Some environmental aspects of ship repair work on floating docks – management of wastes

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ABSTRACT

This paper contains summary of investigations and analyses performed by Institute of Environment Engineering Systems, Warsaw University of Technology, in the area of management of the wastes produced in the course of ship repair work on floating docks. During the investigations carried out in Gdynia Naval Shipyard, were determined substances which qualitatively characterize selected wastes (in their original form as well as their water extracts), and amount of the wastes of basic groups, produced during floating dock service and repair and modernization work carried out on it, was estimated. Recommendations for waste managing on floating docks are presented, including possible ways of utilization of the wastes as well as their final usage (recovery and/or neutralization).

Key words : waste management, quantitative and qualitative characteristics of wastes, waste utilization (recovery and/or neutralization).

INTRODUCTION

Governmental authorities are forced, because of increasing environmental pollution, to establish more and more severe legal acts aimed at stopping the degradation process of environment. It particularly concerns the well-developed countries in which such legislation process is advanced most. Every new investment undertaking must – already in its design stage – account for several requirements aimed at limiting – as much as possible – its detrimental impact on the environment. Such requirements have been established also for shipbuilding and ship repair industry. It means that the engineering processes used in building and repair of ships must comply with the standards for emission of harmful substances, comprised in legal regulations; moreover all materials and devices used in the processes are recommended to be manufactured, selected and used in accordance with the principles of *the best available technology*.

In this paper selected investigations and analyses in the area of management of the wastes produced in the course of ship repair work on floating docks are summed up and presented together with relevant recommendations which – if obeyed – – can make the environment protecting possible.

INVESTIGATIONS ON WASTES

The investigations in question were aimed at determination of selected indices of wastes, which characterize properties of samples of the wastes from repair work carried out on the dock.

In the scope of the investigations carried out in Gdynia Naval Shipyard the substances qualitatively characterizing the selected wastes (in their original form as well their water extracts) were determined, and amount of the wastes of basic groups produced during floating dock service and repair and modernization work carried out on it, was estimated.

The preliminary investigations made it possible :

- ❖ to determine environmental hazards resulting from carrying out repair work
- ❖ to determine qualitative and quantitative characteristics of contaminations contained in the wastes
- ❖ to classify the wastes from the point of view of their impact to the environment
- ❖ to determine possible utilization of the wastes including ways for their final usage.

During the research cycles (two measuring campaigns realized in 2004) the authors were focused on the kinds of produced wastes most important from the point of view of their qualitative and quantitative characteristics. Specificity of repair work on floating dock was also accounted for. The tested wastes came from the following operations :

- ★ **preliminary cleaning** – fouling and paint residues washed--down by using water jet technique
- ★ **actual cleaning** (the wastes resulting from abrasive blasting), and determination of characteristics of the used abrasive material, i.e. copper slag).

Samples were taken in compliance with a Branch Standard (BN) with accounting for specificity of the produced wastes, including the sample taking scheme for loose and granulated materials, adopted by *the Association of Official Analytical Chemists*. The wastes taken from particular repair work operations, assumed to be an original sample, were collected in a specially arranged place, from where an average laboratory sample was taken. In the laboratory the sample was prepared for physical and chemical tests in compliance with requirements of Polish Standards (PN).

In the course of the waste testing the following contamination indices were determined :

- ✦ selected parameters characterizing combustion properties (humidity, losses in roasting at 500°C)

- content of reducing substances (by using the bi-chromate method)
- content of non-polar organic substances
- content of substances extracted with the use of petroleum benzine
- content of phosphor
- content of some heavy metals
- content of some specific substances (some organic tin compounds, PAH, PCB)

The tests of solid waste samples were carried out by using the test methods given in Polish Standards (PN) and Branch Standards (BN) [1].

The tests of water extracts, necessary to assess environmental impact of the wastes and their possible final usage, covered the following items :

- pH value
- COD (by using the bi-chromate method)
- content of dissolved substances
- content of dissolved mineral substances
- content of non-polar organic substances
- content of substances extracted with the use of petroleum benzine
- content of chlorides
- content of sulfates
- content of phosphates
- content of some heavy metals
- content of some specific substances (some organic tin compounds, PAH, PCB)

Tests of water extracts were carried out by using the sewage testing methods given in Polish Standards (PN) [2].

DISCUSSION OF RESULTS OF TESTING THE WASTES

The research report [3] contains all results of the tests in the form of the tables supplemented with comments and interpretation of the results. In this chapter only a general discussion of the test results is given.

Wastes from preliminary hull washing-down

The tested samples are characterized by a very small content of organic substances, which shows that amount of fouling and paint residues with high content of metallic oxides, has been small. The sample from ship's deck washing-down (no. 2) is characterized by a high content of iron and relatively low humidity. The sample from ship's hull washing-down (no. 3) is characterized by a high content of oil products and substances extracted with the use of petroleum benzine, a lower content of iron and much higher content of heavy metals (copper, zinc, lead). Another sample from ship's hull washing-down (no. 6) is characterized by a high content of iron and, like the sample no. 3, much higher content of heavy metals (copper, zinc, lead).

Because of the high content of the specific substances (numbered among those highly noxious) the wastes in question should be considered dangerous [4]. However it should be stressed that in view of the fact resulting from the performed tests, that the allowable level of total concentration of highly noxious substances has not been exceeded, it will be possible to qualify the wastes as different from dangerous if only the full procedure determined in [5] is performed.

Wastes from ballast tanks

The tested sample (no. 7) is characterized by a very low content of organic substances, which shows that amount of fouling and paint residues with high content of metallic oxides, has been small. The sample is characterized by a high content of iron, humidity higher than the preceding samples, as well as a relatively low content of heavy metals.

Wastes from abrasive blasting

All tested samples are characterized by a vestigal content of organic substances and very low humidity, which shows that the content of metallic oxides, paint residues and used abrasive material, has prevailed. For all the tested samples high content of iron is characteristic. The samples of the copper slag containing wastes from abrasive blasting (no. 5, 9 and 10) are characterized by a little higher content of heavy metals than that of the control copper slag samples (no. 4 and 8).

The wastes in question should be considered dangerous [4] because of the high content of the specific substances (numbered among those highly noxious. However it should be stressed that in view of the fact resulting from the performed tests, that the allowable level of total concentration of highly noxious substances has not been exceeded, it will be possible to qualify the wastes as different from dangerous if only the full procedure determined in [5] is performed.

Water extracts from wastes produced during preliminary washing-down

All the tested water extracts are characterized by a similar (low-alkaline) value of pH reaction. The pH reaction value of the water extract sample from the wastes produced during ship's deck washing-down (no. 2a) exceeds that permissible for discharging the liquid wastes to waters or ground [6]. Moreover the sample is characterized by a relatively high content of dissolved substances (mainly mineral ones). Except from an insignificant surpass of pH reaction value the sample satisfies the requirements for liquid wastes discharged to waters or ground.

The water extract sample of the wastes from ship's hull washing-down (no. 3a) is characterized by a relatively high value of COD (slightly exceeding the concentration level permissible for discharging such wastes to waters or ground) and a lower content of dissolved substances. Except from the slight surpass of COD the sample in question does not comply with the requirements for discharging such wastes to waters or ground, as far as zinc and copper content is concerned.

The water extract sample of the wastes from ship's hull washing-down (no. 6a) is characterized by a relatively high content of dissolved substances (mainly mineral ones). Besides, it shows contents of chlorides and copper slightly surpassing their allowable levels, hence it does not comply with the requirements for discharging the wastes to waters or ground.

On the basis of comparison of the test results of water extracts and the criteria for accepting the wastes for storage in storage facilities of particular types, determined in [7] and reflecting the decisions [8], it should be concluded that the wastes produced during ship's deck washing-down should be stored in the storage areas for the wastes different from dangerous and neutral ones. The sample no. 2a does not comply with the requirements for the wastes allowed to be stored in the storage areas for neutral wastes (because the contents of dissolved chlorides and sulfates surpass their allowable levels). And, the sample no. 3a does not comply with the requirements for the wastes stored in the storage areas for wastes different from dangerous and neutral, as far as zinc content is concerned. Hence in view of the surpass (however only slight), the material should be stored in the dangerous waste storage areas, or after an appropriate physical and chemical treatment and resulting change of its washing-out properties (so as to comply with the requirements) – in the storage areas for the wastes different from dangerous and neutral.

The sample no. 6a does not comply with the requirements for the wastes stored in the neutral waste storage areas (because the contents of dissolved chlorides, zinc, copper, lead, and of sulfates a little surpass their allowable levels).

Water extracts from the wastes formed in ballast tanks

The water extracts from the wastes taken from ballast tanks (the sample no. 7a) are characterized by a low-alkaline value of pH reaction, a little surpassing the allowable level for discharging the liquid wastes to waters or ground. Except from the surpass of the allowable pH value, the sample no. 7a complies with the requirements for liquid wastes discharged to waters or ground.

On the basis of comparison of the test results of the water extracts and the criteria for acceptance of the wastes for storage in appropriate facilities it should be concluded that the wastes formed in ballast tanks should be stored in the storage areas for the wastes different from dangerous and neutral ones, as they do not fulfill the requirements for the wastes allowed to be stored in the neutral waste storage areas because the contents of dissolved chlorides and sulfates exceed their allowable limits.

Water extracts from wastes produced during abrasive blasting

Both water extracts from the samples taken during the first measurement campaign, (no. 4a and 5a) are characterized by low concentrations of pollutants hence they fulfill the requirements for the liquid wastes discharged to waters or ground. The low concentration of heavy metals in the water extracts (against that in initial wastes) goes to show that the metals have the form of oxides, in the wastes.

The water extract sample from the copper slag prior to blasting process (the control sample no. 4a) fulfills the requirements for the wastes allowed to be stored in the storage areas for neutral wastes and does not endanger the environment in the case of its storage or use as a building material for application without any treatment e.g. for road foundation hardening. The water extract sample taken from the copper slag mixed with after blasting wastes (no. 5a) is characterized by a little greater content of pollutants, and in the range of chromium content it does not comply with the requirements for the wastes allowed to be stored in the storage areas for neutral wastes. The small surpass makes that the wastes in question should be stored in the storage areas for wastes different from dangerous and neutral, or after an appropriate physical and chemical treatment and a resulting change of their washing-out properties (so as to comply with the requirements) – in the storage areas for neutral wastes.

All the water extracts from the samples taken during the second measurement campaign (no. 8a, 9a and 10a) do not satisfy the requirements for the liquid wastes discharged to waters or ground, as far as their pH value is concerned. Except from the surpass of pH value, they are characterized by low concentration values of pollutants, which satisfy the requirements for liquid wastes discharged to waters or ground.

All the samples comply with the requirements for the wastes allowed to be stored in the storage areas for neutral wastes and they do not endanger the environment in the case of its storage or use as a building material for application without any treatment, e.g. for road foundation hardening.

CLASSIFICATION OF WASTES

According to [4] the tested wastes should be classified into the following groups, subgroups and kinds:

- wastes from preliminary washing-down (removal of fouling and paint residues) COD (tested by the bi-chromate method)
- copper slag (prior to abrasive blasting process) – control sample
- copper slag mixed with the removed wastes (after abrasive blasting process)
- wastes from ballast tank cleaning .

BALANCE OF AMOUNTS OF PRODUCED WASTES

On the basis of [9] and made estimations the following yearly balance of some materials consumed by the shipyard in question, is presented :

Ship surface cleaning prior to painting :

- total yearly consumption of copper slag 3900 Mg/year
- including that for ship repair dock 1800 Mg/year

Welding :

- total yearly consumption of welding electrodes 63000 kg/year
- including that for ship repair dock 3500 kg/year

Painting :

- total yearly consumption of paints 112000 kg/year
- including that for ship repair dock 71000 kg/year

In the course of repair work carried out on the ship „*Polar Siglir*" (GR 6-50) the following amounts of the wastes of the main groups, were produced :

- ⇨ copper slag 320 Mg
- ⇨ bilge oils 24 Mg

Detail data on amount of wastes of the remaining kinds, are lacking.

In the course of repair work carried out on the ship „*Ziemia Suwalska*" the following amounts of the wastes of the main groups, were produced :

- copper slag 425 Mg
- bilge oils 20 Mg
- wastes from ballast tanks 35 Mg
- mixed municipal wastes (200399) 33.7 Mg
- paint package 250 x 20 l tins
- abrasive materials 313 Mg

Detail data on amount of wastes of the remaining kinds, are lacking.

PRINCIPLES OF MANAGEMENT OF THE SELECTED GROUPS OF WASTES

In determining the management principles for the selected groups of wastes the following items were taken into account :

- the present way of dealing with wastes
- the results of performed tests on the wastes in question (those concerning environmental impact of the wastes as well as their technological properties characterizing possible recovery/ neutralization of the wastes with taking into account such total concentration of highly noxious substances, which, after performing the complete procedure determined in [5], would not exceed the allowable level)
- the recommended methods of dealing with the wastes (including both the domestic ones and those established by EU)
- possible ways of recovery/ neutralization of the wastes, resulting from the performed investigations.

In Tab. 1 are presented the recommended ways of dealing with the selected – as the most characteristic for the applied engineering processes – wastes produced in the course of ship repair work on floating docks.

Tab. 1. *The recommended ways of dealing with the selected wastes produced in the course of ship repair work on floating docks .*

No.	Name of waste	Recommended way of dealing with the wastes			Comments
		Collection	Transport	Recovery / neutralization	
1	Wastes from preliminary washing--down (removal of fouling and paint residues by means of hydraulic monitor), sludge [4]	After collection to store - temporarily and selectively - the wastes in tight and appropriately marked containers.	By special transport means - to quay area and farther to a waste storage area. Selective storage and successive transfer for recovery / neutralization.	After solidification the wastes could be used as a material for road foundation. They may be also used e.g. as a material for intermediate insulation layer in waste storage areas, or in the case of the wastes from ship's deck washing-down - to undergo recycling process. The wastes from ship washing-down should be stored in the storage areas for dangerous wastes,or after an appropriate treatment and resulting changes of their washing-out properties - in the storage areas for the wastes different from dangerous or neutral.	Possible recovery/ neutralization of the wastes depends on their properties associated with specificity of used paints as well as quality and quantity of fouling organisms. In the case of a greater concentration of organic substances - application of the thermal processing of the wastes may be considered.
2	Copper slag (prior to abrasive blasting process)	In tight and properly marked containers	By railway or road transport	Copper slag materials prior to blasting process comply with the requirements for the wastes allowed to be stored in the storage areas for neutral wastes, hence they do not endanger the environment both in the case of their storage or use as an untreated building material.	The waste is applied as an abrasive material for cleaning hull surface of ships under repair.
3	Wastes from abrasive blasting process (copper slag mixed with residues after the blasting), sludge [4]	As in No. 1.	As in No. 1.	Usage: for filling void spaces in copper mines, road building – as a filler in manufacturing building materials. The waste should be used as an intermediate insulating layer or stored in the storage areas for the wastes different from dangerous and neutral[1]. After physical and chemical treatment and change of its washing-out properties it may be used as a building material.	Main action should be focused on minimization of its production e.g. by applying the abrasive blasting process operating in closed systems, or by using the high-pressure water cleaning processes operating in closed systems.
4	Wastes from cleaning the ballast tanks	As in No. 2.	Selective storage and successive transfer for recovery / neutralization.	The waste should be used as an intermediate insulating layer or stored in the storage areas for the wastes different from dangerous and neutral. Because of a high concentration of iron the waste may be subjected to recycling process. After solidification the waste may be used as a building material and /or for ground hardening.	Possible recovery / neutralization of the waste depends on its properties associated with specificity of paints used in the tanks as well as quality and quantity of sediments and fouling organisms.

[1] The waste does not comply with the requirements for the wastes allowed to be stored in the neutral waste storage areas.

RECAPITULATION

- The engineering processes used for the construction and repair of ships must fulfill legal standards for limitation of waste emission. It is recommended the materials and devices used for the processes to be manufactured, selected and applied in compliance with the principles of *the best available technology* (BAT). It should be stressed that floating docks are not numbered among the facilities required to be granted with an integral approval, however according to [15] technical solutions applied to new or significantly rebuilt facilities should satisfy the BAT principles (par. 143 of the above mentioned Act).

- An effective method to limit environmental emission of the wastes produced during ship repair work on the dock, is to separate the areas in which such engineering processes are carried out, from the surrounding. This can be reached by placing the repaired ship in a „closed" dock or by applying suitably tight coverings to isolate from the surrounding only that part of the ship in which operations associated with waste emission would be carried out.
- Used materials should contain as small amount of compounds harmful or dangerous to the environment, as possible. Applied devices and processes should allow to minimize amount of produced wastes, and the management of wastes from ship repair work on the dock should be highly effective in selective collecting and processing (recovery / neutralization) the wastes, at acceptable cost.
- A main activity aimed at effective managing the wastes should be to minimize their production (e.g. by applying abrasive blasting technique realized in closed systems or by substituting a high-pressure water - cleaning technique realized in closed system for traditional technology.
- If use of an open-cycle abrasive - blasting technique is necessary then application of copper slag as an abrasive material should be avoided and a less noxious material (e.g. ARMEX® means) used instead, applied a sheltered water--blasting technique and/or special coverings (fitted with an air cleaning system) to separate working areas from the surrounding, or to substitute water jet cleaning for abrasive blasting technique.
- In the case of application of the traditional way of ship surface cleaning as large amount of the wastes as possible should be subjected to recovery processes (selective collecting the wastes and their recovery - see Tab. 1).

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   - PN-91/Z-15005
   - PN-90/C-04528
   - PN-86/C-04573/01
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