January 2014
The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

Pollution control

Informing the National Framework of Contaminated Land

A completed study, funded by the Water Research Commission, has evaluated partitioning coefficients for South African soils to inform the National Framework for the Management of Contaminated Land, with emphasis on the protection of water resources.

Background

Appropriate screening of contaminated land is imperative to the registration of contaminated land, and has significant implications for industry, government and the environment. Inappropriate screening during initial investigations will result in some constituents and sites being screened for further detailed assessment and registered as contaminated land when, in fact, it could be naturally occurring soil concentrations.

On the other hand, some constitutes and sites that pose a potential risk may appear uncontaminated while further investigation is actually warranted. A high degree of uncertainty therefore exists in screening soils for further assessment and registration as contaminated land.

The objectives of this WRC-funded study were to:

- Assess analytical methodologies for use in the setting of screening values for the protection of water resources through a literature study;
- Determine partitioning coefficients (K_ds) for South African soils and its use in the setting of appropriate screening values for the protection of water resources; and
- Determine baseline concentration ranges for soluble contaminants in South African soils to assist in the setting of appropriate soil screening values for the protection of water resources.

This study was conducted in four stages, including an extensive literature review, evaluation and selection of appropriate analytical methods to determine soluble concentrations of constituents in soils and to indicate partitioning coefficients, determination of K_ds of selected metals for a selection of typical South African soils and the determination of baseline concentrations of the soluble fraction of Cu, Pb and V in natural South African soils.

Comparison of analytical methods

The comparison of analytical methods to determine soluble concentrations of elements in soils in order to select the best analytical method to predict soluble pore water quality indicated that pore water quality is overestimated with the fixed soil:solution ration extractions, compared with the saturated paste extract (assumed to be the best indicator of pore water quality). This overestimation was more pronounced in highly contaminated soils and higher soil:solution ratios.

The results of the 1:2.5 water extracts were closets to the result of the saturated paste extract and, in most instances, the results were not significantly different from saturated paste results.

Partitioning coefficient of soil

The K_d of a soil represents the net effect of several soil sorption processes acting upon the contaminant under a certain set of conditions. Soil properties, such as the pH, clay content, organic carbon content and the amount of Mn and Fe oxides, have an immense influence on the K_d value of a soil.

K_ds for Cu, Pb and V for various diagnostic soil horizons were calculated from sorption graphs. In most cases there were contrasting K_d values especially when the cations, Cu and Pb had high contamination levels, the value for V was low.

There is large variation between the K_ds stipulated in the framework and the values obtained experimentally in this study. The results further indicate that a single K_d for an element/metal cannot be used for all soil types/horizons due to the effect of soil properties on the K_d.

Determining soluble baseline concentrations

The objective of determining soluble baseline concentrations for selected trace elements in South African soils was to reference the concept of 'normal' (uncontaminated) soluble concentrations in soils with different soil properties. The soluble baseline concentration ranges for Cr, Cu, Ni, V, Co and Pb were <1 mg/ℓ. For Mn the range is wide with a lower limit of 0.189 mg/ℓ and an upper limit of 39.4 mg/ℓ, indicating a significant variability in soluble Mn concentrations between different soils.

The correlation between soluble concentrations of selected elements and soil properties can be summarised as follows:

- An increase in soluble Cr and Ni concentrations with an increase in organic carbon and clay content (with a decrease at >40% clay). The soil pH seems to have had little effect on the soluble Cr and Ni in the studied soils;
- Soluble V concentration correlated well with soil pH, with the highest solubility at pH <5 and >7.5. the solubility of V decreased when the clay content increased >20%;
- Soil pH had an influence on soluble Cu concentration with a decrease in soluble Cu at pH >6. Correlation with organic C showed an increase in Cu solubility with an increase in organic C content while clay content had no significant effect on Cu solubility;
- The soluble Co concentrations showed very strong correlation with organic carbon and soil pH, with a significant decrease in Co solubility at pH>6;
- A strong correlation between soluble Mn and soil pH and soluble Mn was higher in soils with lower clay content;
- Pb solubility was high at high organic C, low pH and clay contents. Zn solubility was high at high organic C, low pH and high clay contents.

Natural partitioning coefficients

The natural partitioning coefficients give an indication of the 'K_d' of natural soil (no contaminant added).

The natural portioning coefficients for Ni, Cr and Pb increased with an increase in the clay content of the soils. The natural partitioning coefficient of Cu and Co did not correlate with the clay content. Soil pH does not have significant influence on the natural partitioning coefficients of Ni and Cr (and Pb based on limited data), but the chemical envelope of Cu and Co (and Zn based on limited data) show correlation between soil pH and the natural partitioning coefficient. Finally, the natural partitioning coefficients for Cr, Cu and Co were found to be higher at lower organic C contents while there was no correlation between natural partitioning coefficient and organic C content for Ni and Pb.

Recommendations

- The 1:2.5 soil: solution ratio extract should be used to estimate the pore water quality of the soil. This is also the standard method used for the determination of soil pH and therefore considered as an acceptable method and easily implementable by commercial laboratories.
- Based on the K_ds determined in this study for ten different diagnostic South African soils horizons, preliminary additional soil screening values could be calculated which is specific for certain soil types. However, the South African baseline concentrations for natural soils were also considered. Based on these calculations, soil types were grouped together and preliminary risk based on soil screening values were established, which can be used during Phase 1 contaminated land assessments.
- During Phase 2 contaminated land assessments, where more information will be available on soil type and properties, the K_ds can be used to further refine the soil screening values for specific soil types/horizons. Vertic soils, red oxidic soils with high clay content, melanic soils and gley soils can have higher soil screening values for Cu and Pb, since these soils have a strong sorption capacity and the risk for groundwater contamination will be less.
- The K_ds determined during this investigation showed a strong correlation with soil pH and therefore, soil pH can be used to refine the Phase 2 soil screening values.
- The potential risk that a contaminant may pose to groundwater can be assessed by determining the soluble fraction of the contaminant in the soil. A 1:2.5 deionised water extract can be conducted on soil samples during the Phase 1 screening level assessment, and the results can be compared to the Water Quality Guidelines for the specific contaminant to indicate potential risk for groundwater contamination.

Further reading:
To order the report, ***Evaluation of partitioning coefficients for South African soils to inform the National Framework for Management of Contaminated Land with emphasis on the protection of water resources*** (**Report No. 2102/1/13**) contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za, or Visit: www.wrc.org.za to download a free copy.