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Assessing the toxicity of virgin aggregates leachate versus dredged sediments leachate in backfill application

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ABSTRACT The replacement of virgin aggregates has been embedded into several environmental strategies around the world. The high demand for these materials leads to several substitutions with different materials from various sectors. Waste valorization is one of these alternatives. However, the use of such material has several environmental restrictions due to the fact of containing a few distinct pollutants (Ex: As, Ba, Cd, Cr, Cu, Hg, Pb, Zn...). These pollutants can lead to toxicity impacts on humans and freshwater. In France, non-submersible dredged sediments have been used in different applications (backfill, concrete, and others). As a consequence of being contaminated with heavy metals and other pollutants, sediments usage as backfill is constricted by certain environmental requirements (SETRA, 2011). This paper aims to assess the toxicity beyond using dredged sediments in backfill application as an alternative material for virgin aggregates. Comparing both material leachate effects on freshwater ecotoxicity and human health toxicity. Toxicity assessments were based on the USEtox impact assessment method (Bijster et al., 2018). Relying on life cycle assessment as a tool to evaluate the impacts beyond these two materials.

Keywords Virgin Aggregates, Dredged Sediments, Toxicity, USEtox, Life cycle assessment,

INTRODUCTION

Harbors, rivers, and water channels always require a permanent follow-up for their navigability. The previous actions were mainly shortened by simple dredging of sediments from one place and dumping them into another without taking into account the several environmental impacts that can be related to such practices. But as the threats are approaching more and more human health due to the presence of toxic pollutants in the sediment matrix, management of these sediments became restricted to specific ways that have certain conditions. Several policies are taken into action in different countries (As in Netherlands Germany, Norway, and France). These policies aim to prevent soils and freshwater from being contaminated (Palumbo, 2007). In France sediments are considered waste (Décret n°2002-540, 2002), then any action regarding their management must respect the waste management strategies as defined in the waste framework directive (WFD) (Directive 2008/98/EC, 2008). In 2021, the order of (June 4, 2021) sets out the

criteria for the removal of waste status for excavated soil and sediments that have been prepared for use in civil engineering or development respecting specific requirements. Around 250 million tonnes of sediments are dredged each year in the Western Europe area ("LIFE 3.0 - LIFE AGRISED Project," 2018). Then handling dredged sediments represent a big concern to the waterways and ports' authorities. Furthermore, the use of conventional aggregates causes additional negative environmental impacts, and as the demand for virgin material is increasing, many recent studies show the beneficial usage of dredged sediments as a replacement of virgin aggregates in the road, mortar and concrete applications (Achour et al., 2019; Kou et al., 2022; Wang et al., 2022; Zentar et al., 2008...). Therefore, this study aims to compare the toxicity beyond sediments' leaching and virgin aggregates' leaching. The study involved the USEtox impact assessment toxicity method as a characterizing model for the leaching impacts through these two different materials. Both materials were compared as road backfill materials.

MATERIALS AND METHODS

The dredged sediments leaching data used in this study is for dredged sediments taken from the harbor of the Dunkirk area (Achour et al., 2014). The non-submersible sediments are dredged and placed in the dehydration lagoons in the Dunkirk port area. The virgin aggregates' data is for sand extracted in a carrier in the Lille area. Both the sediments and sand used in this study are acceptable to be used as a backfill material according to SETRA thresholds (SETRA, 2011). They also achieve the required mechanical characteristics for use as a backfill as required in the GTR French technical guide (SETRA and LCPC, 2000). Sand and dredged sediments were assessed with a 1 ton as a functional unit. And USEtox method was used to assess the different toxicity impacts on human health and freshwater toxicity. Considering the leachate's direct impact on freshwater by using SETRA liquid to solid ratio (10L/kg) (SETRA, 2011) (Figure 1).

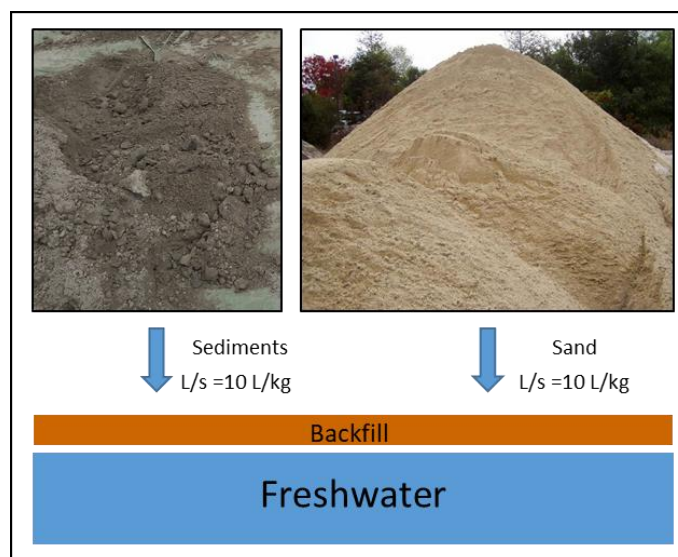


Figure 1. Leachate scheme (L/s: Liquid to solid ratio)

RESULTS AND DISCUSSION

The impacts were calculated in two main categories: Human toxicity (cancer and non-cancer) expressed in (cases) and freshwater ecotoxicity expressed in potentially affected fraction of species integrated over exposed volume and time (PAF.m3.day). The impacts beyond using sediments on the human toxicity levels were very close to the values in the scenario of using sand as a material for the backfill. While on the freshwater ecotoxicity level, the usage of sand shows higher impacts than that in the case where dredged sediments are used. Sand usage's toxicity was about 1.6 times the freshwater ecotoxicity for dredged sediment usage (Table 1). Freshwater ecotoxicity values reflect the high concentration of copper in the leachate of the virgin aggregates (0.95mg /kg of dry matter) in comparison with the dredged sediments' copper concentration (0.57mg /kg of dry matter). Knowing that copper has a characterization factor of 9.92E+06 PAF.m3.day for every one kg released into freshwater (Rosenbaum et al., 2008).

Table 1. Characterization Results

Impact category	Unit	Dredged Sediments	Sand
Human toxicity, cancer	cases	5.431E-08	5.787E-08
Human toxicity, non-cancer	cases	4.043E-06	4.545E-06
Freshwater ecotoxicity	PAF.m3.day	5.886E+03	9.491E+03

CONCLUSIONS AND PERSPECTIVES

The results show the importance of assessing virgin aggregates' toxicity, before any usage in a comparative nature with the available wastes that can be valorized or other alternative materials that can be used. The issue of materials availability and reachability remains one of the most important aspects to be studied, which gives a truly global assessment of the materials used as backfill.

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