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# Polluted river sediments from the North region of France: Treatment with Novosol® process and valorization in clay bricks

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**Abstract**

The paper presents results of studies on the valorisation of polluted river sediments from the North region of France. The first objective of this study is to validate the treatment of polluted sediments with the Novosol® process. This process is based on the stabilization of heavy metals in the solid matrix by phosphatation and the destruction of organic matter by calcination. The results of environmental tests carried out on treated sediments showed that polluted sediments became inert. In addition, the physical characterisations of treated sediments classify them as sandy silt. Thus treated sediments were used as a brick making raw material. The second objective of the study is to determine the optimal mix-design. Four mix-designs were studied with treated sediment ratio varying from 0% to 45%. Physical, mechanical and chemical properties of these bricks were evaluated. The results obtained indicated that sediment proportion is an important parameter in determining the brick quality. Increasing the sediment content resulted in a decrease of brick compressive strength (though it is still higher than that of standard brick) and a decrease of its resistance to freezing and thawing.

Leaching tests, performed according to different standards on substituted brick samples, showed that the quantities of heavy metals leached from crushed bricks were within the regulatory limits. The 35% ratio of substitution appeared to be the most effective considering physical, mechanical and chemical aspects.


*Keywords:* River sediments; Heavy metals; Phosphatation; Calcination; Clay bricks

## 1. Introduction

Channels and ports must be dredged regularly to maintain normal maritime and river activities, thus a great number of industries congest the channels by tipping sediments out [1]. Over the next 15 years, a volume of three million $m^3$ of polluted river sediments is to be dredged in the North of France. These sediments contain both organic and inorganic contaminants, which can end up in drains, rivers, and coastal waters, thus contaminating water resources and polluting the environment. The pollution of these sediments is linked to the industrial history of the region, where certain activities, like iron and steel industries, metallurgy of nonferrous ores and energy sectors, remain polluting. Since international and European laws have become more stringent, sediments have to be treated as waste material. Sea deposit will no longer be licensed as this causes serious damage to marine fauna and flora. Therefore, their management has become an environmental and economical concern for a large number of countries [2]. The dredging operation and the effect of dredged material disposal in open water have been largely investigated [3,4].

Storage in confined disposal facilities requires large spaces and long term monitoring. However, land filling is less accepted by the public opinion. Treatment processes permit a reduction in toxicity and volume of dredged material, but in comparison with open-water and upland dis-

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posal, the treatment cost is not yet competitive enough [5]. This underlines the necessity to find ecological valorisation paths for the processed sediments to make these alternatives economically competitive. Thus, researchers have started to study alternative ways to incorporate large amounts of processed sediments into different aspects of construction and building materials, where raw sediments have to be treated before being valorised.

In recent decades, several types of waste materials have been assessed as raw materials for brick making, for example lightly contaminated harbour sediments [6–8], reservoir sediments mixed with fly ash [9], dried sludge collected from industrial wastewater treatment [10–12], incinerated sewage sludge ash [13–15], fly ash [16], granite sawing waste materials [17], water treatment residuals with excavation waste soil [18] and steel dust [19].

Considering their perpetual availability, particle sizing and their chemical composition, sediments are regarded as a suitable raw material for brick production.

Clay bricks generally consist of natural clay and sand. This material can tolerate the presence of different types of waste materials even in considerable percentages. The present work aims at studying the feasibility of incorporating treated river-sediments, with different percentages, into the production of fired clay bricks. The influence of sediment proportion was therefore examined. We start with a description of the Novosol® process used for the treatment of polluted sediment. The next section deals with the characterisation of raw and treated sediments. Finally, experimental results and the incorporation of treated sediment in clay bricks are established.

## 2. The Novosol® process

In this study polluted sediments were stabilised using the Novosol® process (Fig. 1) which consists of two major phases: phosphatation and calcination. This process was developed and patented by the Solvay Company [20]. During the phosphatation phase, raw sediments are mixed with phosphoric acid $H_3PO_4$ (2–3.5%) in a tubular reactor. The addition of phosphoric acid allows, in the presence of calcite, the formation of calcium phosphates minerals.

These minerals are known for their low solubility and their ability to fix heavy metals [21]. Numerous studies have assessed the efficiency of these compounds for heavy metal remediation of contaminated soils [22,23], fly ashes and municipal solid wastes [24–28]. The calcination phase consists of calcining the phosphated sediments at $\geqslant 650$ °C in a rotary kiln, in order to break down the organic matter (polycyclic aromatic hydrocarbons, dioxins and pesticides). It increases the product toughness, reduces the volumes of processed materials after treatment and allows a better stabilization of metal phosphates. The treatment of one ton of raw sediments with a water content of 50% costs 75€.

Gaseous emissions resulting from the treatment process (essentially $H_2S$ and $CO_2$ and traces of heavy metals) are chemically treated using activated charcoal and sodium bicarbonate (Neutrec® double-filtration dry sodium bicarbonate process patented by Solvay for flue gas cleaning and recycling of residues [29]). Two types of solid waste are generated by this treatment: industrial waste incinerator (IWI) fly ash (20 kg per ton of sediment) and residual sodium chemicals (RSC: 7–13 kg per ton of sediment). The chemical composition of IWI is very complex (based on heavy metal oxides). This residue is chemically stabilised to be incorporated in road-building materials. The RSC are chemically treated and filtered where a raw brine and filtration cake are obtained. The brine is purified and injected into sodium carbonate production.

## 3. Characterization of raw and treated river sediments

### 3.1. Raw sediment

The sediments used come from the Nord-Pas-de-Calais region (France). Two types of sediments were analyzed. The first one ($A_{raw}$) was dredged in the channels of Lille, and the second one ($B_{raw}$) was taken from the river La Marque in the North of France. Table 1 gives the concentrations of heavy metals in these two types of raw river sediments, where five metal species of daily concern were selected (cadmium, chromium, copper, lead and zinc). French levels of reference, given by the Official Journal [30], are also reported in this table. Below level N1, the potential impact is regarded, in principle, as neutral or neg-

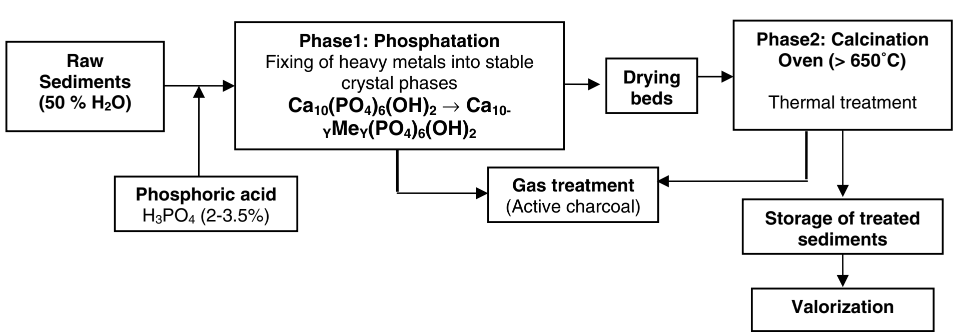


Fig. 1. Schematic representation of the Novosol® process.