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Simplified method for prediction of the oral bioaccessibility of metals and metalloids in soils

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This document was prepared by Technical Committee ISO/TC 190, *Soil quality*, Subcommittee SC 7, *Impact assessment*.

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Introduction

Soils enriched with metals and metalloids such as arsenic (As), cadmium (Cd), and lead (Pb) pose a potential threat to human health if they are directly ingested or transferred through food. Incidental ingestion of soil particles is considered an important exposure pathway of metals and metalloids, more specifically for children through outdoor hand-to-mouth activities. In the current context of managing polluted sites and soils, assessing human health risks from the ingestion of contaminated soil particles remains a challenging area, with significant uncertainties in the methods used to protect public health. In some countries, current practices of risk assessment are based on total concentrations of metals and metalloids measured in soils. However, it is known that only a fraction of these metals and metalloids, i.e. the bioavailable fraction, is assimilated by the body and is likely to induce a toxic effect. Estimating exposure based on the total concentration of metals and metalloids therefore leads to overestimating the risk and possibly misclassifying sites as being at risk. This overestimation leads to excessive measures and costs in terms of management of these sites.

Taking into account the bioavailability of metals and metalloids in soils makes it possible to better assess exposures and risks and thus optimize the management of associated sites. Bioavailability is in practice estimated by the measurement of bioaccessibility, i.e. the soluble fraction that can be released into the gastrointestinal tract and that can reach the bloodstream. Methods have been developed and validated to mimic the availability of metals and metalloids in the human gastrointestinal tract. These in vitro laboratory tests simulate in vivo results. Among these methods, ISO 17924 is a reference method for assessing the oral bioaccessibility of As, Cd and Pb. Because ISO 17924 involves high technical skills and requires numerous chemical and biological reagents to mimic biochemical conditions in the gastrointestinal tract, it can often only be used for a small number of samples. If bioaccessibility needs to be estimated on many samples, a simplified method to predict bioaccessibility is of great interest, in particular for reasons of time and cost.

It has been clearly shown that the bioaccessibility of metals and metalloids in soils critically depends on soil type, their chemical speciation, and the solid-phase distribution in soils. Consequently, a simplified single-extraction method applicable to a range of soils regardless of their pedological, physical and chemical characteristics is needed. A simplified method to study jointly both the gastric and the intestinal phases is particularly advantageous.

This document provides a rapid, simple, and reproducible approach for predicting the bioaccessibility of metals and metalloids in gastric and gastrointestinal phases. The simplified method is specifically designed for As, Cd and Pb in soil samples, as assessed using ISO 17924, and relies on mathematical equations. These equations were derived from studies on French soil samples with a wide range of physicochemical parameters (in terms of texture, pH, content of organic matter and carbonates) and metals and metalloids concentrations (described in Reference [2]).

Digestion with hydrochloric acid (HCl) solution fulfils the criteria to be satisfied by an extractant for routine analyses. It is easy for analytical laboratories to use and reproduces conditions that are close to human physiological conditions (i.e. solid/liquid ratio, reagent, temperature, pH and residence time in the stomach). It can be applied to a wide spectrum of soils (in terms of physicochemical parameters) and elements (more specifically As, Cd and Pb) in a wide concentration range. This document differs from ISO 17924 in terms of application and methodology. More specifically, the simplified test can be used as a suitable proxy to predict the bioaccessibility of metals and metalloids in a first-tier screening on several soil samples. It is intended to help users to select a few samples (approximately 10 % of samples but can be as high as 20 % to 30 % depending on the size of the starting sample, heterogeneity of total concentrations and context, e.g. high pH values, high carbonate content) in a second-tier study and as a validation approach complementary to the method defined in ISO 17924 for better assessment of human exposure.

Because the ISO 17924 test has only been validated against in vivo data for As, Cd and Pb, the HCl test as described in this document is only validated for approximation of the oral bioaccessibility of these elements in soils. The simplified method could potentially be used for other elements; however, because no validation exists for the other metals or metalloids, the data obtained could only be considered as a useful line of evidence in interpreting results.