburg and the theMinistry of Housing, Spatial Planning and the Environment (VROM) in TheNetherlands.

Verification and quantification of zinc slag in roads

Development of a geophysical and geochemical method

Introduction

The area “De Kempen” in the Netherlands and Belgium, was well known for its production of zinc from ore delivered from all places over the world. In the process of zinc production, zinc is removed from the ore and the remaining waste product is zinc slag. This zinc slag is light, and contains high concentrations of all types of heavy metals. Until the 1970’s these zinc slags were spread all over De Kempen in to improve public and private roads. The potential ecological risk of the heavy-metal containing asks for measures to remediate these zinc slags.

One of the major challenges in the pollution problem of zinc slag in “De Kempen” is in the estimated area of 2600 km2, charged with heavy metals from the zinc industry. Given the size of the area, there is an apparent need for a rapid, synoptic method to locate the slags.

A "pilot for applying a geophysical technique for the verification and quantification of zinc slags in roads in De Kempen" was commissioned by ABDK, in cooperation with the provinces of Noord-Brabant and Limburg and the theMinistry of Housing, Spatial Planning and the Environment (VROM) in TheNetherlands. This study aimed at the development of a method by which the presence or absence of zinc slags in the roads of De Kempen can be quantified and verified. The study focussed primarily on four municipalities in the Kempen in Belgium and in the Netherlands: Lommel, Overpelt, Cranendonck and Reusel De Mierden. Besides these municipalities, measurements were also done in Asten, Horst aan de Maas, Nuenen CA, Someren and Eindhoven.

Gamma spectrometer

The goal of the pilot study was to develop a geophysical method for fast screening of the presence of zinc slag in paved and non-paved roads.

Since the mineral composition of ores will differ from the mineral composition from the soils in De Kempen area, we expect that the concentrations of natural occurring radionuclides will also differ the soils found in the area of study. Therefore, one of the main parameters used in the pilot, was the concentration of radionuclides measured with a gamma spectrometer. In this project we used the gamma spectrometer as a geochemical tool, which passively measures material properties in the field (the concentration of K, U and Th). Exactly the same measurement that is done in the field can be repeated on samples in the lab. This allows for setting up a physical model relating radiometry and other material properties (texture, chemical properties) in the lab. This model can then be used to translate the field measurements into the wanted soil property.

The reduction of the measured spectral information into concentration of radionuclides, is mostly done using the Windows analysis method (Grasty et al, 1985). In Windows, the activities of the nuclides are found by summing the intensities of the spectrum found in a certain interval surrounding a peak. In “classic” windows, three peaks are used to establish the content of ^{232}Th, ^{238}U and ^{40}K. A major flaw of the Windows method is the limited amount of spectral information that is incorporated into the analysis. Another weakness is the inherent use of ‘stripping factors’ to account for contributions of radiation from nuclide A into the peak of nuclide B. Our system incorporates a different method to analyze gamma spectra. In contrast to the “Windows” method described before, our Full Spectrum Analysis (FSA) method incorporates virtually all of the data present in the measured gamma spectrum. In FSA, a Chi-squared algorithm is used to fit a set of "Standard Spectra" to the measured spectrum. The fitting procedure yields the multiplication factors needed to reconstruct the measured spectrum from the standard spectra of the individual nuclides. The multipliers equal the actual concentrations of the radionuclides that led to the measured spectrum. The method is described in detail in Hendriks et al (2001) and Koomans et al (2008). Hendriks (2001) shows that the uncertainty in the FSA method is at least a factor of 1.7 lower compared to the Windows method.

Measurements

To see if natural radioactivity can be used as a proxy for the presence or absence of zinc and zinc slags, 300 soil samples from the area were analyzed on both their content of the naturally occurring radioactive elements Uranium-238 and Thorium-232, and zinc / zinc slags (Figure 1). This study showed irrefutably that such a relationship exists: samples that contained zinc slags are also enriched in uranium, and the ratio between the uranium and thorium deviates from 1 (the background ratio found in "clean" samples). These radiation measurements are not only limited to laboratory situations. Using modern equipment, the concentration of radionuclides can also be determined quantitatively in the field (Figure 2), in this case on the roads crossing De Kempen. Using such non-invasive field measurements and a geochemical model relating radiation and pollution, predictive maps could be made of the zinc slag enriched areas (Figure 3).

Results

The predictive maps from the geophysical measurements were validated by analyzing samples from 1060 drillings taken from the roads investigated. The review showed that the agreement between predictions and drilling is excellent. In 80% of the sites where the field measurements predict zinc slags, it is also found in the core samples. In 97% of the locations where our maps showed no zinc slag, zinc slag were also absent in the drill cores. The method developed turned out to be indecisive on 15% of the roads mapped in The Netherlands (Figure 4). For these stretches of road, samples had to be taken to establish the pollution level. Last but not least, the radiation measurements showed to be relatively insensitive to the presence of the thin layer of asphalt on the roads.

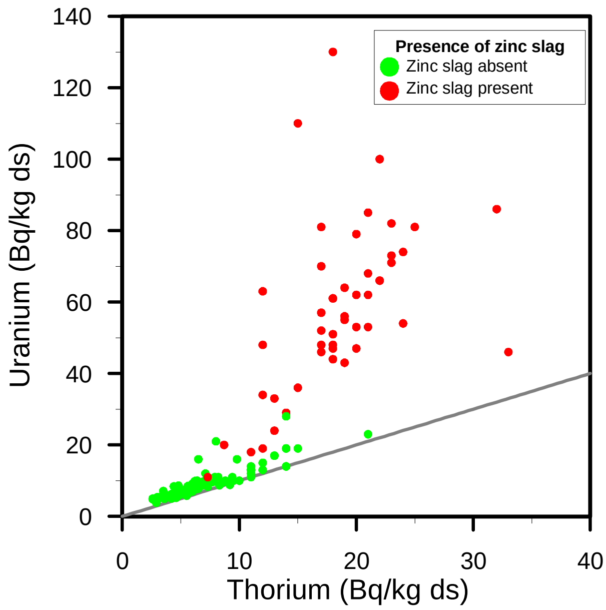

Figure 1: Scatterplot of uranium vs thorium for zinc slag containing material and material that does not contain zinc slag.

Figure 2: Example of fieldwork with the gamma spectrometer placed in a small car behind the van.

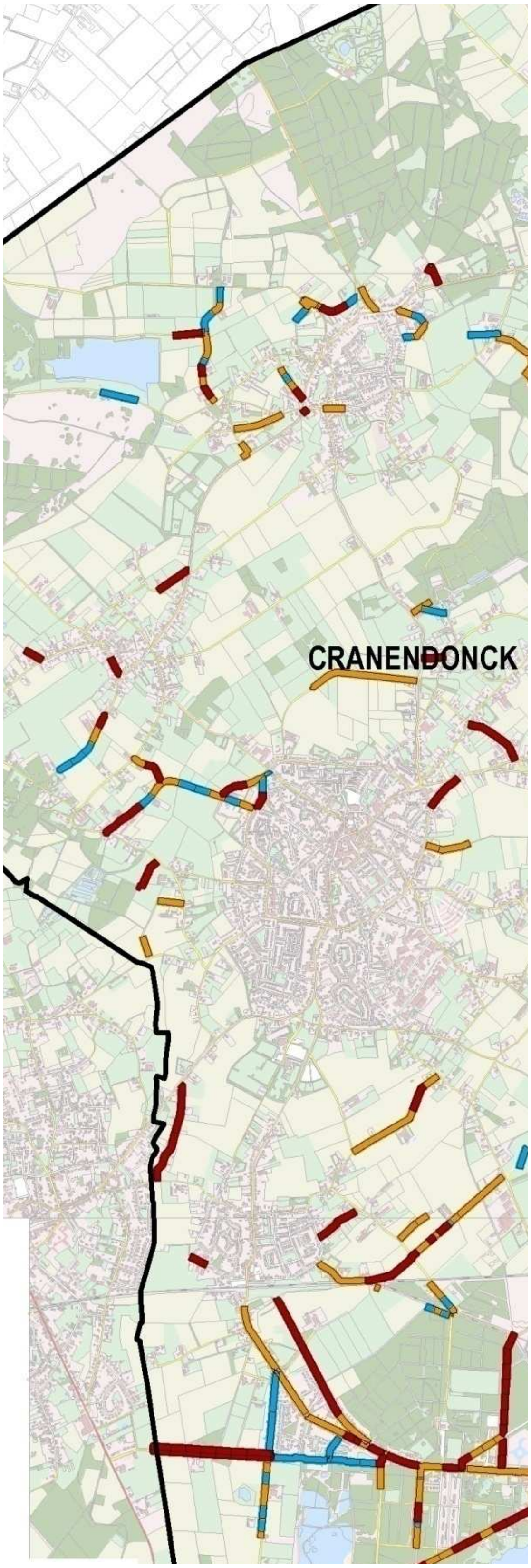

Figure 3: Example of a map showing the values of geophysics interpreted to the presence (red and orange colors) or absence (blue color) of zinc slag.

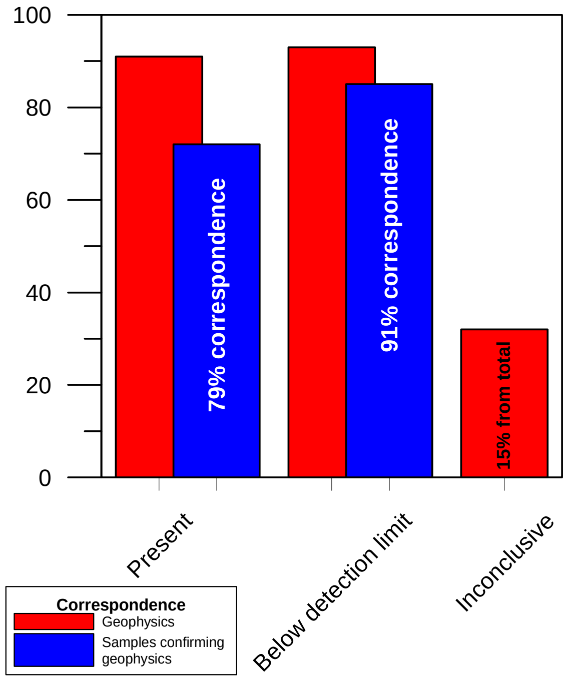

Figure 4: Comparison between the results from geophysics and number of observations from validation measurements by corings.

Conclusions

The result of the "pilot for applying a geophysical technique for verification and quantification of zinc slags in roads in De Kempen" is a rapid, concise and non/invasive method to establish presence or absence of zinc slag in roads. With this method, a complete inventory of zinc slag in De Kempen area has become within reach.

References

Grasty, R.L., Glynn, J.E. and Grant, J.A. [1985] The analysis of multichannel airborne gamma-ray spectra. Geophysics . Vol. 50, No. 12: 2611-2620.

Hendriks, P.H.G.M., Limburg, J. and de Meijer, R.J. [2001] Full-spectrum analysis of natural gamma-ray spectra. Journal of Environmental Radioactivity, 53: 365-380.

Koomans, R.L., Limburg, J., van der Graaf, E.R. [2008] Towards light weight airborne gamma spectrometry. Medusa Explorations BV white paper, www.medusa-online.com