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An Investigation Into The Level Of Heavy Metals Leaching From Canal-Dreged Sediment: A Case Study Metals Leaching From Dreged Sediment

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Abstract. A batch leaching test was performed to measure the leached concentrations of chromium (Cr), lead (Pb), arsenic (As), nickel (Ni), copper (Cu), cadmium (Cd), and zinc (Zn) from dredged sediment samples from the Leeds & Liverpool canal/ Liverpool section. The obtained results confirmed that the leached concentrations of the studied heavy metals were less than the toxicity levels and followed the order: Zn > Cu > Ni > Pb > Cr > As > Cd. The highest concentration was of Zn (about 0.28 mg/L), followed by Cu at a concentration of 0.17 mg/L, while the lowest concentration was of Cd at 0.009 mg/L. Therefore, the dredged sediments from this canal can be safely relocated in dumping sites such as landfills, or reused such as by spreading on agricultural fields.

Key words: Dredged sediment, leaching test, heavy metals, toxicity level

1. Introduction

Accumulation of sediments in the beds of bays, canals, rivers, and navigable harbours negatively influences the commercial growth of these areas and causes floods, [17, 27]. Therefore, accumulated sediments in these waterways need to be dredged on a regular basis in order to maintain navigable waterways and to prevent floods [3, 24, 26]. Globally, dredging processes produce about 600,000,000 m^3/year of sediments, [25]. For instance, in the region of Nord-Pas de Calais in France more than 1,000,000 m^3 of sediment is dredged yearly and more than 30% of this massive amount is polluted, [24]; about 8,000,000 m^3/ year is dredged in Tunisia, [25]. Additionally, about 4,000,000 m^3/ year is removed from the Grand Canal in Hangzhou, [9].

Bottom sediments contain elevated concentrations of different pollutants such as heavy metals, phosphorus, and organic toxicants, [1, 9, 14]. The occurrence of such pollutants is attributed to the long-term drainage of municipal and industrial wastewater, [11, 21, 27], anthropogenic activities, [20, 30], agricultural runoff from adjacent grounds, [1,12, 16] and atmospheric deposition, [1, 4]. Among these different types of pollutants, the pollution of aquatic environments (sediments or water column) by heavy metals is a grave concern due to their high toxicity, persistence, and abundance, [11, 15, 20, 30]. Moreover, some benthic organisms, flora and fauna, accumulate heavy metals in their bodies to toxic levels, which in turn enter the human food chain, causing a variety of different health problems, [15]. It is well documented that the occurrence of heavy metals in aquatic systems near urban areas is

extensive and is increasing due to the increasing growth of industrial and anthropogenic activities, [5, 15]. Hence, dredged sediments must be managed and disposed of safely, taking into account health, environmental and economic impacts, [2]. Typically, there are two alternatives for the disposal of dredged sediments, depending on their pollutant content and their chemical and physical properties. Firstly, reuse of the clean sediments, such as for reclamation of land and production of paving blocks, [2, 25]. While the second alternative is the permanent relocation of polluted sediments, such dumping them in landfills or placing them in an open aquatic site, [2, 26]. For economic purposes, most of the dredged sediments were placed in proper disposal sites, [26]. Nowadays, dumping of heavily polluted dredged sediments in landfill sites is considered the best cost-effective alternative, [3]. However, disposal of highly polluted dredged sediments poses a threat to the surrounding environment due to the leaching of metallic contaminants that provokes negative environmental impacts on surface and groundwater, [8, 13]. In the case of dumping into open water sites, more damage will be caused to the benthic organisms, flora and fauna, and to the aquatic systems, [13, 26]. Moreover, the heavy metals that accumulate in living organisms may enter the food chain, which in turn poses a direct threat to human health, [12, 20]. For instance, high concentrations of cadmium and zinc were found in the leaves of plants growing on dredged sediment landfill (near the river Leie) and elevated concentrations of cadmium were found in small mammals in the area.
Therefore, the objective of the current study is to determine the concentrations and leachability of some heavy metals in dredged sediments from the Leeds & Liverpool canal / Liverpool section in the United Kingdom and compare the results with the standard regulations, which in turn provide the required information to select an environmentally sound disposal alternative. The leachability of heavy metals was measured using a batch leaching test (method DIN 38414-S4).

2. Materials and Methods

2.1 Description of the study area
The Leeds & Liverpool canal lies in the North of England, connecting the cities of Leeds and Liverpool, and has a total length of 204 km (Figure 1). The construction of this canal began in 1770 and was completed in 1816 and then extended in 1822 due to the growing trade in the area (LLCSC, 2006).

This canal was selected as a case study because it has experienced heavy industrial traffic during its lifetime; for instance, it was used to carry several types of goods such as grain from Birkenhead and Liverpool to Lancashire (LLCSC, 2006). Moreover, nowadays it experiences leisure traffic: the central part of this canal annually receives about 1800 boats, and about 1000 boats at the Leeds end (BMD, 2008). Therefore, the sediments of this canal may contain non-negligible concentrations of pollutants such as heavy metals.

Figure 1. Leeds & Liverpool canal

2.2 Leaching test

Leaching is defined as the mechanical or chemical percolation of a constituent of waste from the stabilized layers to the ambient environment due to the passage of water or other solvents, [19], i.e. it simulates the influence of acidic rain on the waste, [8]. Leaching tests have been widely used to determine the potential of organic and inorganic wastes to leach dangerous concentrations of heavy metals into the environment, for example, to measure the leachability of heavy metals from contaminated sediments, [7, 28] and sludge, [22]. Moreover, this test has been widely used to measure the leachability of heavy metals from wastes that were used in asphalt, stone matrix asphalt, soil stabilization, and paving blocks, [19, 29].

In this study, a batch leaching test has been applied according to the standard method DIN 38414-S4 (Qi *et al*., 2011) to measure the leached concentrations of chromium (Cr), lead (Pb), arsenic (As), cadmium (Cd), nickel (Ni), copper (Cu), and zinc (Zn) from dredged sediment samples from the Leeds & Liverpool canal / Liverpool section. These heavy metals have been selected as model pollutants because they have high environmental concern, [10].

Sediment samples were collected during April 2016 from three sites, selected randomly, along the canal path inside Liverpool city (Figure 2). Three 500 g samples of sediments were collected from each studying site; placed in sealed plastic containers and sent to the laboratory.

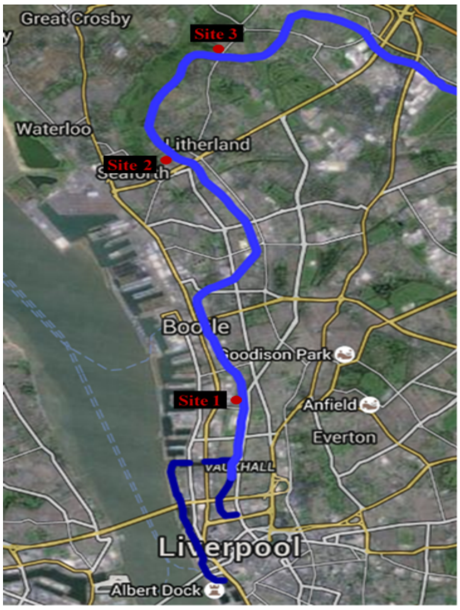

Figure 2. Samples collection sites.

2.3 Pre-treatment and analysis of samples

The 500 g samples of the dredged sediments were dried at 105 0C for 24 h in order to exclude the extra moisture. Then, each specimen was crushed using an automatic desktop mortar and pestle crusher (type: Pascall) and sieved to obtain the required particle size (0.3 mm).

According to the DIN 38414-S4, [23], the leaching test should be carried out at water/ solid ratio of 10:1 (water: solid). Therefore, the current investigation was started by pouring 150 mL of deionized water into a 0.25 L conical flask that already contains 15 g of the crushed sediments. Then, these flasks were tumbled at 30 rpm in a rotary extractor (type: Labnet 222 DS) for 24 h at a constant temperature of 25 ^{0}C (Figure 3). At the end of the tumbling process, the mixture was centrifuged for 30 min at 4500 rpm using a centrifuge device (type: Sigma 3-16 PK). The mixture was left to rest for 15 min and then filtered through 0.6 μm filter paper; 1 mL of nitric acid was used to acidify the collected filtrate and then it was refrigerated. The concentrations of the targeted heavy metals were

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measured using an atomic absorption spectrophotometer (type: Thermo, Model: ICE 3300). Figure 4 shows a Flow chart of Leaching Test according to DIN 38414-S4.

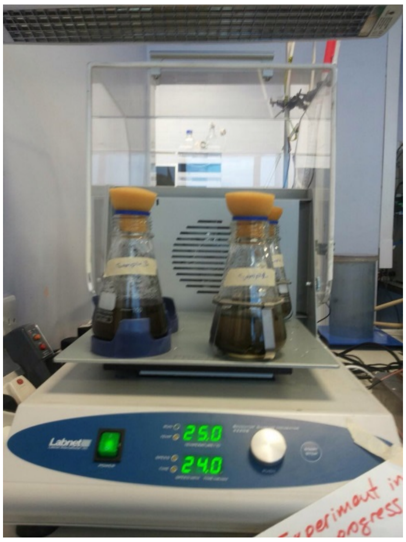
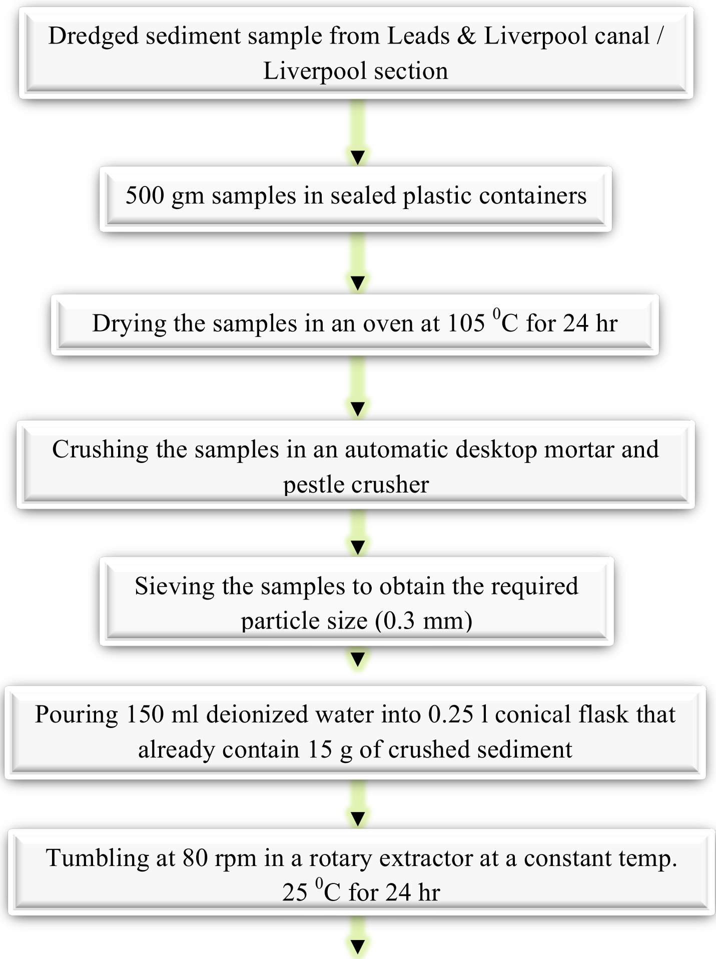


Figure 3. Set of samples under tumbling conditions (type: Labnet 222 DS) for 24 h at a constant temperature of 25 ^{0}C.



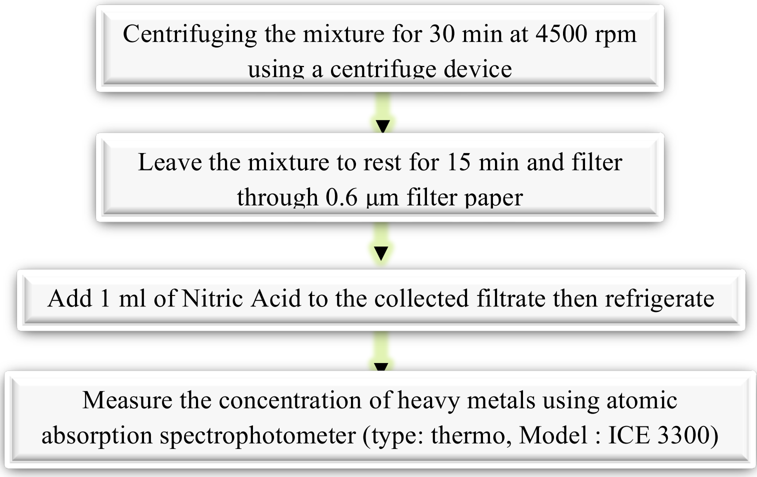


Figure 4. Flow chart of Leaching Test according to DIN 38414-S4

3. Results and Discussion

As mentioned before, the leaching test was performed in order to measure the leachability of some heavy metals from the dredged sediments from the Leeds & Liverpool canal / Liverpool section. This test provides the required information to select the best disposal alternative.

Figure 5 points out that among the studied heavy metals; Zn has the highest concentration (about 0.28 mg/L), followed by Cu at a concentration of 0.17 mg/L, while Cd has the lowest concentration.

Additionally, Figure 5 shows that there was no significant variation amongst the three sites in terms of heavy metals concentration.

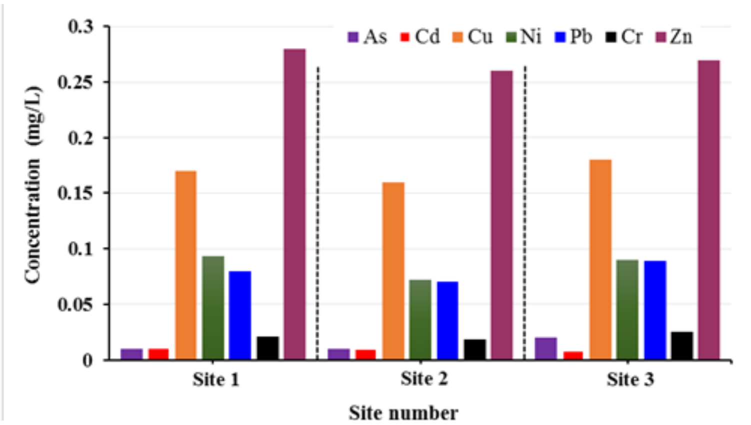


Figure 5: Concentration of the studied in the studied sites.

ments together with the permissible levels of the United States Environmental Protection Agency (USEPA, 1992).The concentrations of the studied elements were within the allowable limits. Standard limitations for the Cu, Zn, and Ni were taken from the Hong Kong regulatory levels, which were listed by, [19].

These low heavy metals concentrations could be attributed to the strict environmental regulations that were recently applied to this canal, where it is forbidden to discharge any industrial or municipal wastewaters into this canal. Moreover, use of this canal has been limited to leisure purposes.
Based on the obtained results, the dredged sediments can be categorized as safe wastes and can be used in soil stabilization, production of some construction materials such as paving blocks, or can be merely disposed of into landfills.

Table 1. Concentration of the studied elements and the regulatory levels

Element	***As***	***Cd***	***Cu***	***Ni***	***Pb***	***Zn***	***Cr***
Average concentration (mg/l)	**0.013**	**0.009**	**0.170**	**0.085**	**0.079**	**0.27**	**0.021**
Permissible concentration (mg/l)	**5**	**1**	**25**	**25**	**5**	**25**	**5**

4. Conclusion

The obtained results indicated that the leached concentrations of the studied heavy metals were less than the toxicity levels and followed the order: Zn > Cu > Ni > Pb > Cr > As > Cd.

Based on the obtained results, it can be concluded that the dredged sediments from the three selected sites of Leeds & Liverpool canal/ Liverpool section can be safely relocated to dumping sites such as landfills, or reused such as by spreading onto agricultural fields.

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