Management of liquid wastes on floating docks in the aspect of its impact on the environment

Piotr Marcinowski, D.Sc., Eng.
Joanna Biernacka, M.Sc., Eng.
Maria Olesiejuk-Kowalska, M.Sc., Eng.
Warsaw University of Technology

ABSTRACT

State of environment pollution in the area of operation of a floating dock was investigated. In the taken samples of liquid wastes, outboard water and bed sediments were determined values of their basic physical and chemical parameters as well as concentration of poly-cyclic aromatic hydrocarbons, butyl tin compounds ($(Bt)_3SnCl$, $(Bt)_2SnCl_2$, $BtSnCl_3$, $(Bt)_4Sn$), polychlorinated biphenyls (PCB 28, PCB 52, PCB 101, PCB 138, PCB 153, PCB 180) as well as heavy metals (Zn, Cd, Pb, Cu, Ni, Cr, Co, Fe, Mn, As, Hg).

Key words : dock, liquid wastes, bed sediments, environment investigations, GC/MS

INTRODUCTION

Management of liquid wastes on the dock is a complex problem. Two main groups of liquid wastes can be distinguished : liquid wastes associated with service of the dock considered as an autonomous floating unit, and liquid wastes resulting from repair operations carried out on it.

In the first group liquid industrial wastes and sewage associated with permanent stay of dock's crew and additional personnel on the dock can be distinguished. The sewage are usually discharged to the quay and further transported to a municipal sewage treatment plant. Qualitative content of dock sewage does not much differ form that of typical living sewage [1,2].

Liquid industrial wastes from the dock are collected in dock's bilge wells and tanks. They comes from leakage of such systems as : main drainage, fire fighting, fuel oil pumping between the dock and floating unit under repair, industrial water supply, power plant, sanitary water supply. They are to a large extent contaminated with oil and subject to deoiling process. The separated organic fraction is pumped out and collected in tanks outside the dock [3,4].

It is extremely difficult to define liquid industrial wastes associated with repair work carried out on a docked floating unit. To this end it is necessary to recognize the object from the point of view of its location, construction and realization of operations carried out on it. Repair operations can be performed with the use of various engineering processes. And, the following characteristics of the unit under repair are also important :

- type of a unit, which influences a way of it use (region of operation, kind and amount of shipped cargo, operations carried out on board, e.g. fish processing on fishing trawlers)
- its construction
- hull and outfit materials as well as kinds of paints used during the preceding repair
- scope of repair work [2,5].

The criteria contained in [6] have to be accounted for in determining noxious substances and those of potentially harmful impact on the environment.

In the case of floating dock the substances
of both the kinds may :

- be generated as a result of repair and modernization work
- be components of materials used for repair of floating units
- be removed as waste materials, out of the repaired unit
- find their way to the environment due to a failure, incorrect work of the dock, or the carrying out of operations against the criteria of the Best Ecological Practice [6,7].

In the tested liquid wastes, concentrations of poly-cyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCBs) as well as butyl tin compounds were determined. PCBs and butyl tin compounds are the group of compounds prohibited for application, but they are contained in many ship elements removed in the course of ship repair. PCBs have found their application in a.o. heat exchangers, condensers, hydraulic devices. And, tin organic compounds, first of all tri-butyl tin (TBT), are used as components of antifouling paints. Such paint coverings have been continuously improved and self-polishing paints appeared in 1980s. It has been demonstrated that though TBT has liquidated organisms fouling ship hulls it has detrimentally influenced the aquatic life (oysters, dolphins and whales). During 21st session of IMO General Assembly was adopted A 895 Resolution ordering to introduce a legal act to ban application of TBT beginning from January 1, 2003.

It was agreed that the systems containing TBT are allowed to be used until January 1, 2008. In the presently manufactured antifouling paints the compounds are not applied at all. However from the point of view of impact on the environment around floating docks it is important whether there is no tributyl tin compounds contained in removed old paint coverings laid during previously carried out repair work [5,8].

OBJECT OF THE INVESTIGATIONS

The investigations dealing with influence on the environment of the repair processes carried out on the dock were realized in three cycles: in January 2004 , May / June 2004, and December 2004 / January 2005.

The investigated object was a ship repair dock of Gdynia Naval Shipyard. Its main parameters were as follows :

- ⇨ lifting capacity : 8000 t
- ⇨ overall length : 151 m
- ⇨ overall breadth : 35.5 m
- ⇨ breadth between side walls : 28.5 m
- ⇨ depth of side walls : 14.5 m
- ⇨ distance between keelblock lines : 27 m
- ⇨ maximum draught : 13.3 m.

Characteristics of repaired or modernized ship as well as scope of operations were accounted for. In compliance with the earlier made assumption the dock and the ship docked on it were considered as one object of the investigations. Measurements were connected with the stay of the three ships on the dock, namely :

- ★ the GR 6-50 fishing trawler *Polar Siglir* of 3000 DWT, built in 1975
- ★ the bulk carrier *Ziemia Suwalska* of 26605 DWT, built in 1984
- ★ the bulk carrier *Ziemia Chełmińska* of 26700 DWT, built in 1984.

MATERIALS AND METHODS

The points of sampling the dock surrounding water and bed sediments (Fig.1) were chosen with taking into account : the dock's construction, ship docking procedure, location of the dock within the dock's basin, and bathymetry of the basin. The samples were taken in four points located at the edge of the dock's basin. Two sampling points were located at starboard hawse holes, one at dock's bow and one in the starboard mid-length. Points 1, 2 and 4 (Fig.1) were located at a distance of 15 m from dock's side walls. Point 3 was placed on the dock's longitudinal axis, before its bow at a distance of 20 m from the arranged oil boom. The samples of outboard water and bed sediments were taken and their physical and chemical characteristics determined. The sampling procedure was in compliance with PN-EN 25667 and PN-ISO 5667 standards.

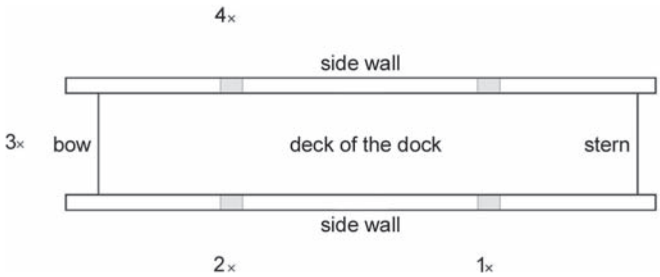

Fig. 1. *Arrangement of sampling points for outboard water and bed sediments around the dock.*

The sampling procedure of the bed sediments was in accordance with [9]. During the investigations were taken the samples of : preliminary washdown waste water, bilge water and ballast water. The preliminary wash-down waste water comes from washing hull's surface by means of fresh water under high pressure to remove salt deposits, corrosion products, living organisms and other contaminations from the hull surface before commencing removal of old paint coverings. For the ship's hull wash-down process the amount of water, ranging from 70 to 290 m^3 , is used. Because of the very large amount of waste water it was necessary to carry out the sampling in such a way as to make averaging the waste water sample from the preliminary washing-down carried out on a greater hull surface area, possible. It was assumed that qualitative and quantitative contents of the taken samples should reflect the contents of real waste water produced during the preliminary washing - down of separated hull surface areas. Three such areas were distinguished: above-water zone, changeable draught zone and underwater zone which distinctly differed to each other. (Fig.2).

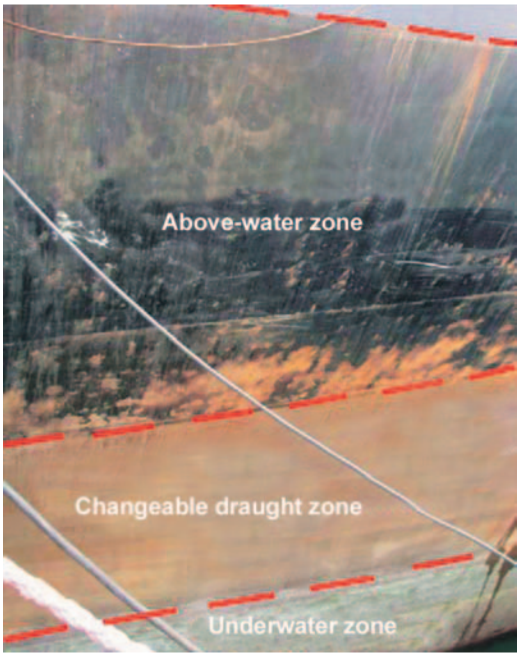

Fig. 2. *Ship side surface with distinctly seen above-water, changeable draught and underwater zone.*

The greatest amount of micro-organisms overgrew the bottom and sides of the ship up to its waterline. Moreover, the surface was to a great extent corroded. The next distinguished hull zone ranging from the waterline up to the Plimsol's Mark (Fig. 2), was characterized by a much smaller amount of fouling organisms than the underwater zone but its corrosion wastage was much greater. The last distinguished hull zone was the above-water hull side above the Plimsol's Mark.

In Fig.3. range of the distinguished zones of hull surface was presented with the bulk carrier *Ziemia Chełmińska* as an example.

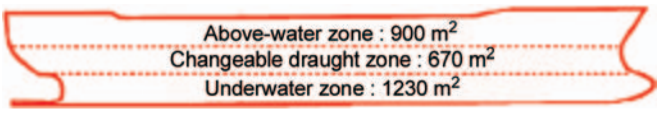

Fig. 3. *The distinguished zones of the ship's hull surface.*

Samples of bilge and ballast water were taken from the places in which they have been collected on the repaired ship.

Determination of values :

- ✸ of physical and chemical properties of the samples of the sediments obtained from liquid wastes, and of bed sediments, namely reaction, density, hydration of residues, total nitrogen and phosphor, was performed by means of the method described in [6],
- ✸ of polychlorinated biphenyls (PCBs) – by means of the authors' own method [11] and
- ✸ of tin organic compounds and poly-cyclic aromatic hydrocarbons (PAH) – with the use of the authors' own method [2].

RESULTS

The samples of water taken from the dock basin were clear and of natural colour. Its high conductivity should be considered as a natural feature of such sea water as that of the Baltic Sea having 7 ‰ salinity. The determined values of concentration of cations and anions (chlorides, sulphates, bicarbonates, magnesium, calcium) were on the level of concentration of those ions in the Baltic Sea waters. On the basis of values of COD, permanganate index and BOD the tested waters may be numbered among medium-contaminated sea waters of coastal zone. Values of the basic physical and chemical parameters of the sea water taken in the course of repair work during both campaigns, did not significantly differ from the results of the analysis of the water taken at the same sampling points, before commencement of the ship's repair work on the dock. Their qualitative and quantitative contents corresponded with those of sea water. Comparing the results of determination of content of heavy metals in the water samples taken before commencement of repair work on the dock and during carrying out the work, one can observe a significant rise of concentration of the following substances :

- cadmium – four times
- zinc – over three times
- copper, nickel, chromium, cobalt, manganese – over two times.

Determined concentration values of the remaining heavy metals contained in two samples taken from the same places are similar.

The bed sediment samples taken in the point 1 and 2 consisted of a black silt of a loose uniform consistence free from any thick fractions (stones, residues of aquatic macrophytes). The samples emitted distinct smell of hydrogen sulphide and oil products. The bed sediment sample taken in the point 3 consisted of a dark-grey silt containing an amount of a deep red-olive green sand of medium-size grainage. In the sample taking place, below 30 cm of sediment depth, a distinct boundary was found between the surface layer of silt and lower, neighbouring layer of sand. The bed sediment sample taken in the point 4 consisted of a grey watery silt having distinct smell of hydrogen sulphide. The sample was uniform, without any coarse - grain components. In the case of the samples taken in the point 1 and 2, depth values of the silt layer, its macroscopic description and values of its basic parameters were similar to each other. Results of analysis of the bed sediment sample taken in the point 3 only slightly differed from those of the remaining bed sediment samples. The tested bed sediment samples were characterized by a large degree of watering and large content of mineral substances in dry sediment mass (87.9%-93.35%). The performed tests indicate that the taken samples have been highly contaminated by heavy metals. Out of the all determined metals, iron was of the highest content (2% do 3.3%) relative to dry sediment mass. Attention should be paid also to the significant content of zinc, copper, lead, nickel and manganese. Results of determination of content of specific organic pollutants in bed sediment showed that it was highly contaminated. To a large extent the degradation of bed sediment is due to poly-cyclic aromatic hydrocarbons and tin organic compounds, and to a smaller extent - polychlorinated biphenyls. The high content of the PAH and tin organic compounds, especially of tri-butyl tin, determined in bed sediment, indicates that repair activity, in particular the processes of preliminary washing - down the hull surface and removing the old paint coverings, could contribute to the bed sediment degradation within the dock basin.

The physical chemical properties of the waste water samples taken during preliminary washing-down operations carried out on successive ships under repair, significantly differed from each other. The samples showed a specific colour whose kind and intensity depended on a degree of corrosion wastage of cleaned hull surface, amount of micro-organisms removed by water stream from hull surface, effectiveness of washing devices per unit area of washed down surface. The large quantity of ordinary suspended matter, dry residues and COD as well as degree of turbidity was equivalent to the amount of removed corrosion products together with residues of loosely bounded paints and amount of hull fouling micro-organisms. In the case of some samples the great share of losses , amounting to 37- 42% , during roasting the dry residues, as well as the high concentration of organic nitrogen and general phosphor, may indicate that the content of residues of organisms removed from hull surface in the total amount of removed material, was high (Fig.4). In single samples of waste water from the preliminary washing-down, an increase of COD accompanied with that of concentration of oil products was observed. The situation took place in relation to the sample coming from the preliminary washing-down of oily surfaces.

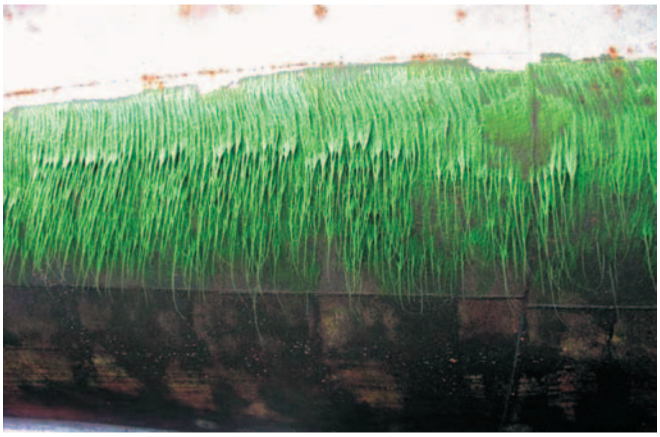

Fig. 4. *Algae fouling the ship hull .*

The waste water samples were also characterized by high conductivity, large amount of dry residues as well as high concentration of chlorides sulphates. It was amounts of the sea salt washed out from hull surface, which influenced such properties of waste water.

During the preliminary hull wash-down process significant amounts of material were removed, namely more than 2 g per litre of waste water , in which mineral substances amounted to 55% . High quantities of COD in waste water tell about its significant contamination. Very high ratio of COD and BOD contents in some samples indicates that the collected material contains substances which are hard to be disintegrated in a biochemical way, or noxious substances. Results of content determination of organic tin compounds and poly-cyclic hydrocarbons confirm that observation. In the hull wash-down waste water samples was found a high concentration of organic tin compounds, among which tri-butyl tin dominated, whose concentration was from a few to several hundred times greater than that of the remaining organic tin compounds, Fig.5 and 6. Significant amounts of tri-butyl tin, both in dissolved and suspended form, were determined in the waste water samples taken in the course of preliminary hull washing-down. Whereas PAH were first of all present in suspension fraction of the waste water samples, as compared with their vestigial amounts found in the filtered samples, Fig.7.

The waste water sample taken in the course of washing - - down the first, new-laid paint layer, was characterized by its natural colour, oil-product like smell as well as by a small amount of the well-settling sediment of maroon colour. Surprisingly high was the amount of the dry residue, in which the content of mineral substances was about 92%. From comparison of the ratio of COD and BOD contents it results that the dissolved substances may subject to biodegradation.

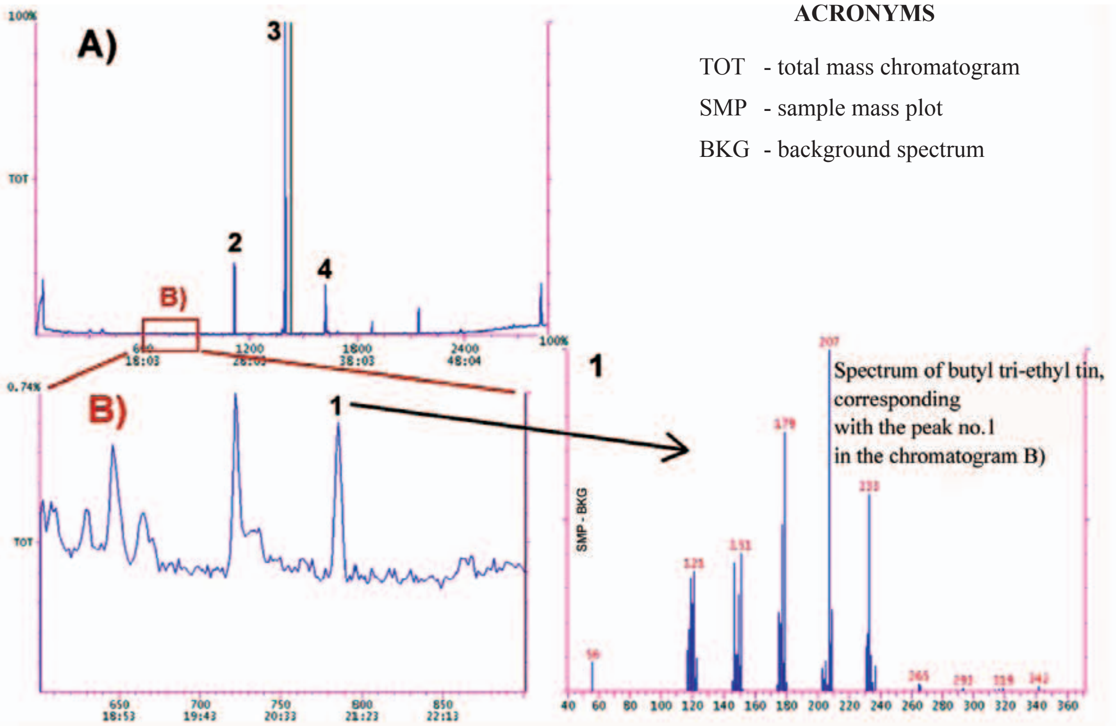

Fig. 5. Examples of chromatograms showing spectra of organic tin compounds found in a sample of filtered waste water .

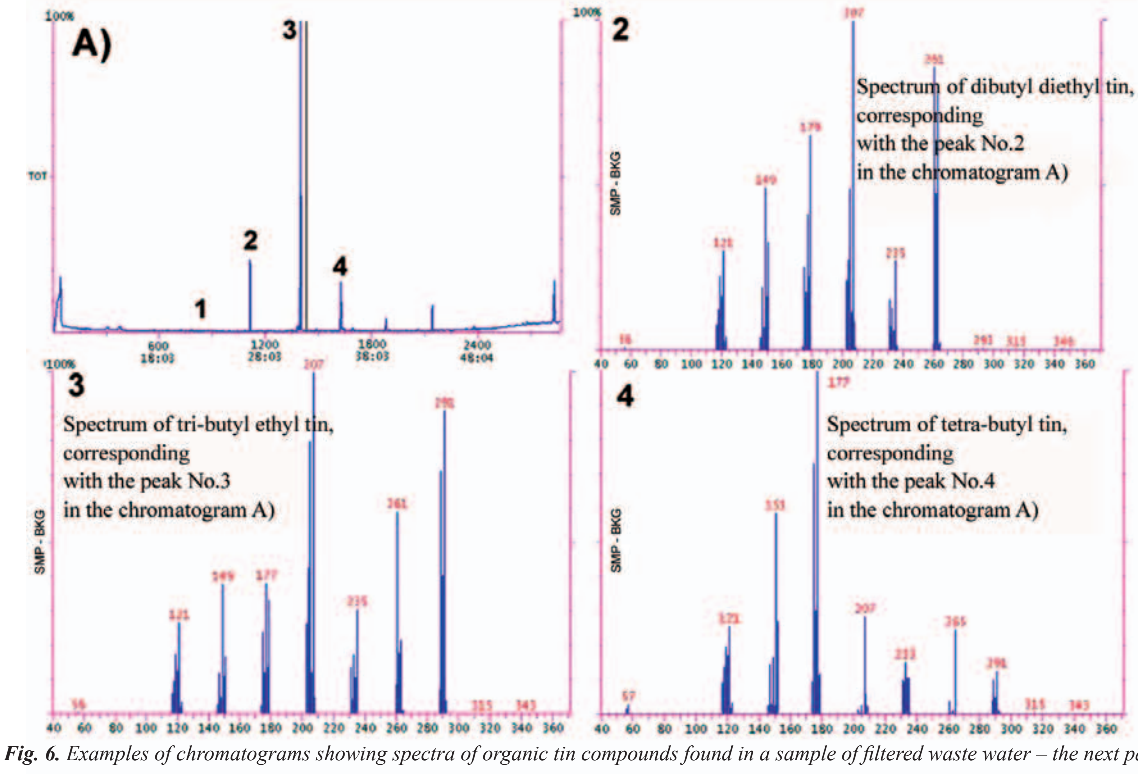

Fig. 6. Examples of chromatograms showing spectra of organic tin compounds found in a sample of filtered waste water – the next part .

SUMMARY

The liquid wastes produced on the dock in the course of ship repair work can detrimentally impact the environment. Effective methods should be implemented to prevent the environment from their influence by separating the spaces where repair work is usually carried out on the dock. It seems rational to design and realize a system for collecting the produced liquid wastes. Waste water from preliminary hull washing-down and ship bilge water (after releasing bottom drain plugs) may be collected in dock's deck drainage wells and then discharged through drainage ducts to a trimming tank. Application of such a solution requires rebuilding the dock [8]. Another solution may be to force waste water to flow gravitationally along the pontoon deck, by trimming the dock by stern. The liquid wastes collected aft may be further processed. Information found in the subject-matter literature does not allow to indicate which method of treatment of preliminary hull wash-down waste water is the only best. On the basis of the obtained results of determination of the properties of suspended matter and easily settling suspension, as well as turbidity and colour, it can be assumed that to preliminarily purify the waste water will be necessary. The preliminary purification should be performed just after collection of the waste water. The

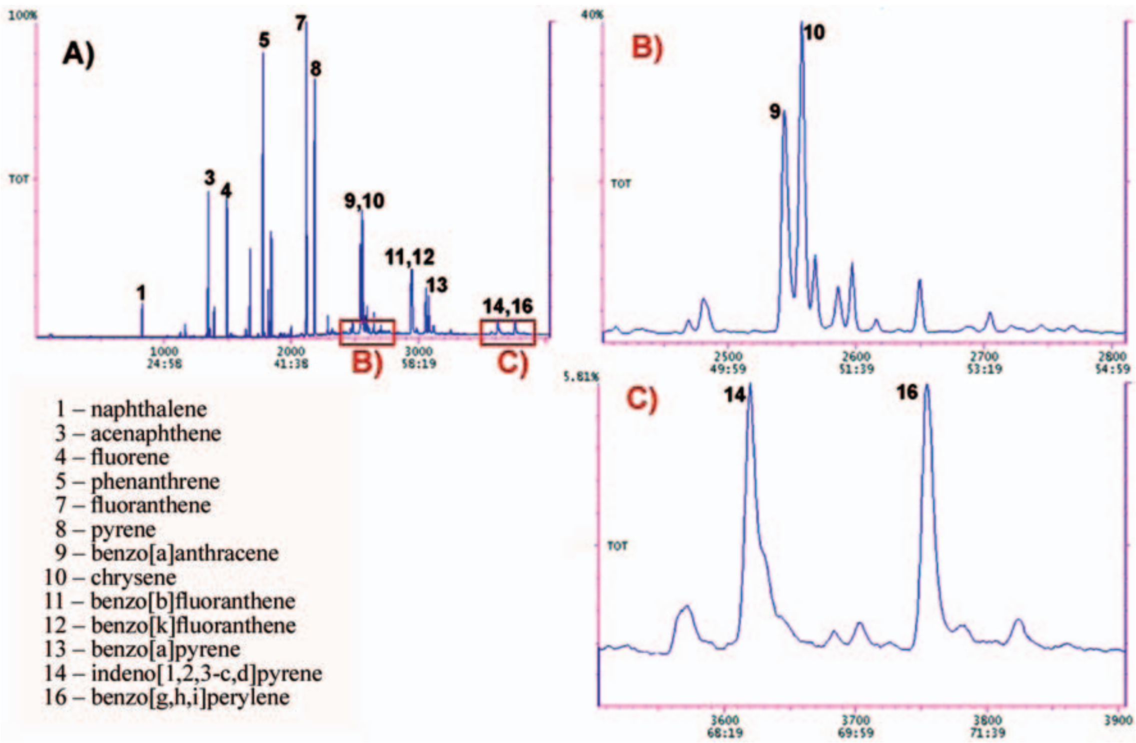

Fig. 7. *Examples of chromatograms of PAH in the form of suspension, found in a sample of waste water from ship hull washing-down .*

separated suspension should be considered as a waste. After preliminary purification the waste water should be subjected to a coagulation process in view of the results of determination of turbidity, colour, content of heavy metals and tri-butyl tin in filtered samples. It can be assumed that the coagulation process will require correcting pH value of the liquid wastes free from a thick suspension layer removed in advance. The sediment obtained from coagulation should be considered as a waste. On the basis of scarce literature data it can be expected that to apply aluminium salts as a coagulant, at pH = 6, would be most effective [12].

Some researchers indicate that after coagulation additional purification would be necessary. The task can be realized by removing dissolved wastes with the use of the activated - - carbon adsorption method. The carbon bed can be cleaned by applying the extraction method with the use of appropriate solvents dosed to water stream, or utilized together with absorbed contaminations, by means of the high-temperature combustion process [13].

Without performing some technological tests it is not possible to decide which method of purification of the waste water from preliminary hull washing-down is the best.

Moreover in particular cases, when the content of highly oiled bilge water in whole amount of liquid wastes discharged from the dock is large, all technological procedures can be applied only after separation of organic fraction. The separation of oil products should be performed by using a flow oil separator. The collected oil products should be taken as a waste; additional research on their possible utilization and classification should be arranged.

Resigning from actions aimed at improvement of waste water management will lead to further degradation of the environment. However actions aimed at making changes in ship repair technology realized on the dock, and at improving waste water and garbage management may not suffice to improve state of environment in the surrounding of dock's basin because of a secondary release of noxious substances to surrounding water from highly contaminated bed sediments which will be a source of secondary pollution even for many years.

BIBLIOGRAPHY

1. Rosochowicz K.: *Przyjazne środowiskowo doki pływające* (Environment- Friendly Floating Docks). Gdańsk University of Technology. Gdańsk, 2004
2. Nawalany M. et al. : *Environment-Friendly Floating Docks*. KBN Report No. 134/E-365/SPB/EUREKA/T-12/DZ 114/2003-2004. Warsaw University of Technology. Warszawa, 2005
3. Doerffer W.: *Design assumptions for an ecological dock for Baltic Sea* (in Polish). Gdańsk, 2003
4. Wieszczeczyński T.: *Analysis of crucial problems and requirements dealing with outfit of floating docks in the aspect of environment protection* (in Polish). Gdańsk University of Technology. Gdańsk, 2004
5. EPA : *A Guide for Ship Scrappers. Tips for Regulatory Compliance*. EPA 315-B-00-001, 2000
6. *The convention on the marine environment protection in the Baltic Sea area , adopted in Helsinki on 9 April 1992* (in Polish, published by State Acts Publishers): Dz. U. z 2000 r. Nr 28, poz. 346
7. *International Convention for the Prevention of Pollution from Ships (MARPOL 73/78)* (in Polish), Published by PRS. Gdańsk, 1997
8. Host P.M. : *Drydock Water Pollution Control Efforts at Norfolk Naval Shipyard*, Environmental Programs Division, Norfolk Naval Shipyard, 1994
9. *NOAA National Status and Trends Program for Marine Environmental Quality*, Technical Memorandum NOS ORCA 71, 1993 Silver Spring, Maryland, USA
10. Morabito R., Massanisso P., Quevauviller P.: *Trends in Analytical Chemistry*, Vol. 19. Nos 2 and 3, 2000
11. Szperliński Z., Marcinowski P.: *Photochemical processes of polychlorinated biphenyls in selected elements of ecosystems of lentic waters* (in Polish). KBN report, Warsaw University of Technology. Warszawa, 2002
12. Ashcroft P.L., David A.: *Process Water Treatment for the Removal of TBT in Ship Washdown Waste Waters*. Proceedings of Marine Technology Society. Washington, D.C. Vol. 5, 12 P. 1999
13. Champ M. A.,.Schafran G. C., Fox T. J.: *Review of Advanced Technologies for Removing TBT from Ship Washdown and Shipyard Runoff Wastewaters*. MS for 23rd UJNR Proceedings, 1999