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Dynamics of metals bound to suspended sediments in floods and on channel banks of the ephemeral Wadi Sekher, northern Negev desert, Israel

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ABSTRACT

This study examines the variation in the concentration of eight heavy metals (Cu, Ni, Pb, Cd, Cr, Co, V, Sc) bound on suspended sediments during flow events and those deposited in channel banks. The study was undertaken in Wadi Sekher, an ephemeral flash-flood channel draining the Neot Hovav industrial chemical complex in the semi-arid northern Negev, Israel, at sites varying with bank height and distance from the industrial complex.

Metal concentrations were found to be higher in the initial flow and recession than during peak flow. Bound metal concentrations were mainly affected by suspended sediment composition and concentrations. During peak flow the suspended sediment concentration rises and quartz sand is a major constituent. This leads to a decrease in bound metal concentrations, as the larger particles have a weaker affinity to binding. In six sediment samples, taken during the first 15 min of two floods, the bound metal concentrations changed similarly. These changes are suggested to represent variations in the source and cannot be attributed to dilution or binding effects.

Six banks were sampled along Wadi Sekher, from the Neot Hovav hydrometric reach downstream to the confluence of Wadi Sekher and Wadi Beer-Sheva, at specified heights, following a bank-full flood. In every cross-section, a significant difference ($p < 0.01$) was seen in Cu, Cd, Co, V and Sc concentrations with bank height, with highest concentrations at bank-bed intersection. Downstream variations in bound metal concentrations along Wadi Sekher were statistically ($p > 0.05$) undifferentiated, indicating that the industrial area is not a source point for these metals, and that a constant input exists into the channel from tributaries along the channel.

Due to the difficulty in sampling flash floods in ephemeral channels, existing data are not abundant, and our understanding of these environments is therefore limited. This study improves knowledge of interrelated variations in bound metal concentrations in fluvial deposits, in suspended sediment and in water during flash floods.

1. Introduction

Semi-arid environments produce high sediment yields and high suspended sediment concentrations (SSC) in runoff due to their high vulnerability to erosion; they are among the most erodible landscapes worldwide (Langbein and Schumm, 1958). Suspended sediment concentrations in drylands may reach 100–400 g/l (Benkhaled and Remini, 2003; Fisher and Minckley, 1978), in comparison to humid environments where concentrations usually do not exceed 1 g/l (Walling and Fang, 2003). These high SSC's are related to sparse vegetation, surface crusted soils, surfaces with low permeability or bare rock, trampling of the surface by animal herds and relatively high rainfall intensities. In addition, long intervals between rain and flow events enable fine aeolian sediment buildup on hillslopes (Alexandrov et al., 2009a; Bullard, 2005). Surface alteration due to intensive agriculture and removal of natural vegetation may also result in high sediment yields (Alexandrov et al., 2009b).

Heavy metals in aquatic environments are mostly associated with particulate matter. Altogether 90–99% of the total metal load in rivers is transported in the particulate phase, and specifically with the finer-grained fractions (Miller, 1997; Miller et al., 1998; Walling and He, 1998; Zhang et al., 2016). This tendency is attributed to various chemical and physical factors, particularly to the low activity of heavy metal ions in aqueous solutions and to the large surface area of small suspended particulates. It also depends on cation-exchange capacity, surface charge, concentration of iron and manganese oxides and

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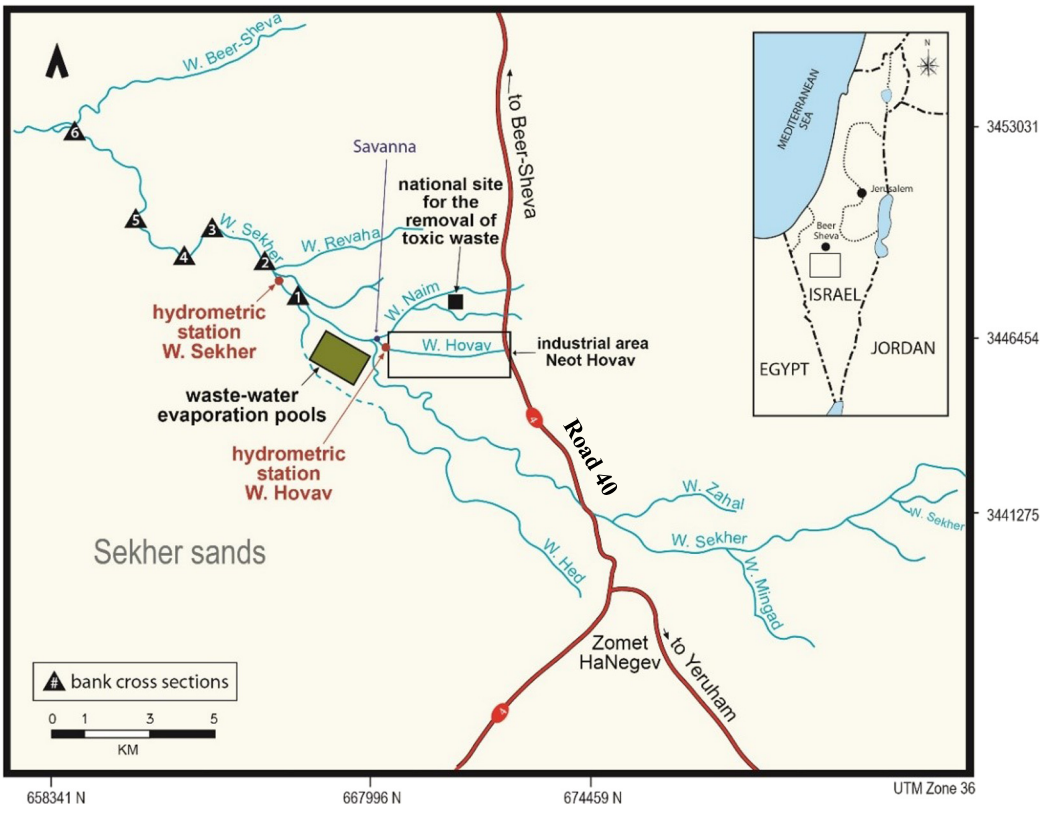

Fig. 1. Map of study area: Wadi Sekher from the confluence with road 40 to Wadi Beer-Sheva; Neot Hovav industrial area; waste-water evaporation pools; confluence of Wadi Sekher-Wadi Naim-Wadi Hovav; Savanna;hydrometric station on Wadi Sekher; locations of sampled bank cross-sections (1–6).

hydroxides, organic matter content and the concentration of clay minerals (Marron, 1989; Miller, 1997; Miller et al., 1998; Sparks, 1995).

Heavy metals transported in the particulate phase or bound to suspended solids constitute a major environmental risk due to their prolonged residence time in river sediments - tens to thousands of years (Hudson-Edwards et al., 2001; Lecce and Pavlowsky, 2014; Macklin et al., 2006; Taylor et al., 2009). Banks and floodplains can become secondary repositories, while fluvial processes of sediment transport, bank erosion, sedimentation on floodplains and channel changes reintroduce contaminated material into surface waters years after their initial release and after their sedimentation in the fluvial system (Dennis et al., 2003; Dhivert et al., 2015; Guan et al., 2016; Macklin et al., 2006; Turner et al., 2008).

The measurement and sampling of flashfloods in arid areas is logistically difficult due to their sporadic nature, their very fast appearance and disappearance and the automation required for the sampling of transported sediments. These difficulties result in limited studies carried out in arid, ephemeral channels (Alexandrov et al., 2003). Even fewer studies concern the fate of metallic elements in the fluvial system (Taylor and Hudson-Edwards, 2008). Often, studies of sediments in these environments are undertaken by sampling the channel bed when it is dry, but not during flow events (Cohen and Laronne, 2005). Such studies can determine the spatial distribution throughout the channel, but do not provide information concerning temporal changes in suspended sediment concentration and bound metal concentrations during flow events. Therefore, our understanding of the interrelated variations in bound metal concentrations in fluvial deposits, in suspended sediment and in water during flash floods is limited.

In the semi-arid northern Negev, Israel, suspended sediments have been shown to comprise 90% of the total sediment load (Alexandrov et al., 2003; Alexandrov et al., 2009a; Miller, 1997; Schwartz and Greenbaum, 2009), and to have high concentrations. For example, in Wadi Eshtemoa SSC values as high as 229 g/l were measured (Alexandrov et al., 2003); in Wadi Bikhra almost 60 g/l and in Wadi Sekher 223 g/l (Alexandrov et al., 2009a). All three Wadis are located in the northern Negev.

The Neot-Hovav industrial area is situated in the northern Negev Desert, Israel (Fig. 1). This industrial area comprises multiple chemical industries, and is drained by the ephemeral Wadi Sekher. The potential pollutant source (Neot Hovav industrial area), the flash flood characteristics of a dryland ephemeral channel draining the area and its high suspended sediment concentrations are conditions that have hitherto not been investigated. Hence, our research objectives were 1) examine temporal variations in bound heavy metal concentrations in suspended sediments transported during flow events and in sediments deposited on channel banks after flow events, and 2) determine whether heavy metals are contributed to Wadi Secker from the Neot Hovav industrial area, Israel.

2. Materials and methods

2.1. Study area

This study focuses on Wadi Sekher, located in the northern Negev desert, Israel (Fig. 1), an ephemeral stream flowing northwestwards to Wadi Beer-Sheva. It drains the Neot Hovav (formerly termed Ramat Hovav) industrial park, which includes various chemical industries, including those of pharmaceuticals, pesticides and fertilizers. Since 2005 industrial effluents do not surface in the channels surrounding the industrial area due to the deployment of several drains. The solute