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# Assessment of health risks due to arsenic from iron ore lumps in a beach setting

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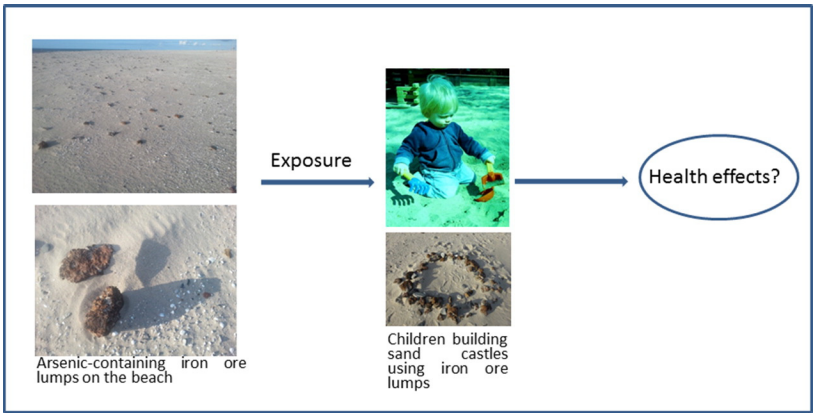
## HIGHLIGHTS

- Arsenic containing iron ore lumps on the beach raises concern about possible human health effects.
- Specific exposure scenarios related to playing with iron ore lumps on the beach have to be developed.
- By lack of consensus on the reference dose three different types of assessments have been evaluated.
- Unacceptable human health risks due to exposure to arsenic from the iron ore lumps are unlikely.

## GRAPHICAL ABSTRACT

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## ABSTRACT

In 2011, an artificial hook-shaped peninsula of 128 ha beach area was created along the Dutch coast, containing thousands of iron ore lumps, which include arsenic from natural origin. Elemental arsenic and inorganic arsenic induce a range of toxicological effects and has been classified as proven human carcinogens. The combination of easy access to the beach and the presence of arsenic raised concern about possible human health effects by the local authorities. The objective of this study is therefore to investigate human health risks from the presence of arsenic-containing iron ore lumps in a beach setting. The exposure scenarios underlying the human health-based risk limits for contaminated land in The Netherlands, based on soil material ingestion and a residential setting, are not appropriate. Two specific exposure scenarios related to the playing with iron ore lumps on the beach ('sandcastle building') are developed on the basis of expert judgement, relating to children in the age of 2 to 12 years, i.e., a worst case exposure scenario and a precautionary scenario. Subsequently, exposure is calculated by the quantification of the following factors: hand loading, soil-mouth transfer effectivity, hand-mouth contact frequency, contact surface, body weight and the relative oral bioavailability factor. By lack of consensus on a universal reference dose for arsenic for use in the stage of risk characterization, three different types of assessments have been evaluated: on the basis of the current Provisional Tolerable Daily Intake (PTWI), on the basis of the Benchmark Dose Lower limit (BMDL), and by a comparison of exposure from the iron ore lumps with background exposure. It is concluded, certainly from the perspective of the conservative exposure assessment, that unacceptable human health risks due to exposure to arsenic from the iron ore lumps are unlikely and there is no need for risk management actions.



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## 1. Introduction

### 1.1. Background

In 2011, an artificial hook-shaped peninsula of 128 ha beach area was created along the Dutch coast at Ter Heijde (near The Hague) for coastal protection. Through natural processes such as wind, sea currents and tidal activity, it is expected that the newly formed beach surface area will grow with an additional 35 ha in the future (The Sand Motor, 2016). As building material, 21.5 million $m^3$ of sand were taken from the sea bed of the North Sea, 10 km off the coast. This sand, however, included thousands of iron ore lumps, which are now present on the beach surface in a more or less regular pattern (Fig. 1), and are probably also present under the surface layer. The iron ore lumps show irregular forms; the dimensions range from grit size up to a maximal length of 30 cm.

Iron ore lumps are iron-containing sedimentary deposits with red-ochre-yellowish colours (Fig. 2), which have been formed since the early Pleistocene. In addition to tens of percents of iron, deposited out of the water, and to sand, silt or clay, it generally includes a series of additional chemical compounds. One of these compounds is arsenic, which is strongly adsorbed by goethite (α-FeOOH) and magnetite (Fe3O4). Consequently, the arsenic in the iron ore lumps on the beach is from natural (not anthropogenic) origin.

### 1.2. Human health risks

Arsenic is a metalloid that occurs in the environment and in food products in different chemical forms. Elemental and inorganic arsenic have been classified as carcinogenic to humans, Group 1 (IARC, 2012), which implies that there is sufficient evidence of carcinogenicity in humans from epidemiological studies. These studies have shown inorganic arsenic compounds to cause cancer of the lung, urinary bladder, and skin. In addition, a positive association has been observed in these studies between exposure to inorganic arsenic and cancer of the kidney, liver, and prostate. The toxicity at low levels is one of the reasons that arsenic holds the highest ranking on the current U.S. Agency for Toxic Substances and Disease Registry 2013 substance priority list (ATSDR, 2013). This list represents, in order of priority, 275 substances which are most commonly found at facilities on the National Priorities List (NPL) for soil pollution in the USA and which are determined to pose the most significant potential threat to human health due to their known or suspected toxicity and potential for human exposure at these NPL sites.

The combination of easy access to the beach, including the possibility of human contact with the iron ore lumps, e.g., when children use the lumps as building material for sand castles, and the presence of arsenic raised concern about possible human health effects by the local authorities.

**Fig. 1.** View of the artificial peninsula along the Dutch coast at Ter Heijde (near The Hague) with iron ore lumps on the surface.

**Fig. 2.** Frontal view of an iron ore lump (with a pen shown for scale).

### 1.3. Delineation and objective

The concentration of arsenic in the upper layer of the sand was low, i.e., comparable to amounts found at locations not impacted by anthropogenic activities, elsewhere in The Netherlands. Average and median values were 3.0 and 2.7 $mg/kg_{DW}$, respectively (University of Utrecht; unpublished data). The $95^{th}$ percentile and the maximal value were 5.6 and 6.3 $mg/kg_{DW}$, respectively. These higher end concentrations are substantially lower than the $95^{th}$ percentile of the background concentration of 20 $mg/kg_{DW}$, found in 'relatively undisturbed soils' in agricultural areas and nature reserves in The Netherlands (Lamé et al., 2004). The same conclusion holds for several other investigated metals.

The artificial, hook-shaped peninsula includes a small lagoon. The level of arsenic in the water of this lagoon was also low. The maximal values measured were 5.2 μg/L (Royal Haskoning; unpublished data) and 11.0 μg/L (University Utrecht; unpublished data) (referenced in Van Bruggen et al., 2014). These high-end concentrations are of the same order of magnitude as the current drinking water standard of arsenic of 10 μg/L. Since it is unlikely that individuals drink the brackish water from the lagoon in substantial amounts on a regular basis and arsenic does hardly permeate through the skin, the human health risk from exposure to arsenic in lagoon water are assumed negligible.

As a consequence, the focus on this study is on the iron ore lumps on the beach surface. The objective of this study is defined as follows: to investigate human health risks from the presence of arsenic-containing iron ore lumps in a beach setting.

## 2. Materials and methods

### 2.1. Measured concentrations

Seven iron ore lumps have been collected. Since the iron ore lumps originate from the same location in the sea bed, and hence have been formed in the same geological epoch, it is assumed that variation in arsenic concentration between the lumps is relatively limited. Moreover, particular likely places for playing on the beach could not be identified; the whole beach stretch is more or less appealing for children (and adults) to access and to recreate. Therefore, the iron ore lumps were taken at arbitrary locations.

The total arsenic concentrations in five iron ore lumps have been measured using XRF (X-ray fluorescence). To evaluate the relatively inaccurate XRF measurements, the arsenic concentrations in two