TREATMENT OF DREDGED SLUDGE FOR DEMOBILIZATION OF POLLUTANTS, INCLUDING DEVELOPMENT OF METHODS FOR ASSESSING ITS EFFICIENCY

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ABSTRACT

Highly contaminated dredged harbour sludge has been mixed with lime, calcium carbonate, gypsum, waste kiln dust, cement, coal fly ash, and red mud for mechanical and/or chemical stabilization. Analyzing the products by electron microscope, microprobe and chemical extraction methods indicate, that new mineral formations fill the pores and stabilize the material. Heavy metals are incorporated into carbonates, sulfates and hydroxides; they show a shift in their phase specific bonding, but not always towards stronger fixation of metals than in the original material.

INTRODUCTION

The quantity of sediment which is dredged from the harbour of Hamburg amounts to about 2 million m^3 per year. The possibilities of disposal of these materials are severely limited because of the high concentrations of heavy metals and organic toxicants. At present upland deposition in heap-like form is favoured. This alternative demands minimization of emissions from leachates into the groundwater, which can be achieved by both hydraulic measures and by influencing mobility of pollutants. With respect to critical heavy metals, which are in part relatively weakly bound to the original sludge particles, it is assumed that their bonding strength can be positively influenced by chemical additives.

SAMPLE PREPARATION AND TEST METHODS

Dredged sludge from Hamburg harbour is primary classified by a combination of hydrocyclone and up-stream separation in uncontaminated sand and a highly contaminated mud fraction, which is dewatered up to a stiff consistency.

During the subsequent solidification tests non-hydraulic, hydraulic, potentially hydraulic and puzzolanic stabilization agents such as lime, calcium carbonate, gypsum, waste kiln dust, high-grade special cement, coal fly ash and red mud are added in concentrations of 5 to 20 w/w percent. The additives are mixed in individually and in various combinations. Mixtures are poured into prismatic moulds (40 x 40 x 160 mm) and are stored in a conditioning cabinet at 80% ±2.5 % humidity and 20°C ±0.5°C.

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After storage the solidified samples are tested and analysed by means of X-ray diffraction, scanning electron microscopy (+EDAX), electron microprobe, and proton-induced X-ray emission microprobe (PIXE) with respect to texture and structure, mineral content and balance sheet of materials as well as to get information about the sites of fixation of pollutants in the stabilized products. The specimen, prepared according to the test specificiations for building materials, are examined for physical parameters such as setting behaviour, change of volume, bending tensile strength, crushing strength and compressive modulus of elasticity.

RESULTS

Microscopical investigations of solidified samples in thin sections show affection of grain boundaries (reaction rims), mineral intergrowth, recrystallization of minerals and formation of new minerals, such as carbonates, sulfates, hydroxides, calcium silicate hydrate, calcium aluminate and sulfate hydrates.

While untreated air-dried sludge indicates a porous texture, the solidified samples, especially those being treated with hydraulic additives, show a kind of "bridging" between the sludge particles, consisting of acicular and fine fibrous hydration products. Oftenly the sludge particles are coated with hydration products and other new minerals, which also grow into the pores. Admixture of gypsum results in a "framework" of recrystallized gypsum in the micropores (Figures 1 - 3). These findings suggest, that solidification of the studied specimen is caused by the growth of new mineral phases forming an unorientated meshwork (intersertal texture), which are enclosing the sludge particles.

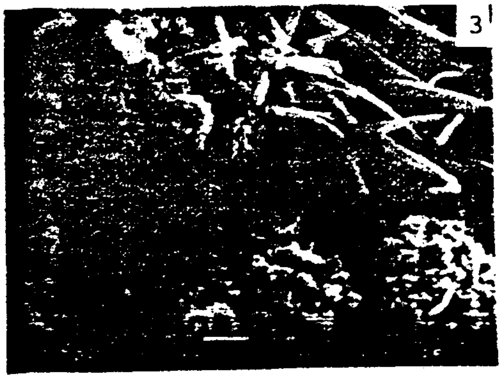

fig. 1
untreated air-dried harbour sludge

fig. 2
pore-filling of recrystallized swallotail gypsum twins

fig. 3
pore-filling of calcium silicate hydrates

Apart from mechanical solidification treatment with additives contributes to a variable degree of chemical stabilization of heavy metals. PIXE-graphs (which cannot be reproduced here due to the lack of colour printing) suggest that in various recrystallized and new minerals (carbonates, sulfates, etc.) elements such as lead, chromium, zinc, copper and nickel can either be locally enriched or statistically distributed.

Results from a six-step sequential extraction procedure applied before and after stabilization (1) indicate, that copper, nickel, zinc and cadmium, which are mainly associated with the organic/-sulfidic phases in the original material, are shifting to either moderately reducible fractions (copper), carbonate phases (zinc), or carbonate and cation exchangeable fractions (Cd, Ni). The latter compounds are relatively unstable and the metals may become remobilized by lowering of pH or by complexation with organic degradation products. With respect to the possible impact on water quality, however, one has to consider the chemical conditions in the deposit, i.e. the presence of a relative high buffer capacity by addition of lime, calcium carbonate, cement, alkaline fly ash, etc. or by formation of new sorption sites, e.g. on hydrous iron oxides. In the systems studied here, mobility of chromium is not affected by the additives. The behaviour of lead, which is shown in Figure 4, indicates a decrease of the carbonate fraction in the original material following the addition of lime, gypsum, and lime/red mud mixtures; these shifts to moderately reducible fractions should be associated with an increase in chemical stability of lead compounds.

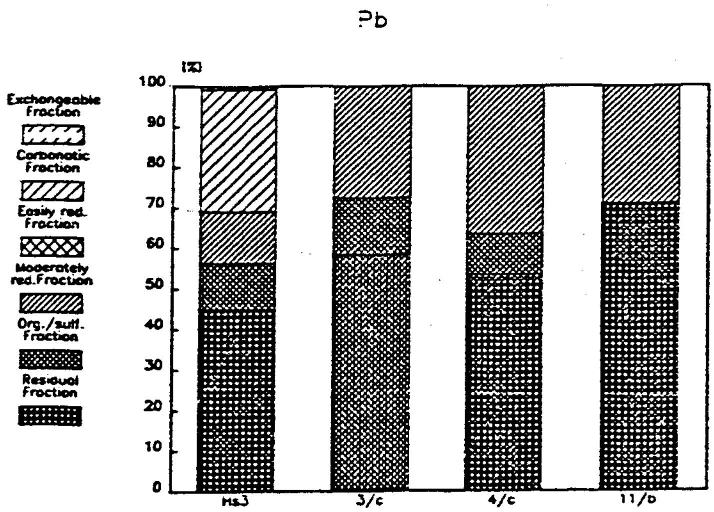

fig. 4
chemical extraction results on untreated sludge (Hs3), sludge/lime (3/c), sludge/gypsum (4/c), sludge/lime/red mud (11/b)

(1) Förstner, U., Calmano, W., Conradt, K., Jaksch, H., Schimkus, C. and Schoer, J.: Chemical Speciation of Heavy Metals in Solid Waste Materials (Sewage Sludge, Mining Wastes, Dredged Materials, Polluted Sediments) by Sequential Extraction. Proc. Int. Conf. Heavy Metals in the Environment, Amsterdam. Pp. 698-704. CEP Consultants Edinburgh 1981.