Technical aspects of environment protection with respect to a small inland passenger ship

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ABSTRACT

The article presents brief information on impurities which can be emitted to the environment by an inland passenger ship and discusses methods and devices which can help reduce or avoid these emissions.

Keywords : environment protection, small inland passenger ship, passenger ship

INTRODUCTION

Inland and coastal ships often navigate on water regions which come under the regulations of both the marine and land administration. Water regions of this type in Poland include the Gdanska and Pomorska bays, and the Vistula and Szczecin Lagoons. From the point of view of environment protection, the inland ship should meet the regulations included in the Marpol convention, and those given in acts, instructions, and other legal documents concerning inland waters. These regulations, issued by various administrations, are often incompatible to each other, therefore the range of requirements to be met by the inland ship can be wider than those concerning a classical seagoing ship. A problem of current importance is also the variety of amendments to these regulations, especially those concerning environment protection.

The present article, based on Ref. [1], discusses types of impurities which can be emitted to the natural environment by a small inland passenger ship, quotes selected relevant legal regulations, and formulates certain suggestions on how to avoid or reduce these emissions. In the analysis the following assumptions were made :

★ Ship design, equipment and operation is to be "environment friendly" to as high extent as possible – with minimum influence exerted on the environment during the entire "life cycle", including times of building, operation (and all types of repairs), and scrapping. All that means that the ship should meet not only the regulations resulting from the current law in force (concerning natural environment protection), but at its design stage the regulations which have not come in force yet been but are known to be valid in the nearest future should also be taken into account, along with other relevant requirements, concerning seagoing ships for instance.

★ Ship design and equipment should meet the regulations of a selected classification society, environment protection conventions in force, and local standards resulting from the law of a country, or countries, on the territory of which the ship is going to navigate. The object of more detailed discussion will be Polish regulations which are now compatible, to a high extent, with the law in force in the remaining EU countries.

For the ship to meet the above requirements, as early as at its design stage a series of decisions is to be made on its construction and equipment. In numerous cases prevention or minimisation of impurities emitted to the environment consists in selecting a proper solution rather than a real machine, and in this process an important role is played by ship designers. For instance, the selected machines must not include parts made of noxious materials (asbestos, for instance), and must not emit to the environment considerable volumes of noxious wastes as a result of its normal use.

SHIP CHARACTERISTICS

The characteristics of a ship are given here to identify possible sources and types of impurities which can be emitted to the environment. For this purpose reports prepared within the framework of the !EUREKA-INCOWATRANS project were used. The basic data define [2] :

⇨ A cruising passenger-sanatorium ship (high comfort secured)

⇨ Sample cruising route : Berlin – Torun – Gdansk – Elblag – – Krolewiec

⇨ Number of passengers and crew : maximum 80 ÷ 100 people

⇨ Time of voyage: about 14 days, with longer stops in selected ports, attractive from the tourists' point of view

⇨ Two-element ship structure: a pusher tug (a driving module with crew's quarters and part of passenger cabins) and a barge (luxurious passenger cabins); total length : ~110 m, design draught 1 m

⇨ On the cruising route there are places such as passages under bridge spans, which require increasing draught (extra ballasting)

⇨ The delivery is required of: mechanical and electric energy, heat for heating purposes, drinking and sanitary water; the sources of mechanical and electric energy will be supercharged piston-type internal combustion engines fed with liquid or gas fuel

⇨ The waste (including noxious components) and sanitary sewage will be taken off the ship.

IDENTIFYING TYPES OF IMPURITIES EMITTED TO THE ENVIRONMENT

The impurities resulting from ship operation include :

- oil and oil mixtures from the bilge, liquid fuel, lubricating oil, and power hydraulics systems
- maintenance garbage from the ship engine room and deck (definition according to Annex V to the Marpol convention)
- products of fuel burning in piston engines (nitric oxides, sulphur dioxide, unburned hydrocarbons, solid particles, carbon dioxide)
- leakage of working agents from cooling and, possibly, fire extinguishing installations
- emission of hydrocarbon vapours from fuel tanks
- undesirable water organisms and pathogens existing in the transported ballast water and sediments covering the bottoms of the ballast tanks
- noise emitted by power plant and general purpose ship machines and devices
- utilisation of wastes (including ship scrapping).

The impurities resulting from ship function include :

- sanitary sewage and waste waters (definition according to Annex IV to the Marpol convention)
- service and kitchen garbage (definition according to Annex V to the Marpol convention).

The above listed impurities are emitted to the atmosphere and water, and increase soil pollution (sewage and waste transported to land).

LEGAL REGULATIONS

The ship can be used for navigation on Polish inland waterways if it meets the regulations of the act on inland navigation [3], complemented by relevant executory instructions [4, 5]. These regulations define requirements concerning the process of ship building and equipping, protection of water and air purity, and noise emission. They also refer to PRS codes of practice.

The act [3], the uniformed text of which was published in June, 2006, has implemented to the Polish law the purview of the 82/714/EWG directive (amended in 1994 and 2003), which formulates technical requirements for water regions constituting the inland waterway network in Western Europe, except the Rhine and Mozela Rivers. The regulations in force on these rivers, drawn up by the Central Commission for Rhine Navigation (CCNR), are more severe.

Until December 2006, the CCNR and EU regulations were harmonised, which resulted in issuing a new voluminous directive [6, 7], formulating technical requirements for inland ships and revoking the 82/714/EWG directive. New requirements will make it possible to adapt (and unify) codes of practice valid in particular EU countries to advanced standards in force in Rhine navigation. The deadline for introducing new legal, executory, and administrative regulations is December 30, 2008. Until then all relevant legal acts are to be modified [3, 4 and 5].

At present, the volumes of impurities emitted to the atmosphere in the exhaust gases generated by Diesel engines installed on inland ships are limited by the regulations formulated in the instructions [8], which implement a series of EU directives (including so-called Rhine Regulations) concerning the quality of the atmospheric air. The deadline for all regulations of these instructions to come into force is December 31, 2008 r. The final regulations say that since July 1, 2007, engines which meet requirements formulated by the Central Commission for Rhine Navigation (stage II) can be introduced to trade and mounted on inland navigation ships. The limits for gas impurities and solid particles emitted by those engines are given in Table 1. Similar limits (at stage IIIA) refer to the impurities emitted by category V1-V2 engines used as propulsion on inland ships [8].

The quality of the fuel, and most of all the content of sulphur, is defined by the directive 2005/33/WE, introduced in Poland following the resolution of the Minister of Transport and Construction, dated May 4, 2006 [9].

Since January 1, 2010, the content of sulphur in the fuel delivered for use to the ships mooring in ports of EU member countries and to inland navigation ships will not be able to exceed 0.1% m/m.

As the planned sailing route goes beyond the borders of Poland and the European Union, it is advisable to meet also the environment protection requirements formulated in the regulations of international conventions (Marpol, for instance). It is the classification societies which are obliged to implement these regulations. Five of them met their obligation by issuing supplements to their regulations in the form of notations of so-called environment classes (Table 2). The Polish Register of Shipping (PRS) issued a collection of technical requirements [10], being in fact a summary of basic IMO requirements but not composing conditions for obtaining additional class notation. An abridged collection of selected (most severe) requirements for obtaining the above mentioned notation is given in Table 3.

Additional requirements formulated in various regulations are quoted further in the article.

Table 1. *Limits of gas impurities and solid particles emitted by Diesel engines, according to Rhine Regulations [8, stage II].*

Engine power P_N [kW]	Carbon monoxide CO [g/kWh]	Hydrocarbons HC [g/kWh]	Nitric oxides NO_X [g/kWh]	Solid particles PT [g/kWh]
$18 \le P_N < 37$	5.5	1.5	8.0	0.8
$37 \le P_N < 75$	5.0	1.3	7.0	0.4
$75 \le P_N < 130$	5.0	1.0	6.0	0.3
$130 \le P_N < 560$	3.5	1.0	6.0	0.2
$P_N \ge 560$	3.5	1.0	$n \ge 3\,150$ rev/min $\Rightarrow 6.0$ $343 \le n < 3\,150$ rev/min $\Rightarrow 45 \times n^{-0.2} - 3$ $n < 343$ rev/min $\Rightarrow 11.0$	0.2

ACTIONS ORIENTED ON MINIMISING THE EMISSION OF SHIP IMPURITIES

Main propulsion

Studying the legal regulations and identifying the emitted impurities allow a conclusion to be formulated that their volume is most significantly affected by the applied solutions

Table 2. *Collection of environmental class notations for seagoing ships [11 ÷ 15].*

Classification Society	Class notation
Det Norske Veritas	CLEAN and CLEAN DESIGN
Registro Italiano Navale Group	GREEN STAR
Lloyd's Register	ENVIRONMENTAL PROTECTION
American Bureau of Shipping	ENVIRONMENTAL SAFETY
Germanischer Lloyd	ENVIRONMENTAL PASSPORT

Table 3. *Abbreviated requirements for obtaining environmental class notation, taking into account DNV, RINA, LR, ABS and GL regulations [11÷15].*

Sanitary sewage Sanitary sewage and waste waters ("grey" sewage) are to be processed, or stored and then transported to land. The sewage processing machine (if used) should meet requirements of the MEPC.2(VI) resolution.
Dealing with garbage The garbage (according to the definition given in Annex V to the Marpol convention) should be sorted, stored and transported to land.
Emission of nitric oxides Each Diesel engine of power higher than 130 kW, excluding engines intended for use in emergency cases, should meet the NO_X emission standard equal to 60% of the volume defined, according to the Formula 13 Annex VI Marpol, from the following relations : for n<130 rev/min $\Rightarrow$ 17 g/kWh, for 30 rev/min $\leq$ n< 2 000 rev/min $\Rightarrow$ $45.0 \times n^{(-0.2)}$ g/kWh, for n $\geq$ 2 000 rev/min $\Rightarrow$ 9.8 g/kWh.
Emission of sulphur dioxide The fuel burned in engines installed on the ship: maximum content of sulphur 0.2% m/m (light fuel) or 1%m/m (heavy fuel). Alternatively: max. 2.0 g SO_X/kWh in the exhaust gases.
Fire extinguishing installation Substances used in fire extinguishing installations should have GWP<1650 and ODP=0. The use of halons is prohibited.
Cooling installation The use of such refrigerants as CFC and HCFC is not allowed. Natural refrigerants are to be used, or, alternatively, HFC revealing GWP<1890 and ODP=0.
Ship hull painting Ship hull is to be covered with paints without TBT.
Arrangement of tanks for fuel, lubricating oil, and oil wastes Tanks are to be separated from shipboard and/or bottom by cofferdams.
Required is main propulsion redundancy (obtaining class **RP** notation, according to DNV regulations is considered sufficient).

of the main propulsion and power generation systems. Of high significance is the selection of the fuel and machine in which the chemical energy of the fuel is converted into the mechanical energy (Fig. 1).

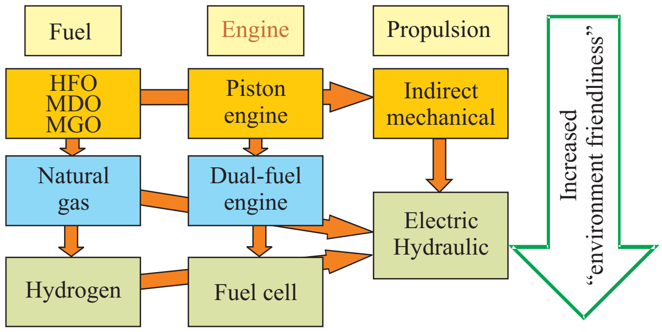

Fig. 1. *Scheme of actions oriented on selecting propulsion and power generation systems for the designed ship.*

The fuel can be diesel oil, liquid or gas hydrocarbons (CNG, LPG) or hydrogen (compressed, or in another arbitrary form delivered to a fuel cell).

At the present state of technology each piston engine can be fed with the gas fuel. Advantages resulting from the use of the natural gas (CNG) or liquefied oil-originated gases (LPG) as fuels include, first of all, low toxicity of the emitted exhaust gases, compared to those generated in the process of diesel oil burning.

From the safety point of view, the use of the natural gas in the ship's power plant is more profitable. The natural gas is lighter than the air and in case of leakage in the supply installation it moves up, which facilitates ventilation. LPG is heavier that the air and in case of leakage, some problems may occur with ventilation of the room in which the tank or gas installation is located.

A basic disadvantage of the use of the natural gas as engine fuel is its low energy density. As a result, tanks for these types of fuel (in case of CNG, the working pressure in high-pressure tanks is equal to 20 ÷ 25 MPa) take more space than those for liquid fuels or LPG. An obstacle making the wider use of the natural gas as engine fuel in Poland more difficult is its poor distribution network.

Hydrogen is a specific gas fuel, which differs most from the conventional (liquid and gas) fuels by the exhaust gas composition. Due to the absence of coal in the fuel, the carbon dioxide practically does not exists in the exhaust gas of the engine fed with hydrogen, and the main exhaust gas component accompanying the nitrogen is the steam. In fact, the only toxic components of the exhaust gas are nitric oxides.

From the point of view of environment protection, the most favourable inland ship propulsion in the nearest future seems to be a combined combustion-electric propulsion system, in which medium-speed current generators meet the requirements given in Table 1 for the level of impurities emitted in the exhaust gas. A most recent design of Volvo Penta (engine D16 with 478 kW output, Fig. 2 meets requirements of IMO, EPA2, Rhine River Step 2 and Clean Design DNV class notations. A collection of permissible emission limits of nitric oxides, according to different regulations given in Fig. 3, suggests that a sufficient requirement to be met by the piston engines with output below 560 kW, which may be used as the main drive on the designed passenger ship, is meeting the Rhine Regulations [8].

At present, there are no offers of dual-fuel or gas engines with output of an order of 200 ÷ 300 kW on Polish markets. Offers of those engines solely refer to the constructions used in road transport and stationary power systems.

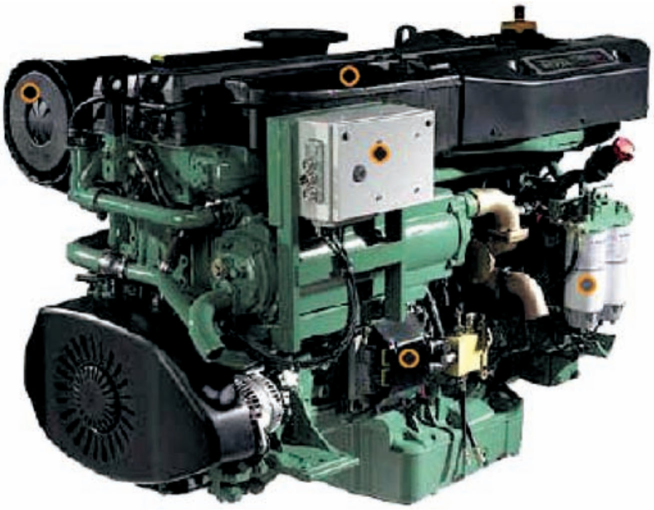

Fig. 2. *General view of Volvo Penta engine, type D16 [www.volvo.com].*

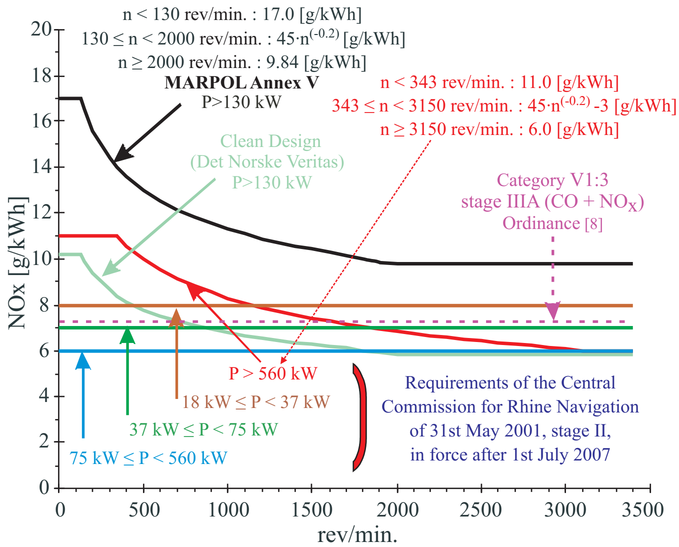

Fig. 3. *Permissible levels of emission of nitric oxides, acc. to [8, 11, 16].*

An alternative for the piston engine can be the use of fuel cells that directly convert the chemical energy of the fuel into the electric energy. The fuel cells are extremely environment friendly, as the by-products, such as H_2O, CO_2 or N_2 are pure, and the emission of nitric oxides, sulphur oxides, carbon oxides and hydrocarbons is very low. Moreover, they reveal low noise emission. They can be located anywhere, in practice, and occupy very little space. A disadvantage of the fuel cells is low current voltage obtained form a single cell, V< 1 V, and that they generate the direct current. At present, one of the biggest disadvantages is also their price, as the cost of a fuel cell with several hundred kW output power is over 1 million $.

A possibility to make a choice between a piston engine and a fuel cell forces the use of an electric motor as the propeller drive. A sample design of the combined combustion-electric propulsion system is shown in Fig. 4. The power plant comprises electric current generators with output power of about 200 kW each, frequency inverters, alternating-current motors, and propellers (mounted in nacelles, or as screw plus nozzle systems). The electric current generators can be replaced by fuel cells.

The propulsion system shown in Fig. 4 can be simplified using a so-called rim drive propulsor (RDP). The propulsor's propeller has a number of blades, with permanent magnets fixed to blade tips, thus constituting the rotor of the motor (Fig. 5).

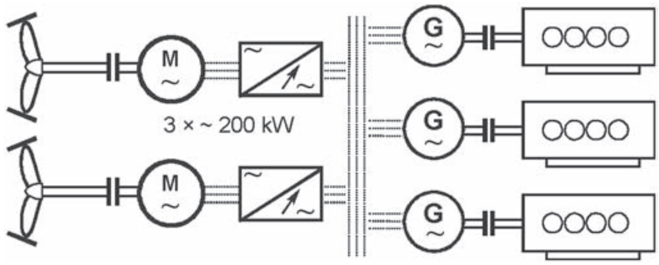

Fig. 4. *Scheme of a sample propulsion system design.*

The nozzle in which the propeller rotates is simultaneously the motor stator. The entire propulsor is slung under the ship hull. Art present the propulsor is undergoing research and implementation tests.

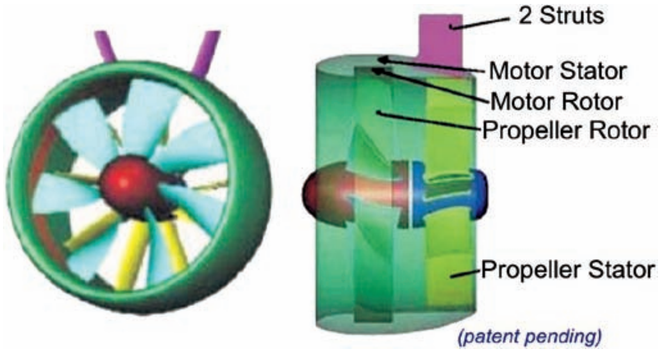

Fig. 5. *View of the rim drive propulsor RDP[17].*

Within the framework of the INCOWATRANS project, propulsion system solutions were analysed [18, 19], and methods for reducing volumes of impurities emitted in exhaust gases generated by piston engines were discussed, along with present and future abilities to use other fuels than the diesel oil (CNG, LNG, hydrogen, etc.).

Sanitary waste and sewage

Procedures of dealing with ship waste are given in [5]. According to the definition used in the regulation, the waste includes used oils and lubricants, and all other waste and garbage which contains oil (bilge water, used filters, oil packages, etc.), as well as the sewage from kitchens, bathrooms and laundries, fecal matter, the organic and inorganic waste collected from the hotel and gastronomy centres. All waste is to be stored on the ship and then transported to land reception points, in time intervals which prevent overfilling the used containers (tanks) or exceeding permissible levels of water in engine room bilges.

According to the regulations of the act on waste [20], the land reception point is considered a waste generator, therefore is has to have a relevant administrative decision.

Following the above recommendations, a relevant number of hull tanks, or other separate fixed tanks for storing waste are to be provided.

In order to store used oils, the engine room is to be equipped with one of more tanks of cubic capacity at least 1.5 times as big as the volume of the used oil which can be collected from oil sumps of all installed combustion engines and gears, plus the volume of the hydraulic liquid collected from hydraulic liquid tanks [6, 7].

Ship operation conditions allow the bilge water to accumulate only in the engine room bilges, with its further direct transport to land, without using a storage tank (which, however, can be used optionally). The bilge water can be disposed of during relatively frequent stays in ports. According to various sources [21], an approximate volume of the bilge water equals 0.5 ÷ 1.5 m^3/day for ships with main engine output < 1000 kW. The recommended minimum capacity of the bilge water storage tank (for seagoing ships) equals 1.5 m^3 – according to PRS, DNV and LR regulations. The use of the gas fuel decreases oil contamination of the bilge water. In co-operation with the engine producer the use of so-called EPLs (*Environmentally preferable lubricants*) can be analysed. These lubricants are vegetable or synthetic oils revealing lower toxicity, and shorter biodegradation time than the oils obtained from crude oil processing. The same remark refers to oil lubricated shaft pipe bearings.

For storing sanitary sewage and waste waters, tanks should be provided with sufficient cubic capacity calculated taking into account the number of people on the ship, the adopted water use standards and type of sanitary installation (conventional or vacuum). The use of the vacuum installation considerably reduces the volume of the sewage to be stored. Installing a typical sewage processing machine is not required. The capacity of the tanks can be assessed based on elementary indices (table 4.) given, for instance, in PRS or RINA regulations. The collecting tank should have a capacity securing that it is not overfilled during two days, the least, taking into account the maximum number of people on the ship.

Table 4. *Elementary sanitary sewage indices.*

PRS (changes 1/2000)	RINA (Pt.F, Ch.7, Sec.1, 2.4.4
70 dcm^3/(day and person) for installations with separation into „black" and „grey" sewage, 180 ÷ 280 dcm^3/(day and person) for installations without sewage separation, 25 dcm^3/(day and person) for vacuum installations	96 dcm^3/(day and person) for conventional installations, 11 dcm^3/(day and person) for vacuum installations.

A system should be provided on the ship for collecting, preliminary processing (sorting, disintegrating, pressing) and storing of the waste, understood as the service and kitchen garbage collected from the engine room and deck areas. It is advisable to use three different waste tanks (bags, boxes, containers, etc.), the minimum, for collecting :

❖ the waste containing plastics

❖ kitchen and pantry garbage, including materials contaminated with food

❖ other garbage which can be subject to further sorting, in particular raw materials, such as waste paper, glass, scrap, etc., intended for further processing.

The ship can be equipped with machines for disintegrating and pressing of the waste. These actions decrease the space required for waste storage and facilitate its discharge to land. Disintegrating machines (mills) are usually installed in the kitchen and generate liquid mixture of food with water, stored in a separate tank. Pressing machines allow the volume of the waste to be reduced.

The cubic capacity of the tanks can be assessed using recommendations given in [22] and collected in table 5.

Another way is to use the below given data [21] being rough estimation of the volumes of garbage (world average) collected on passenger ships, tankers, bulk and general cargo ships, container ships, and harbour ships, assuming the minimisation of the volumes of the waste stored on ship and no discharge at sea :

✰ food waste – 1.4 ÷ 2.4 kg/day and person,
✰ service waste – 0.5 ÷ 1.5 kg/day/person,
✰ maintenance waste – up to 20 kg per day, depending on the age of the ship.

Dealing with other waste types, or their minimisation

Arrangement of tanks for fuel, lubricating oil, and oil wastes – it is advisable for seagoing ships to use protecting measures against oil leakage in case the ship hull is damaged, by separating the tanks from the bottom or shipboard by cofferdams. For instance, obtaining the Clean Design DNV class notation is connected with obtaining the OPP-F notation. Relevant requirements are given in [11, P.6 Ch.1 Sec.6 - Arrangement of Fuel Oil Tank]. Similar requirements are formulated by Lloyd's Register [13, P.7 Ch.11 Sec.3] and refer to obtaining an additional mark P in the ship class symbol. The most detailed requirements concerning the distribution of oil tanks are given in RINA regulations [12, P.F, Ch.7, Sec.1].

Ballast – ship operation conditions provide ballasting only when sailing under bridges with low passing clearances. As a consequence, the ballast water will be in practice taken and disposed of in the same sailing region. Therefore all procedures of dealing with the ballast water, the goal of which is to minimise passing undesired water organisms between different water regions, do not apply to the designed ship.

Hull painting – the underwater part of the ship hull should be covered with paints which do not contain TBT (table 3).

Noise – here the Code on Noise Level on Board Ships, dated 1981, which was worked out by IMO, can apply along

Table 5. *Capacities of ship waste tanks, acc. to [22].*

	Gross capacity						
	Up to 400 gt		400 ÷ 1600	1600 ÷ 4000	4000 ÷ 10000	> 10000	Ships transporting more than 50 people
	Up to 10 people	Up to 50 people					
Minimum total capacity of tanks, in m^3	0.1	0.5	0.4	1.2	2.5	5.0	1.0 m^3 per 100 people and 1 day
At least three tanks should be used. The waste contains, on average, glass, carton, etc. - in 50%, plastic – in 25%, and food waste– in 25%.							

with the regulations of the Minister of Environment of July 29, 2004, on permissible noise levels in the environment (Regulation Gazette, 2004.178.1841). An alternative is meeting requirements formulated by classification societies, which define the level of noise, vibrations and microclimate in ship compartments for so-called comfort classes. For instance , there is a notation COMF-V(…) and COMF-C(…) used by Det Norske Veritas. A compulsory obligation is to meet the following directive requirements [6] :

- noise generated by the ship in motion must not exceed 75 dB(A) at a distance of 25 m and in direction perpendicular to the shipboard
- except for loading operations, the noise generated by the ship at a standstill must not exceed 65 dB(A) at a distance of 25 m and in direction perpendicular to the shipboard

Substances damaging the ozone layers – on the ship these substances can be used as working agents in cooling systems. A limitation here is defining the maximum permissible ODP and GWP values (table 3) for the refrigerant which is to be used in the installation. Sample values of these coefficients for selected working agents are given in table 6.

Table 6. *ODP, HGWP and GWP for selected refrigerants.*

	Natural	ODP	GWP (100 years)	GWP (500 years)
HCFC-22 (R22)	no	0.0555	1 700	4 100
HFC-134a (R134a)	no	0	1 300	3 100
CFC115/HCFC22 (R502)	no	0.33	5 900	
Propane (R-290)	yes	0	3	
Ammonia (R717)	yes	0	0	0

Scrapping – at present, the regulations concerning recycling of seagoing ships are given in Res. IMO A.962(23) [23]. The instructions are arranged in 10 chapters, the most important of which are: (4) – identifying potentially harmful materials and (5) – **green passport.** The latter is the document, written out by the shipyard or the ship owner, which among other data includes the information on dangerous substances entering into the composition of the ship, its equipment and installations. The resolution also includes 5 **Appendices** with lists of harmful substances and instructions concerning the methods of making their inventory. These lists are rather voluminous and, what is more, are subject to changes resulting from activities performed on the IMO forum. Such a passport could be prepared for the designed ship – but its preparation is only possible based on the working documentation.

CONCLUSIONS

The above collected brief information on impurities emitted by the ship to the environment and the overview of machines to be installed on the ship in order to reduce or avoid these emission allow the following suggestions to be formulated :

- the regulations concerning environment protection against impurities emitted by inland ships are not as complete and clear as those in force for seagoing ships
- when designing an “environment friendly” inland ship, the regulations in force for seagoing ships can be additionally used, which is obligatory for ships navigating in coastal areas
- at present new legal regulations are implemented which refer to various impurities emitted by the ship – all this requires modifications of a series of machines and devices installed on ships, or introducing new technologies, which is executed, as a rule, with some time delay
- a general remark is the statement that for the ship to be called “environment friendly”, at the design stage certain selections or decisions are to be made on propulsion and power generation systems, individual ship installations and types of the materials. This latter refers not only to the materials used for building pipeline connections and electric cables, but also to those composing machines and mechanisms delivered as a whole to the built ship. They should contain as little harmful or dangerous materials as possible.

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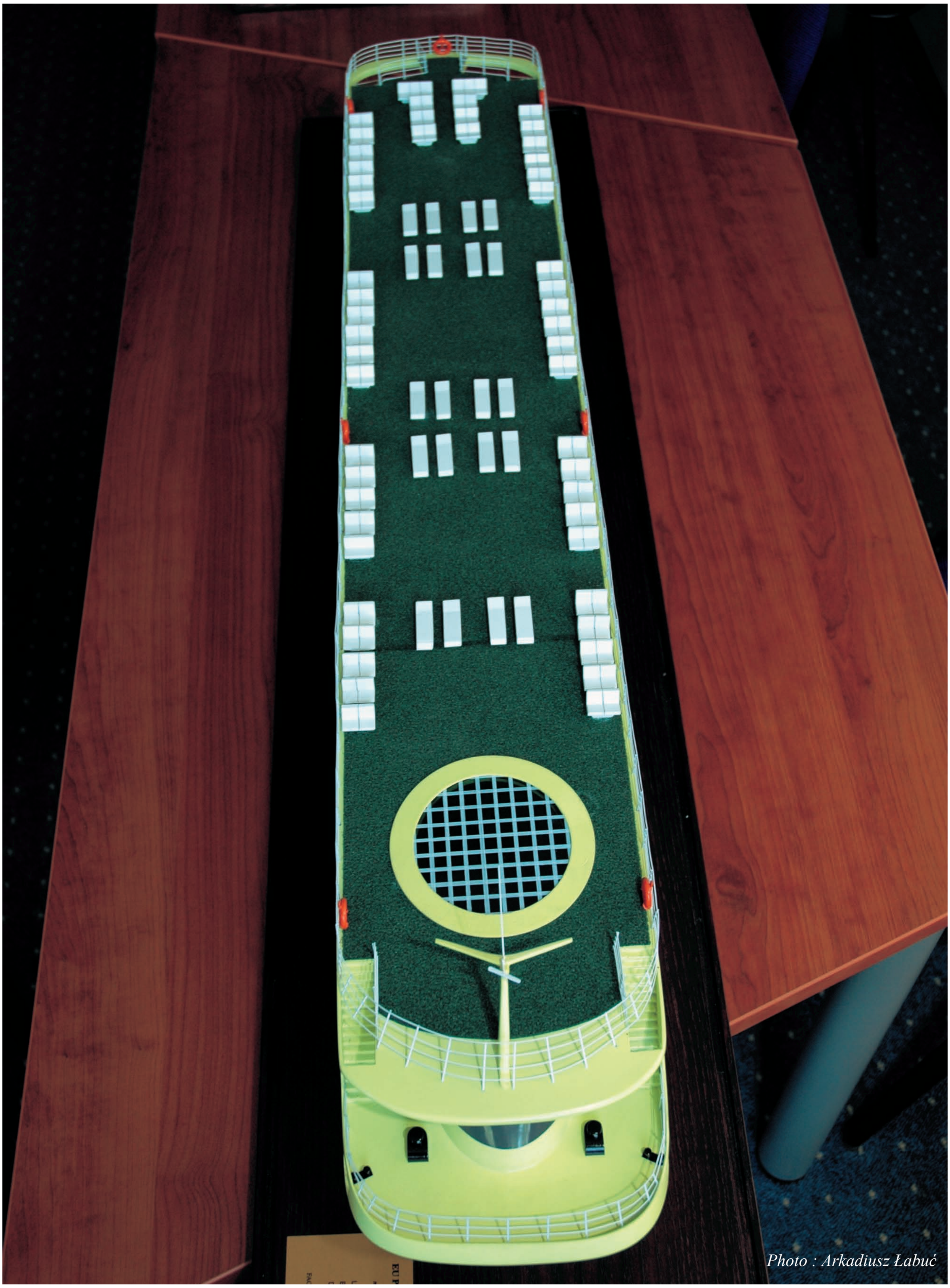

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