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Sampling of contaminated harbour sediments

Etude des échantillons de sédiments portuaires pollués

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ABSTRACT: To evaluate the marine harbour sediments contamination, core sampling was performed using the specially developed piston sampler. The obtained undisturbed core samples allowed the estimation of different pollutants occurring in bottom sediments, as well as biogenic substances and some bacteria e.g. with hydrocarbons decomposing ability. The possibility for application of bioremediation to the harbour sediments which were characterised by relatively rich contents of organic matter was considered.

RESUME: Nous avons construit le carotier à piston spécial pour prélever des échantillons non remaniés de sédiments portuaires pour avoir la possibilité de déterminer le degré de leur pollution. Le prélèvement des échantillons a permis de déterminer les différents contaminants apparues dans les sédiments et aussi des substances biogénésiaques et certains microbes capables de décomposer des hydrocarbures. Nous avons envisagé aussi la possibilité d'utilisation de la bioremédiation des certains sédiments portuaires qui se sont caractérisé par le contenu des composants organiques relativement riche.

1 INTRODUCTION

The dredging of sediments from Polish harbours, necessary for maintaining the right depths of waterways, concerns the removal approximately 3.7 million cubic meters per year of heavily contaminated material. The dredged material was usually dumped at sea or disposed of at land dumping ground causing among others serious pollution of the marine environment.

To check and evaluate the sediment contamination, sampling of sediments in harbour basins was performed, particularly in a region which included two oil tank berths for handling heavy and light fuel, as well as in a region in the vicinity of a shipyard.

In the region of the harbour basins of the total area reaching 94.5 ha there were taken 35 surface sediment samples, and 22 core samples (of the height up to 0.9 m). The sediments samples were taken under conditions appropriate for retaining their natural state.

On the basis of the results of these investigations it was also intended to evaluate the capabilities of applying the biological method to the elimination of harmful organic substances from the sediments, while simultaneously attention was concentrated on the inorganic pollutants such as heavy metals, which can have a negative effect on the micro-organisms taking part in the bioremediati

2 MATERIALS AND METHODS

To allow reliable evaluation of the harbour sediments contamination, undisturbed core samples from various locations in the harbour basins and navigation channels were necessary. To meet this requirements a special piston sampler was designed and constructed, which allowed to take undisturbed core samples of the sediments, together with a certain layer of the sediment covering water. The main data of the piston sampler are:

- ♦ outside diameter of the sampler cylinder = 100 mm,

- ♦ inside diameter of the sampler cylinder, equal to the diameter of the core sample = 92 mm,
- ♦ length of the sampler cylinder equal to the length of the core samples = 0.5, 1.0 and 1.5 m,
- ♦ length of the steel rod for piston sampler operation, equal to the water depth in the place where samples have to be taken up to 15 m.

The lower end of the piston sampler made as a circular strengthening ring of stainless steel, was closed and opened using a remote controlled pneumatic membrane.

The piston sampler connected with the rod was pressed from the deck of a floating platform and after reaching the desired depth in the sediments (0.5 to 1.5 m), was closed pneumatically. Samples of undisturbed structure and, of required length (taken using exchangeable cylinder soil containers) were transported to the laboratory in the samplers original cylinders.

To collect disturbed samples of sediments the special grab sampler was developed. This sampler allowed to collect supplementary samples of disturbed structure from the surface layers of the bottom sediments. The soil container of a volume 6.5 dcm³ was filled by means of a lever mechanism at the harbour bottom. The penetration depth of the grab in the sediments, depending on their state, reached 0.4 m.

Samples for bacteriological tests were cut out of the subsamples centres with care of preserving sterility. It was taken for granted to carry out bacteriological analyses as soon as the samples reached the laboratory. Only in exceptional cases the laboratory tests were performed for some later time, which made it necessary to freeze the samples.

The physical and chemical investigations of the samples were performed when the gravel fraction (above 2 mm) had been separated and the samples had been averaged. For the reason that it was possible to change the bacteriological and chemical composition, the samples

were stored at -30° C. The samples intended for bacteriological tests were defrosted not longer than half a hour to avoid a growth of the sedimentary microflora.

The averaged samples of the harbour sediments were subjected to total mineral oil tests, heavy metal tests, PHA tests, and bacteriological tests (estimation of the share of the bacteria involved in the decomposition of hydrocarbons in the total number of heterotrophic bacteria).

The contents of organic carbon was indicated using the modified technique by Mentzel and Vaccaro, while mineral oils by the application of the infrared spectrophotometric method (Olańczuk-Neyman, et al., 1994).

PAH were determined by means of HPCL making use of a chromatography of Merck-Hitachi firm provided with detector UV-VIS of L-4250 type pump L 6200, integrator D 2500, and Rheodyne Model 7122 dispenser, detector DAD L 2050 (Gazda et al., 1995). Heavy metals were indicated using atomic absorption spectrophotometric technique.

The total number of bacteria was denoted by making use of ZooBell agar, while bacteria decomposing the hydrocarbons, using the Kahle Anders agar medium with different hydrocarbon substrates (naphthalene, motor oil „Marinol”). Incubation time was three weeks at room temperature.

3 RESULTS

It has been proved that the harbour sediments tested contain considerable quantities of various pollutants, mainly of antropogenic origin. The contents of organic carbon in the sediment samples ranged from 1.61 to 4.60%. The highest mineral oil content, reaching as much as 5470 mg/kg of dry matter, has been found in samples which were taken from the area of the fuel handling berth, and the magnitudes of that order occurred both in the surface samples and in the core samples.

PHA appeared in all the surface and core samples in concentrations exceeding the target value (abbr.:TV) or the short term value (abbr.:STV) (Netherlands Government, 1994). Especially high PAH concentration was noted in the case of samples taken from a direct neighbourhood of the two fuel handling berths and along the outfitting berth of the repair shipyard. The highest transgression of STV related to benzo(a)pyrene was contained in two core samples amounting to as much as 96 times. In both the core samples it has been pointed out that the total amounts of benzo (a) anthracene and chryzene have been exceeded 50 times in relation to the short term value. In general, taking into consideration all the samples, both surface and core, it was possible to note that generally STV for the other PAH tested (fluoranthene, benzo(b)fluoranthene and benzo(k)fluoranthene) were exceeded. Simultaneously attention has been paid to the level of the inorganic pollutants of heavy metal type, which can be mobilised in the case of a change in the redox potential value occurring in the habitat, or during the technological treatment processes of the sediments.

The contents of two heavy metals, mercury and chromium, in all the samples did not exceeded the target value. On the other hand, the contents of copper and occasionally lead and zinc, at some investigation points, exceeded the intervention value (Netherlands Government, 1994). For example, along the out-fitting berth of the repair shipyard the content of copper reached about 344 mg/kg of dry matter, lead nearly 865 mg/kg of dry matter while in the case of zinc 797 mg/kg of dry matter, which corresponds to excessive intervention values 1.8, 1.6 and 1.1 times, respectively. Minor excessive values, relating

only to copper (as much as 1.4 times) have been noticed in samples taken from the opposite quays at a distance of about 400 m, while the concentration of lead and zinc exceeded only the target values. The cadmium content in all the surface sediment samples was greater than the target value (0.8 mg/kg) but never attained the intervention value (12.0 mg/kg).

The bacteriological tests have proved that the bottom sedimentary high concentration of heavy metals, in contrast to remaining samples, are characterised by a lower number of heterotrophic bacteria. The percentage share of the bacteria able to oxidize motor oil, as well as the percentage share of bacteria oxidizing naphthalene in total number of heterotrophic bacteria also was lower in these particular samples.

4 CONCLUSIONS

The investigations performed with the use of the developed samplers proved that the introduced equipment allows to obtain samples which can be used for estimation of all occurring pollutants, as well as their values and distribution.

The analysis of the chemical and bacteriological investigations has proved that the chemical composition of sediments, among others, the total contents of organic carbon, PAH, and the contents of heavy metals have a significant effect upon the number of the heterotrophic bacteria involved in the mineralization processes of organic pollution.

The low percentage share of the bacteria degrading hydrocarbons in the total number of bacteria present in the sediments investigated indicates that the decomposition of this type of pollutants in the sedimentary environment is restrained. The hampering effect on the biodegradation processes can undoubtedly have the heavy metals.

Finally it may be stated that applied core sampling using specially designed core sampler was fully useful for obtaining undisturbed samples for chemical and bacteriological analysis.

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