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SHIP WASTE QUANTITIES PREDICTION MODEL FOR THE PORT OF BELGRADE

This study focuses on the issues related to the waste management in river ports in general and especially in the port of Belgrade. Data on solid waste, waste oils, oily waters, gray water and black water have been collected for a period of five years. The methodology of data collection is presented. Trends of data were analyzed and the regression model was used to predict the waste quantities in the Belgrade port. This data could be utilized as a basis for the calculation of the equipment capacity for waste selective collection, treatment and storage. The results presented in this study establish the need for an organized management system for this type of waste which can be achieved either by constructing and providing new specialized terminal or by providing mobile floating facilities and other plants in the Port of Belgrade for these kinds of services. In addition to the above, the legislative and organizational strategy of waste management has been explored to complete the study because the impact of good waste management on environment and prevention of environmental accidents would be highly beneficial. This study demonstrated that addressing these issues should be considered at international as well as national level.

Key words: ship; solid waste from ships; liquid waste from ships; waste management; wastewater; waste oil.

The Danube River is dealing with environmental problems at international, regional and local levels. The Environment, as a significant element of international relations, is going to be a determinant fact in the 21st century. The most effective environmental governance nowadays, within the Danube basin, is a regional strategy assisted by both national and regional precautions. The problems of environmental deteriorations are named environmental problems in general and present one of the most complex issues that threaten the human kind till now [1].

Danube catchments are closely linked to the Black Sea regarding water protection. Different environment protection strategies are discussed based on EU water policy on one hand, and the experience gained from central European development, which has a long tradition in solving the problems of multinational river basins, on the other [2]. The major

source of contamination to the Black Sea arises as a result of the inputs of contaminants from international rivers, especially the River Danube. Other international rivers are also crucial in the pollution of the Black Sea, although the Danube is the dominant pollutant source. The fact that the total riverine input is about 85% of the total pollution load of biochemical oxygen demand (*BOD*) demonstrates the significance of the control of the riverine source [3].

In the national section of the Pan-European Waterway Corridor VII, where the Port of Belgrade is situated, passenger and cargo traffic is carried out with no established system of control and management of ship-generated solid waste and wastewaters. The laws regulating this domain are being voted in Serbian Parliament recently [4-11]. The implementation of those laws is supposed to regulate a part of the problem.

The amount of traffic on the inland waterways of the Republic of Serbia and storage capacities have been examined [12]. The aim of collecting and analyzing relevant data was to define the criteria for estimating solid and liquid waste quantities in this important port. This subject was not sufficiently elaborated in the literature. On the basis of the criteria established by the authorities of the Port of Belgrade and the

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information on the number of watercraft dockings in ports and harbors, a preliminary assessment of the quantities of individual waste types has been carried out [13]. The five year period (2005-2009) has been studied.

The Port of Belgrade is situated at 44°48' North 20°28' East. It stretches along 1.168 kilometers of the right bank of the Danube, in immediate vicinity of Belgrade city centre [14]. The Port of Belgrade is located at the intersection of two Pan-European transport corridors (River Corridor 7 and Road Corridor 10) and it is an important transport, loading and cargo centre for Central Europe. The port also manages the passenger terminal on the nearby river Sava. Port transfer capacity is 3,000,000 t per year. It also has 300,000 m² of warehouses and 650,000 m² of open-air storage areas. The Port of Belgrade has been operating on present location, and under this name, since 1961. There is a plan to move the port to the other side of the Danube, providing more space for the development of Belgrade.

The Port of Belgrade successfully supports visible trade, using all the benefits of the modern river, railway, road and multimodal transport. The Port and the waterways enable the transfer of goods among all countries situated around the North Sea-Black Sea main lines of navigable communication. By way of standard and multimodal transport, the movement of goods *via* the Port of Belgrade expands farther into the land, connecting all European countries.

The key segments of the Port of Belgrade business operations are warehousing, port services and the passenger dock on the River Sava. Port services comprise: port operations, public and customs warehouses, and container terminal; forwarding and transportation mediation.

Port operations comprise: reception of goods, preparation of goods, overhaul and storage handling between all transport modalities, including anchorage, pilotage and docking services. The port possesses certificates for specialized services: ISO 9001: 2000 - Quality Management Systems; ISO 14001: 2004 - Systems environmental management; OHSAS 18001: 2007 - Systems Occupational Health and Safety at Work, but does not possess the IPPC license for processing waste treatment plant [15-17].

Wastes are defined as substances or objects disposed or to be disposed or are required to be disposed in accordance with the provisions of national legislation [18]. Ship waste is all waste, non-hazardous and hazardous, that has occurred during ship navigation, as well as the waste being transported by cargo vessels. In general, ship waste includes:

- Solid waste - solid municipal waste (from watercraft this waste is similar in composition to domestic waste) and ship cargo residues (residues of any type of ship cargo in ship warehouses or tanks occurred after debarking, cleaning or washing of ship warehouses, deck or tanks, including the excess and spilled cargo during embarking/ debarking operations) [19].

- Liquid wastes include: waste oils (waste lubricating oil that needs to be changed periodically to ensure its lubricating function of motors [20] and wastewaters.

- Wastewaters can be divided into oily and non-oily wastewaters. Oily wastewaters originate from engine rooms and machinery spaces, e.g. pump rooms. Oily wastewater handling is regulated by the bilge water regulations in Annex I to the MARPOL 73/78 Convention [21]. Non-oily wastewaters are divided into other non-contaminated drains and contaminated, sewage type wastewaters. The non-contaminated wastewaters are drainage waters from exposed deck scrubber systems, dedicated sprinkler drainage systems, AC room condensation collecting system, etc. Gray and black water (defined by the Rule 1 of the Annex IV to MARPOL 73/78 Convention, oily or bilge wastewaters (often contaminated with oil and cargo residues, together with other pollutants: non-organic salts, metals such as arsenic, copper, chrome, lead and mercury).

The sources of contaminated wastewater on board ships are basically the same as in communities ashore. Annex IV to the MARPOL 73/78 Convention defines sewage in the following way:

- drainage and other wastes from any form of toilets and urinals;

- drainage from medical premises (dispensary, sick bay, etc.) *via* wash basins, wash tubs and scuppers located in such premises;

- drainage from spaces containing living animals;

- other wastewaters when mixed with the drainages defined above (for example a mix of sewage and gray water).

Sewage is also called black water and the discharge of ship sewage is restricted on the basis of the MARPOL 73/78 Convention. Sewage on board ships differs from that of municipalities by its short retention time and smaller water content. On board ship, the sewage ends up almost directly in the treatment plant; therefore, the amount of dissolved BOD is lower than in municipal systems and the cleaning process is easier. The smaller water volume of the sewage on-board ship makes it more concentrated when compared to the municipal sewage [22].

Gray water consists of non-sewage wastewater, including drainage from dishwashers, showers, laundry, baths, galleys, and washbasins. Gray water represents the largest category of fluid waste generated by cruise ships. The discharge of gray water is not restricted by international law and in some cases it is discharged directly into the environment. However, in certain sea areas and during berthing the sewage and gray water must be stored or treated.

The procedure of waste treatment, from the point of view of a port, starts from the moment of notification by the vessel commander about the quantity and type of waste to be delivered, followed by the reception in port, its transport and finally, treatment in the appropriate facilities or waste disposal. The economy concept of watercrafts waste management is considered in order to prepare pilot activities for management of oily and greasy ship waste. This was the concept of the Waste management for Inland Navigation of the Danube (WANDA) Project (Program Interreg III B CADSES). The project aims was to develop and promote a permanent and coordinated transnational advanced waste system for vessel waste along the length of the Danube River [23,24]. Some strategies for waste material management from watercrafts were developed in Serbia [25]. The aim of this strategy was to develop the legislative as well as procedures for waste storage.

As a result of international efforts in waste management the Danube Commission was established with the aim to define international strategy for waste management. The main result of this activity was the "Recommendation for the organized collection of ship-generated hazardous waste" and this document addresses the tasks of ship waste collection, equipment reception points establishment, procedures and organization of waste collection organization, identification and further disposal or treatment.

Recommendations for the organized waste collection stipulate that the state takes upon itself and guarantees waste collection by determining the reception points for further treatment on shore, in accordance with the infrastructure plans and plan for development of ports and waterway reception points. The study of water treatment terminal for Belgrade provided a possible partial solution for the problem of wastewaters from ships, since these wastewaters could be collected and processed in such facility [26].

The state should find the most suitable mode for financing the development and construction of the project, so that shipping companies would be encouraged not to discharge the waste and wastewaters in the Danube, which has been common practice until

now. It is anticipated that all countries, within five years from the recommendations taking effect, should build the infrastructure for waste reception, and assume the responsibilities related to the organizational, financial and other required measures.

The aim of this work was to incorporate all international [10,11,15,16,18,21,27,28] and national recommendations and studies [4-9,17,33] in order to develop the ship waste quantities prediction model for the port of Belgrade. The established waste quantities could be further utilized as a basis for general project and preliminary feasibility study for the new terminal for the reception, treatment and storage of waste and wastewaters from ships and consequently for the calculation of the equipment capacity for waste collection, storage and treatment.

RESEARCH

Survey of present state

As a result of daily activities of watercrafts functioning different sorts of waste are generated. They are mainly collected in specialized terminals in ports and harbors and further classified, treated or deposited in land-fields.

The ports and harbors facilities in Serbia in general, are not built according to today's standards and did not pass the quality certification for waste treatment. Cleaning and washing of the tanks is conducted exclusively when transport is finished, and currently there is no control of wastewaters discharged during these processes. Therefore, this problem should also be included in a list of problems identified in the waterways of the Republic of Serbia given as follows:

- there are no specialized ships for collection of solid and liquid wastes from the watercrafts;
- the port of Belgrade has no certificate in waste treatment as declared on their web site;
- there are no services for waste material collection from the watercrafts;
- synchronization in collection of wastes exists only in cases of accidents;
- there is a significant probability of uncontrolled wastewater discharge from international watercrafts in the Danube river on the way through Serbia. The lack of control and management system encourages such behavior.

Conditions for environmental protection in the new laws and their implementation should enable establishing new procedures for waste management and this could lead to improvement of safety conditions. Additionally, the country lacks inherent conditions for the development of a competitive inland waterway

system that complies with the international Convention on Co-operation for the Protection and Sustainable Use of the River Danube [27] (signed by the RS government), or with the conventions, regulations, and standards for the protection of vessels, people and the environment.

Management of ship-generated waste

Considering that the waste treatment on sea and ocean ships is already regulated, it can be assumed that the same should be applied to river ships. The amount of garbage on board should be estimated, if possible separately according to category. The Garbage Record Book contains many references to estimated amount of garbage [28].

The EU Commission (2000) set out the specific requirement that all EU ports should provide reception facilities for vessels normally using that port. Those facilities should accept a wide range of ship-generated waste including oily waste, chemical waste, sewage and garbage. All wastes generated on board watercrafts visiting those ports should be discharged into reception facilities, unless ships had sufficient capacity on board to travel to their next port of call, with a system of watercraft documentation and inspections to ensure that ships are capable of reaching that next port without the need to discharge waste illegally at sea. The directive also includes a requirement for advance notification by ship's crew to ports of their intention to use facilities; a fee system is established to encourage use of facilities and a system to monitor compliance by watercrafts and the provision of adequate sanctions for non-compliance [29].

Methodology of waste quantities calculation

The first step in solid waste management for ships is the prediction of quantity of waste that could be generated. This enables adequate design and capacity calculation for waste treatment facilities on the vessel as well as in the port's terminals.

The context of this paper is to study management of ship solid and liquid waste for systematization of data and their analysis. Data considered included the number of ships, annual number of ships stops, number of passengers, crew members and quantity of different kinds of solid and liquid waste from ships. The aim of this analysis is to provide data for equipment design and plants for stocking, transport, treatment of solid waste, waste oils and wastewaters on ships themselves and in ports. Special attention is given to trends of quantities of waste collected with the purpose to enable construction of plants having sufficient capacity for longer period of time.

The main criteria for waste production on ships were the duration of stay of passengers and crew members on a ship. The average number of days that a passenger spends on a ship, producing waste, is 3 days; for crew members it is 5 days [12].

Solid waste is estimated based on number of persons per day, one person generates approximately 1 kg of solid waste daily. The density of this waste is estimated to be approximately 0.25 kg/dm³ based on analogies with domestic waste and comunal waste [30-32], which means that the daily volume of solid waste generated per person is approximately 4 dm³.

The estimation of quantity of waste oils that are going to be deposited in Serbia, was based on the number of ships that annually stop in harbours of Serbia. The assumption was that once per year the ship should change machine oil and that due to this reason a ship would stop in one of the harbours in Serbia [12]. The quantities of disposed waste oil per harbour are estimated to be proportional to relative number of stops in specific port.

Quantity of oily water is estimated based on number of ships that annually stop in harbours of Serbia. For each ship (with assumed machinery consisting of two diesel engines and two diesel generators) the estimated daily amount of oily water from bilges of ship machinery complex is 20 dm³ [12]. The quantities per harbor were assumed to be proportional to relative number of stops in specific port.

Criteria for gray water quantity calculations are based on number of passengers or crew members for cruise and cargo ships. Duration of cruise was also one of the parameters. During a one-day-voyage the water consumption for personal needs is smaller compared with longer trips, this applies also for laundry cleaning, cabins and restaurants maintenance and other ship facilities. Showers typically uses 17 to 30 dm³/min, low water consumption showers use 9.5 dm³/min. In present calculation it was considered that the shower use was approximately 15 dm³/min. Other quantities are calculated according to empirical data. Some estimates of wastewater generation have been [22]: 1 min of shower produces 12-14 dm³ total daily gray water: accumulation is less than 300 dm³ per day per person; total daily kitchen and laundry accumulation is less than 70 dm³ per day.

Black water quantity calculations are similar to those for gray water and they are based on toilet flush volumes. Some estimates for toilet flush volumes depends on type of toilet flush: gravity feed 6.8 dm³ per flush, vacuum feed toilet flush 1.2 dm³ per flush. In the Baltic Sea area study daily black water accumulation in large cruise ships with more than 140 pas-

sengers, is estimated to be 20-30 m³. Quantites estimated for ships that are active on the Danube river are assumed to be simmilar to those estimated for ships operating in the Baltic Sea [22].

RESULTS AND DISCUSSION

The Belgrade port authorities provided the authors with data of number of ships and number of passengers and crew members on watercrafts that were stationed in the Port of Belgrade in period 2005-2009. This data was used to calculate quantity of all types of waste produced in this period.

Table 1 provides the data on the number of the cargo and cruise ships together with the number of passengers and crew members.

Table 1 shows constant increase of number of passengers and crew members on ships in period 2005-2008, followed by slightly larger increase in year 2009.

Based on data in Table 1, in Figure 1 yearly quantities of solid waste from ships in period 2005-

-2009 are presented, while in Figures 2-5 are given the corresponding quantities of waste oils, oily wastewaters, grey and black waters, respectively.

Figure 1 shows quite moderate increase of quantities of solid waste generated on ships (QSWS) in period 2005-2008 and larger increase in year 2009. The presented trend line corresponds to the best fit of available data. According to best fit the predicted quantity for 2011 of around 5,000 m³ could serve as the basis for calculation of capacities of waste collection facilities in the port. This waste should further treated by organizations certificated for waste treatment and disposal.

Figure 2 shows almost same quantities of waste oils from ships (QWOS) in period 2005-2008 and increased level in 2009. The trend indicates that one could expect the significant increase in next two years.

Waste oil from ships should be separately and properly collected. The predicted quantity of QWOS for 2011 is around 79 m³. According to National Strategy for Sustainable Development [33], 2017 is the

Table 1. Number of passengers/crew members from watercrafts in the Port of Belgrade in period 2005-2009

Year	Number of dockings in a year		Number of passengers	Number of passenger ships crew members	Number of cargo ships crew members
	Cruise ships	Cargo ships and groups			
2005	320	301	38400	9600	3010
2006	349	307	41880	10470	3070
2007	396	320	47520	11880	3200
2008	400	328	48000	12000	3280
2009	533	394	64000	16000	3947

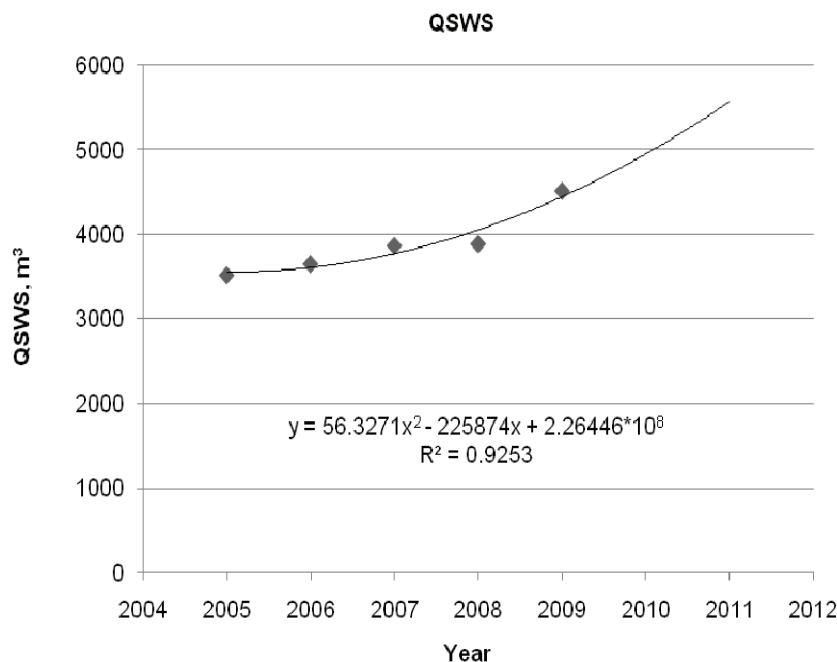


Figure 1. Quantities of solid waste (QSWS) collected in the Port of Belgrade together with a trend line.

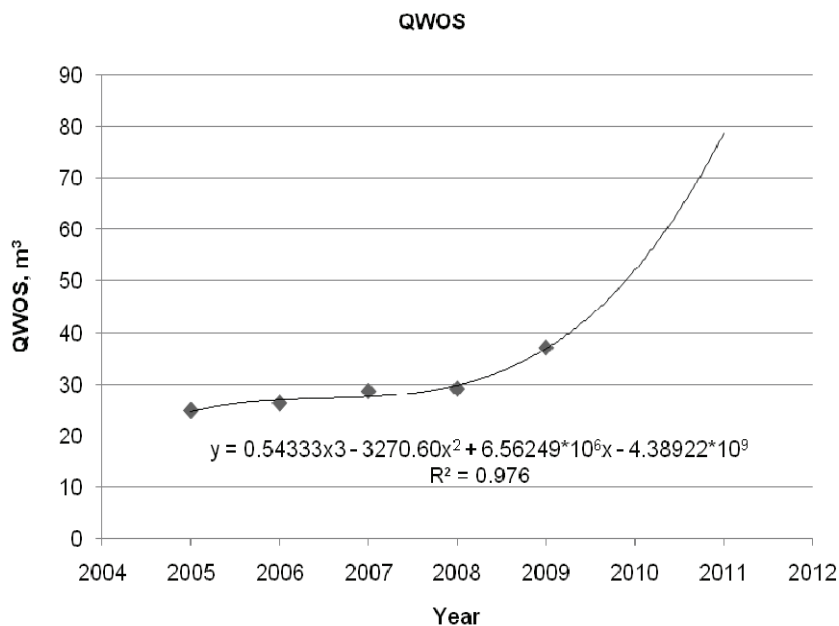


Figure 2. Quantities of waste oils (QWOS) collected in the Port of Belgrade together with a trendline.

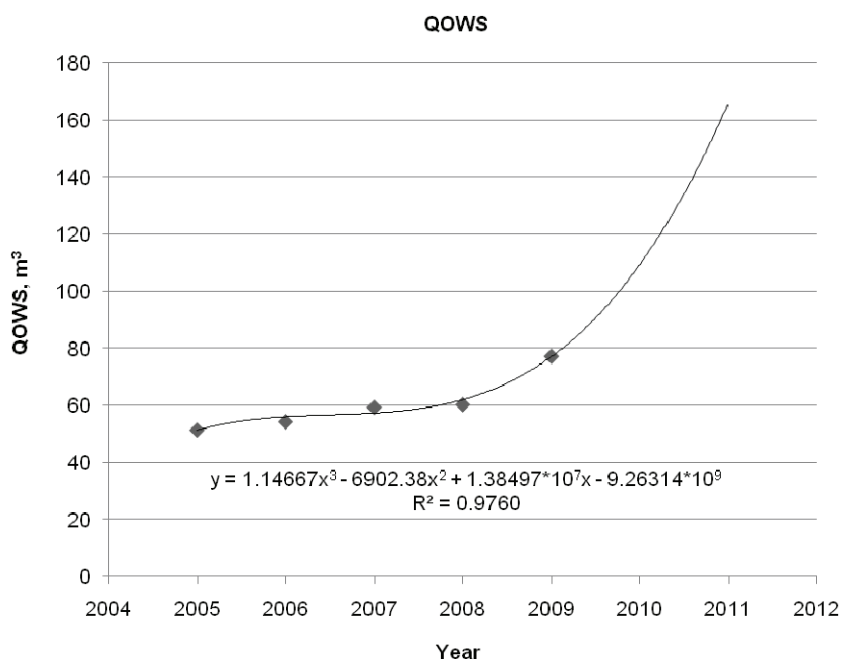


Figure 3. Quantities of oily wastewater (QOWS) collected in the Port of Belgrade together with a trend line.

deadline for appropriate regulation of waste and wastewaters including the entire waste from ships. Therefore, the general project and preliminary feasibility study should be finished as soon as possible. The obtained predicted ship waste quantities for the port of Belgrade for 2011 can be used as basis for the preliminary feasibility study for collection, separation and treatment of waste from ships in the Port of Belgrade. This preliminary feasibility study should give suggestions for different variations of the flow of implementation depending on the preliminary analysis

system. Namely, this preliminary feasibility study should suggest which of two alternatives for management of this type of waste is more appropriate either transportation to specialized waste oil treatment facility, *i.e.*, Oil Refinery Belgrade or construction of appropriate facility within terminal of the Port of Belgrade.

Figure 3 shows the same trend for oily wastewater from ships (QOWS) as for QWOS. The trend line indicates a significant increase that could arrive in next two years. The predicted quantity of QOWS for 2011 is around 165 m³. The capacity of collection and

storage of this sort of waste in the port can increase significantly very soon. Therefore, the preliminary feasibility study for collection, separation and treatment of waste from ships in the Port of Belgrade can consider here presented predicted QOWS for 2011 as basis for collection, separation and treatment facilities and appropriate equipment requirements.

The data presented in Figure 4 which estimated that the increase of quantity of gray water from ships (QGWS) could be important in next two years. This

indicates that the capacity of plants for gray water collection should be increased or the strategy of their management after reception should be considered. The predicted quantity of QGWS for 2011 of around 105,000 m³ can be used as basis for the General Project or Preliminary Feasibility Study for collection, separation and treatment of waste from ships in the Port of Belgrade.

The trendline on Figure 5 indicates the quantity of black wastewater from ships (QBWS) increase in

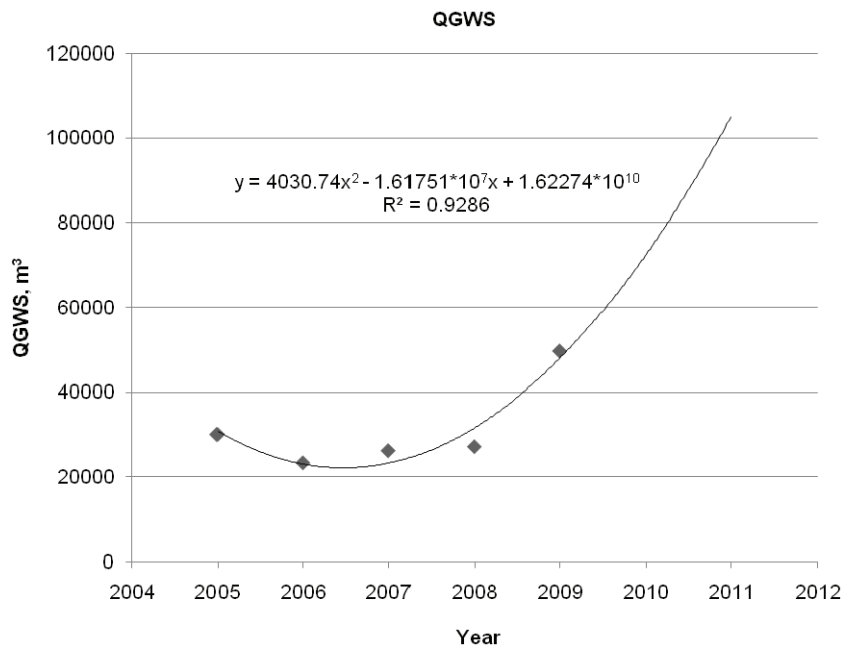


Figure 4. Quantities of gray water (QGWS) collected in the Port of Belgrade together with a trend line.

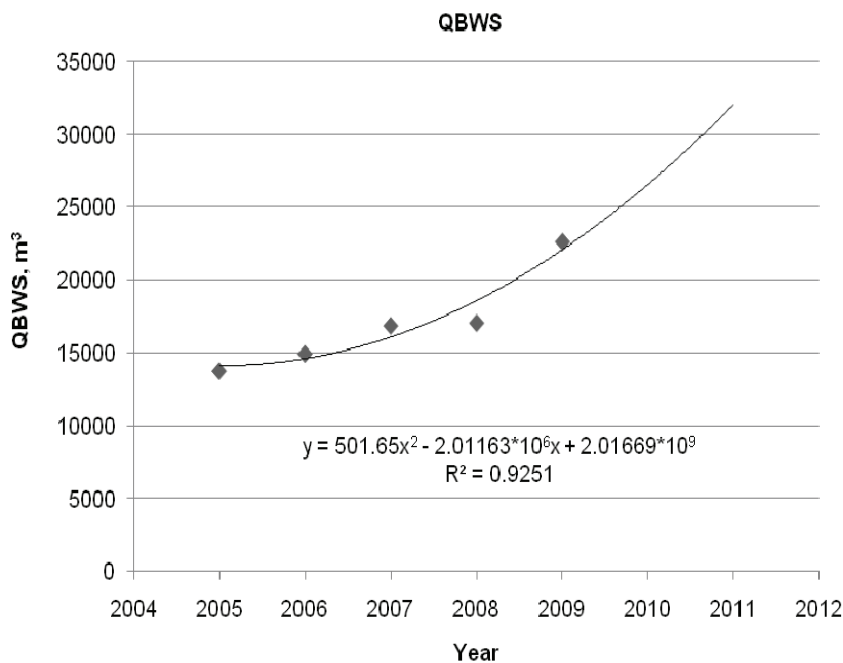


Figure 5. Quantities of black water (QBWS) collected in the Port of Belgrade together with a trend line.

next two years that is less important than the prediction for the other liquid waste from ships: QWOS, QOWS and QGWS and very similar with trend line for the QSWs. The predicted quantity of QBWS for 2011 is around 32,500 m³.

Gray and black wastewater should be pump out from the vessel to storage tanks installed at the terminal or directly to the wastewater treatment plant. If the preliminary feasibility study proves that the above solution is not adequate, in this case the gray and black water should be pump out directly to the municipal sewer system to finally be treated in the municipal wastewater treatment plant.

CONCLUSION

The situation of legislation concerning ship navigation by inland waterways and their technical maintenance is analyzed, together with the policy of waste management. The study presented here is based on implementation of these laws. The aim was to answer to both technical and legislation demands concerning regulation of waste collection and treatment of all types of wastes generated from ships. Ship wastes need collection facilities, as well as the strategy for further treatment. A part of the waste can be treated on the ships themselves, but all untreated waste quantities should be treated either in port facilities or should be sent to municipal facilities for further handling. This study was based on the assumption that all identified and estimated waste quantities will be managed in new the Port of Belgrade terminal. The data received from the Port of Belgrade authorities enabled the authors to estimate the quantities of solid waste, oily waters, waste oils, gray and black water generated from ships. The data was analyzed in terms of waste generation trends and an annual increase is observed. The best fit equations were used to predict the projected annual quantities of each type of waste for the Port of Belgrade. The obtained trends enabled extrapolation of the capacity requirements that can be used as the basis for the general project and the preliminary feasibility study for collection, separation and treatment of waste from ships in the Port of Belgrade and the construction of a new terminal. This new terminal should fulfill as many requirements as possible concerning waste and wastewater management including collecting, classification and treatment.

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Nomenclature

BOD -	Biochemical oxygen demand
IPPC -	Integrated Pollution Prevention and Control
ISO -	International Organization for Standardization
QBWS -	Quantity of black water from ships
QOWS -	Quantity of oily wastewater from ships
QGWS -	Quantity of gray water from ships
QSWs -	Quantity of solid waste from ships
QWOS -	Quantity of waste oils from ships
WANDA -	Waste management for inland Navigation of the Danube

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NAUČNI RAD

MODEL ZA PREDVIĐANJE KOLIČINE OTPADA U LUCI BEOGRAD

Ovaj rad se fokusira na sporna pitanja u vezi sa upravljanjem otpadom u rečnim lukama uopšte, a posebno u luci Beograd. Podaci o čvrstom otpadu, otpadnim uljima, zauljenim otpadnim vodama, sivoj i crnoj vodi, prikupljeni su za period od pet godina. Analizirani su trendovi i korišćen je regresioni model za predviđanje količine otpada u Luci Beograd. U radu je prikazana metodologija za prikupljanje podataka o čvrstom otpadu kao i o otpadnim vodama, otpadnim uljima i zauljenim vodama. Ovi podaci se mogu koristiti kao osnova za proračun kapaciteta opreme za selektivno sakupljanje otpada, njegov tretman i skladištenje. Rezultati prikazani u ovom radu dokazuju potrebu za organizovanim sistemom upravljanja za ovu vrstu otpada, koji se može postići ili izgradnjom i opremanjem novih specijalizovanih terminala ili obezbeđenjem mobilnih plovnih objekata i drugih postrojenja u luci Beograd, za ove vrste usluga. Da bi se upotpunila ova studija, pored istraživanja koja su gore navedena, istraživana je zakonodavna i organizaciona strategija upravljanja otpadom, pošto je uticaj dobrog upravljanja otpadom na životnu sredinu i sprečavanje akcidenata ne samo veoma pozitivan, već i neophodan. Ova studija će pokazati da pitanja kojima se bavi treba uzeti u obzir kako na nacionalnom, tako i na međunarodnom nivou.

Ključne reči: brod; čvrst otpad sa brodova; tečni otpad sa brodova; upravljanje otpadom; otpadne vode; otpadno ulje.