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Exploring the Toxic Legacy of Urbanisation: Investigating Heavy Metal Contamination in Saida's Urban Sediments

Belaid Fatmi*, Abdelkrim Hazzab

Modelling and Computational Methods Laboratory, University of Saida Dr. Tahar Moulay, Saida, Algeria
*Correspondent author email: belaidfatmi1@gmail.com

ABSTRACT

This study investigated urban pollution in the watershed of the city of Saïda, located in northwestern Algeria, focusing on heavy metals and organic pollution in sediments from urban drainage. The results identified, characterised and quantified these pollutants by comparing the total trace metal content of sediment samples with standards and reference values. They also highlighted the cycle of pollution generation and regeneration in the urban catchment, influenced by rainfall events and sediment extraction periods, and demonstrated the role of the drainage network as a physico-chemical reactor in the mobilisation of pollutants. The extent of pollution is assessed using pollution indices and factors, which showed high concentrations of various metals in the sediments, indicating significant pollution. Contamination levels ranged from very high for cadmium to moderate to high for lead, copper and chromium, while zinc and nickel showed low contamination. Conversely, cobalt and iron showed no contamination, but the sediments remained highly contaminated according to the contamination criteria. The results showed an anthropogenic enrichment exceeding critical thresholds and an ecological risk ranging from high to severe.

Keywords: Urban pollution, heavy metals, sediments, anthropogenic enrichment, ecological risk.

1 Introduction

Due to the significant disruptions and changes in urban activity, urban managers and health professionals are now prioritising the control of urban pollution[1]. Many of the environmental problems associated with urban pollution are exacerbated by rainfall, when both its qualitative and quantitative indicators are at their highest[2]. Particles and sediments are the primary transporters of organic and mineralogical pollution, and they carry this pollution. Wastewater, sediment deposits from the dry weather network, and visible and dissolved pollutant loads carried by runoff have all been recognised as sources of pollution in urban areas[3]. Enhancing knowledge of the origins and consequences of pollution in Algeria's urban environment is the aim of this study. Saida, which is located in western Algeria, was selected as the center of attention because of its significant industrial and urban growth, which increased traffic and pollution levels. Using particle pollutants found in urban runoff sediments, the study aims to identify the sources of pollution and the paths taken by pollutants as they migrate.

The goal of the experimental strategy is to identify, describe, and measure the amounts of contaminants especially heavy metals in sediments that come from urban wastewater treatment plants. The investigation aims to address many questions, including the most likely sources of pollutants, the most common contaminants and their concentrations, the granulometric fractions associated with heavy metal pollutants, the temporal variations in pollutant levels, and the contributions from diverse pollution sources.

2 Experimental

The sediments studied came from the outlet of the urban basin of the city of Saida, and the sampling period was chosen to coincide with the first rainy season (September-January). The granulometric analysis was carried out using stainless steel sieves ranging from 63 to 250 µm, and the organic matter content was measured by weight loss after calcination at 550°C, according to standard NF EN 12879. Trace elements are dissolved by acid etching according to standard NF EN 13346 and then measured by atomic absorption spectrometry according to standard NF EN ISO 11885. Two methods are used to assess the level of contamination: a chemical assessment based on the contamination factor, enrichment factor and geo-accumulation index, and an ecological risk assessment based on the ecological risk index and ecological potential.

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3 Results and Discussion

The sediment samples are analysed and found to contain colloids, microorganisms and plant debris[4]. The organic matter levels range from 3.10 to 13.04%. Coarse sediments (> 250 µm) exhibit higher levels of organic matter due to initial leaching and biofilm formation. The heavy metal levels, particularly iron content, are higher than UCC reference levels due to anthropogenic causes. A temporal evaluation conducted over three episodes indicates that pollution originated from multiple sources initially, decreased, and then regenerated (Fig.1). This demonstrates the complex relationships between heavy metals, organic matter, and sediments.

During rainfall events, three distinct phases of urban catchment pollution can be distinguished. First, pollution is increased by the exchange of particles and pollutants caused by the flushing of sediments from runoff and deposits from sewer networks (Fig. 3) [5]. In the second episode, the pollutants are transported by the network, which is also characterised by a decrease in sediments and organic matter and an increase in surface leaching (Fig. 2). The network is again active as a physico-chemical reactor in the third episode, which shows a significant accumulation of sediment and an increase in the metal load in organic matter[6]. While the findings for lead, copper, and chromium are moderate to highly polluted, a more detailed qualitative evaluation utilizing the contamination factor and geo-accumulation index values reveals that cadmium is extremely contaminated. The geo-accumulation index values for zinc and nickel indicated little pollution.

Sediments are unaffected by iron and cobalt contamination. However, the sediments are highly contaminated in terms of the degree of contamination. The results also show that there is anthropogenic enrichment, as the enrichment factor values are higher than the critical value. The same results indicate that there is a serious ecological risk associated with the sediments, with a potential risk rating of high to severe. High levels of pollution are found in the urban area under investigation, especially from lead, zinc, chromium, cobalt, copper, nickel, and cadmium, according to a comparative examination. With concentrations as high as 2.48 mg/kg, cadmium surpasses the guidelines limits. Similarities with other Mediterranean basins are revealed through comparisons, indicating comparable pollution sources. The anthropogenic causes of lead and zinc excesses over the standard levels. Natural-origin iron remains stable.

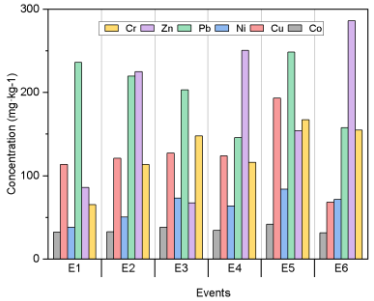

Figure1: Variability of metals concentrations in the fraction (<63 µm)

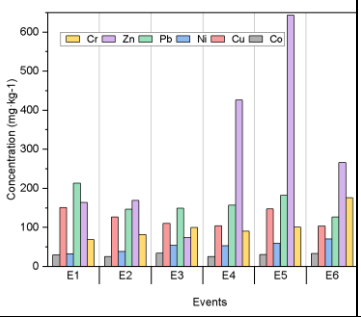

Figure2: Variability of metals concentrations in the fraction (63 - 250 µm)

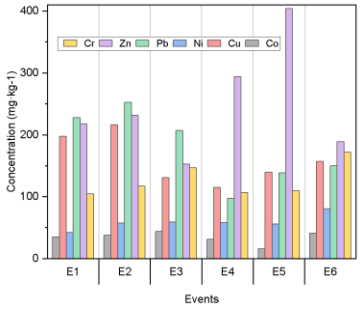

Figure3: Variability of metals concentrations in the fraction (>250 µm)

4 Conclusions

The study results revealed that the accumulation of sediments in the sewer system and urban surfaces during dry periods contributes to the high metal concentrations observed. Physico-chemical exchanges influenced by environmental conditions regulate the sediment balance in sewers, acting as both a reactor and transporter. While iron levels remained below average, other metals exceeded reference values, indicating anthropogenic inputs. Pollution factor and index analyses showed very high contamination levels in the area, posing ecological risks particularly for cadmium. The findings confirm the need for preventive actions to control heavy metal pollution in catchment sediments. Regular contaminant monitoring and targeted remediation efforts focusing on industrial and urban pollution sources are needed. Improving wastewater

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infrastructure while promoting responsible public practices could help limit metal inputs and sediment contamination.

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