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Preliminary Design of a Ship for Waste Sorting from Croatian Islands

Abstract

In the Environmental Protection Strategy of the Republic of Croatia, waste management is defined as a national priority, and the vision is a landfill-free concept. The backbones are recycling centers with sorting plants where separately collected waste will be prepared for recycling. Concept of sustainable development is a key determinant of the development of the Primorje-Gorski Kotar County (PGKC), and the fact that permanent disposal of waste of any kind will not be possible on the islands is particularly important for this County. Mixed municipal waste generated in PGKC should be first sorted at the local transshipment station on the island, and then transported by road to the county center for waste management, which is an expensive and complex process. Given that sea transport is known to be the cheapest, one possible solution would be to place a waste sorting plant on a suitable ship which would collect waste by sailing around the island, thus avoiding the need for each island to have its own sorting plant. The paper presents a preliminary design of a ship for sorting waste collected from the large islands of PGKC. The mission requirements of the ship were elaborated initially, and then a basic design of the ship was made, accompanied by the corresponding naval architecture calculations, general arrangement plan and outline specification.

Keywords: Croatian islands, waste management, ship for waste sorting, preliminary design

1. Introduction

There has been a lot of talk and writing lately about the “circular economy”, which by definition is a model of production and consumption that includes sharing, borrowing, reusing, repairing, rebuilding, and recycling existing products and materials to extend product life, and at the same time reduce the amount of waste. Circular economy strategies can have a strong impact on reducing greenhouse gas emissions and thus play a key role in combating climate change.

The circular economy is also one of the goals of the European Union (EU), which is why the European Commission presented an action plan in March 2020 [1]. The plan includes proposals for more sustainable product design, waste reduction and citizen empowerment, for example by introducing "rights to repair", with an emphasis on areas such as electronics, information and communication technology, batteries and vehicles, packaging, plastics, textiles, construction and food, water and nutrients. Basically all products from these areas require huge amounts of resources. In February 2021, the European Parliament voted on a new circular economy action plan and called for additional measures to achieve a carbon-neutral, environmentally sustainable, non-toxic and fully circular economy by 2050, including stricter recycling rules and binding targets for the use and consumption of materials by 2030. Members of the European Parliament called on EU member states to increase high-quality recycling, move away from landfills and keep incineration to a minimum.

The goal of the European Union and its waste policy is to move towards a circular economy. Its task is greater sustainability and contribution to the achievement of climate goals changing and conserving the world's resources, creating local jobs, all for the purpose of giving Europe an edge over the competition in the world. The importance of the circular economy for the European industry has recently been highlighted in the renewed EU industrial policy strategy. The transition to a circular economy will also contribute to achieving the goals of the Sustainable Development by 2030 [2].

In the paper, the situation with waste in the EU and Republic of Croatia is briefly discussed, while a stronger focus was given to the aspects of collection of waste from the large islands of the Primorje-Gorski Kotar County (PGKC). As a possible solution for the disposal of waste from large islands of this County, specially designed ship was considered. Initially, the mission requirements of the ship were elaborated, and then a preliminary design of the ship was made with the accompanying naval architecture calculations, general arrangement plan and outline specification. In that way, the need for each island to have its own plant for waste sorting could be avoided.

2. Waste management in the EU

The European Union produces more than 2.5 billion tonnes of waste each year. On July 4, 2018, new EU rules came into force with legally binding targets for waste recycling and waste reduction with fixed deadlines for EU member states that had to adapt their national legislation for the transition to circular waste in the next two years. Republic of Croatia was obliged to incorporate waste directives into its legislation by July 5, 2020. The foundations of EU waste management policy are contained in the Council of Europe Resolution on the Waste Management Strategy (97/C76/01) [3], based on the Waste Framework Directive (74/442/EEC) and other EU waste management regulations [4]. Five basic principles have been established: waste management hierarchy, self-sufficiency of the disposal plant, best available technology, proximity to waste disposal and producer responsibility.

From 2005 to 2016, the average amount of waste per capita fell by 7% in the EU, but there are significant differences between countries. Richer countries and countries engaged in tourism produce more waste. Thus, the amount of waste is growing in Denmark, Germany, Greece, Malta and the Czech Republic, and falling in Bulgaria, Estonia, Hungary, Romania and the Netherlands. In absolute values per capita, the first are Denmark, Malta, Cyprus and Germany while the Czech Republic and Slovakia produce the least waste. Denmark, for example, produces 777 kilograms of municipal waste per capita, while Croatia produces 403 kilograms. But in Denmark only 1% of municipal waste ends up on landfill while in Croatia that share amounts to 78%. In Croatia, only 21.5% is recycled and 0.1% is incinerated. According to 2016 statistics, 47% of municipal waste in the EU is recycled and composted [5]. However, practices vary between countries and many EU member states still use underground disposal for municipal waste. Underground disposal is almost non-existent in northern and western Europe (Belgium, the Netherlands, Sweden, Denmark and Germany), but as many as 12 countries dispose of more than half of their waste underground. Along with Latvia, Slovakia and Bulgaria, Croatia is above 60%. Textiles and hazardous waste from households will have to be collected separately by 2025. By 2024, bio-waste will also be collected separately or recycled at home by composting. In line with the UN Sustainable Development Goals, EU member states should aim to reduce food waste by 30% by 2025 and by 50% by 2030. In order to prevent food waste, EU member states should encourage the collection of unsold food products and their further redistribution [5].

3. Waste management in the Republic of Croatia and Primorje-Gorski Kotar County

The waste management strategy in the Republic of Croatia was adopted in 2005 with the purpose of establishing a framework within which the amount of waste generated will have to be reduced, and at the same time managed sustainably [6]. The Strategy is an integral part of the National Environmental Strategy adopted in 2002 [7], in which waste management is identified as a national priority. The idea of waste management in the Republic of Croatia is the so-called a landfill-free concept aspired to as an ideal. The Strategy and Waste Management Plan of the Republic of Croatia as its implementation document are part of the continuous waste management planning that is reflected at all levels, from national to local.

The backbone of the Waste Management Plan in the Republic of Croatia are recycling yards, recycling centers with sorting plants and composting plants where separately collected waste will be prepared for recycling.

Some of the most important measures are the encouragement of separate collection of paper, cardboard, metal, glass, plastic and bio-waste, separate collection of waste on the doorstep, introduction of incentive measures in the collection of public municipal waste collection service by composition and quantity, introduction of municipal waste

disposal fee, home and municipal composting, construction of sorting plants, IT support for monitoring waste flow and a number of educational and informative measures [8].

The concept of sustainable development is a key determinant of the development of the Primorje-Gorski Kotar County (PGKC) and its implementation in the field of waste management is given special attention. The solution to the problem of waste in PGKC consists of the establishment of a single county center for waste management (CWMC) on Marišćina in the municipality of Viškovo near the city of Rijeka, with the establishment of a network of recycling yards and transshipment stations and remediation of unregulated and inappropriate landfills throughout the County. According to the current legislation, the local self-government unit must close the landfill within one year from the day of the official commissioning of the CWMC, after which all unsorted waste would be taken to the county landfill [9, 10]. The adopted approach is fully in line with the Waste Management Strategy of the Republic of Croatia [5], and the fact that in the future permanent disposal of waste of any kind will not be allowed on the islands is particularly important.

The group of large islands in PGKC makes the islands of Cres, Lošinj, Krk and Rab. In the area of the islands of Cres and Lošinj, as well as the surrounding smaller islands (Susak, Ilovik, Unije, Srakane), the municipal activity of collecting, transporting and handling municipal waste is performed by the city company "Komunalne usluge Cres Lošinj d.o.o." [11, 12]. The collected municipal waste is disposed of at the Prižić (Cres) and Kalvarija (Lošinj) landfills. The company's most significant investment in the field of waste management is the rehabilitation of the Kalvarija municipal waste landfill in Mali Lošinj, with the construction of a transshipment station, recycling yard and composting plant and the rehabilitation of the existing waste disposal area.

Utility company "Ponikve eko otok Krk d.o.o." is an example of responsible municipal waste management [13]. Thanks to a well-thought-out strategy and systematic long-term implementation, the company has not only achieved the goals set by the Croatian Waste Management Plan, but also greatly exceeds the average recycling of municipal waste achieved at the EU level. The company manages the Treskavac landfill located in the Municipality of Vrbnik. All municipal waste from the area of the island of Krk is brought to this landfill, and next to the landfill there is a recycling yard, sorting hall and composting hall where separately collected waste is additionally separated, pressed and baled as well as composted. The sorting plant was delivered by the domestic manufacturer Tehnix d.o.o. from Donji Kraljevec, Croatia, [14]. The sorting plant was needed because it is simply not possible to separate waste so well in households that it would be immediately ready for further marketing.

On the island of Rab, the collection, transport, disposal, trading and mediation in waste management are performed by the companies "Dundovo d.o.o." (City of Rab) and "Lopar Vrutak d.o.o." (Municipality of Lopar) [15]. The Sorinj landfill is an officially unregulated landfill for non-hazardous waste, to which waste collected from the area of the City of Rab and the Municipality of Lopar has been disposed since 1969. Considering the legal regulations, the stability of the disposed waste and the impact that

the disposed waste has on the environment, the local self-government units on Rab are aware that it is necessary to rehabilitate and close the Sorinj landfill as soon as possible, which must be coordinated with location, i.e. with the beginning of waste acceptance from the area of the City of Rab and the Municipality of Lopar at CWMC Marišćina.

4. Design of a ship for waste sorting

Since the CWMC Marišćina has started operating, all utility companies from PGKC are obliged to dispose of their mixed municipal waste there. If the issue of waste on the large islands in the PGKC is considered, unsorted municipal waste should first be accepted and disposed of at the local transshipment station on the island (if any), then loaded on a truck and taken to CWMC Marišćina. Since these are islands, road transport is expensive and complex. In addition, waste disposal at the waste management center is paid per tonne of waste, and it can be expected that the price will increase over time, so this could be one of the additional motives for sorting waste on the island and significantly reducing the amount of waste which has to be transported.

Since the maritime transport is well known as the cheapest among the available transport possibilities, one of the possible solutions would be to place a waste sorting and baling plant on a purpose-built ship. The ship would call the ports on the islands, collect waste and then process it. This would avoid the need for each island to have its own sorting plant, and at the same time would greatly reduce the need for truck transport from the island. This was the main idea for the development of a preliminary ship design for the sorting of mixed municipal waste from the Croatian islands, with special consideration being given to the islands of Cres, Lošinj, Krk and Rab. The ports of calls of the ship would be the ferry port Valbiska on the island of Krk, Lopar and Mišnjak as the main and alternative port on the island of Rab, Merag on the island of Cres and the port in Mali Lošinj. Apart from the islands in PGKC, the ship could also collect and sort mixed municipal waste from other Croatian islands throughout the year.

The mission requirements of a ship were initially elaborated, and then a preliminary design of a ship was prepared with the corresponding naval architecture calculations, general arrangement plan and outline specification. The design itself is specific because there are no similar ships in the world with a plant for sorting and baling mixed municipal waste. The purpose of the ship would be to sort municipal waste without a biodegradable component (bio-waste) that must first be separated on the island. Separately collected bio-waste, which includes waste from gardens and parks, food and kitchen waste from households, catering and retail facilities, would be treated in composting plants on the islands. In the Republic of Croatia, bio-waste accounts for approximately one third of mixed municipal waste. Glass packaging would be similarly to bio-waste also separated on the island and further separately disposed. The ship would have a special plant for sorting waste, and in addition to sorting waste, it would have certain storage capacities and equipment for manipulating the output of

the sorting plant - bales of compressed waste: plastic, PET and MET packaging, paper, cardboard and RDF ("refuse-derived fuel"). RDF is a fuel derived from waste, and is produced in waste management facilities from non-hazardous unsorted municipal waste and can be used as a substitute fuel for energy production in industrial plants. This waste fuel consists of paper, cardboard, wood, textiles and small plastics, it is dry and stable and free of unpleasant odors. Due to its high calorific value, it is used as a fuel throughout the EU in various plants, from cement kilns to heating plants and thermal power plants. After collecting waste on the islands and processing it, the ship would sail to the port where bales of sorted waste would then be taken over by a collection company authorized to manage a certain type of waste.

When elaborating the mission requirements, the following main restrictions were set for the ship:

- the length and beam of the ship must be as small as possible, certainly within the dimensions of the existing ferries operating on lines between the aforementioned islands and the mainland,
- the draft of a fully loaded ship should not exceed 2.4 m due to the depth of the sea in the ports which the ship would call,
- the size of the ship must allow the installation of the entire waste sorting and baling plant,
- the waste sorting and baling plant must be shielded from the direct effects of the weather.

A sorting plant for mixed municipal waste from the company Tehnix d.o.o. from Donji Kraljevec, Croatia [14], was selected for waste sorting. Tehnix d.o.o. is one of the well-known eco-industries in the world, and their business goal is the development and production of the best technologies that achieve sustainable development and a circular economy. The company has developed and manufactured more than 300 machines and pieces of environmental equipment for which it has received hundreds of world awards and medals.

Taking into account the quantities of municipal waste shown in Table 1. [16], in cooperation with Tehnix d.o.o., a sorting plant with a capacity of five tonnes of waste per hour was selected. This is also the plant with the smallest capacity from the production program of the Tehnix d.o.o., and that capacity would be quite sufficient for the amount of waste on the islands. Figure 1. shows a waste separation and baling plant.

Table 1. Amount of waste on the islands of PGKC in tonnes per transshipment stations (data from January 2020), [16]

Month	Island of Cres	Island of Lošinj	Island of Krk	Island of Rab
January	51	286	375	280
February	36	295	408	260
March	50	419	515	300
April	82	549	709	320
May	103	562	838	360
June	186	604	1.248	680
July	282	855	1.815	800
August	325	945	2.011	824
September	172	538	1.045	371
October	90	341	715	219
November	66	300	520	200
December	53	240	455	180
Total	**1,495**	**5,935**	**10,654**	**4,794**

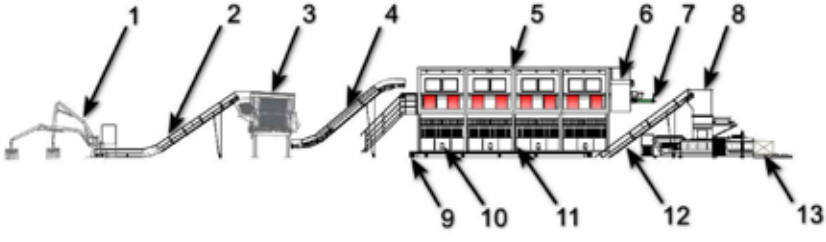

Figure 1. Waste sorting plant of Tehnix d.o.o. (1- grab; 2 - angle chain conveyor (entrance to the sieve); 3 - sieve; 4 - angle chain conveyor (exit from the sieve); 5 - four sorting cabins; 6 - magnetic separator; 7 - cross conveyor; 8 - automatic baler press; 9 - floor conveyor; 10 - pressure plate; 11 - box partitions; 12 - angle chain conveyor for baler; 13 - waste fraction bales)

The sorting plant is located on the main deck of the ship, and is designed so that the flow of material is in-line from the stern to the bow, without returning to any of the previous stations of the plant. The process begins with the delivery of mixed municipal waste by a truck that enters the ship with its rear end. The truck is weighed and then the waste is unloaded at a special waste collection point on the deck of the ship. Here the waste is picked up by a grabber and transferred to an angular chain conveyor which lifts it to a compact sieve in which the waste bags are opened. After the sieve, the waste is sent to the sorting booths by chain conveyor for manual sorting. The cabins are elevated because below them are boxes with bins for receiving sorted waste. A

total of four sorting cabins are provided, through which the conveyor passes through the middle, and on each side of the conveyor there are workers who manually separate the waste. The workplace functions in such a way that the worker stands between two bins that are at the height of the chain conveyor that brings the waste, and manually inserts a certain fraction of waste into them, which then falls down into the sorting waste bin. On the deck of the ship next to the sorting cabins there is a floor conveyor that extends the entire length of the cabins. When the receiving bins are filled with waste, they are pulled out and the contents are unloaded on that floor conveyor which takes the waste to an angular chain conveyor which inserts the sorted waste into an automatic baler. Bales with approximate dimensions of 1.2 m x 0.8 m x 1.0 m come out of the press. The size of the bale matches the dimensions of the standard European pallet, and the average mass of the bale is about 400 kg. Bales are manipulated by two electric forklifts permanently on board. For storage of bales, space is provided on both sides of the main deck and below the main deck. Workers in the sorting plant would have accommodation on board and would be treated as the ship's crew.

During the design of the ship, a round was made through the so-called design spiral, [17, 18, 19]. The following steps were considered in detail: mission requirement, main dimensions of the ship, hull shape, hydrostatic data, freeboard, arrangements, structure, resistance and propulsion characteristics, mass and center of gravity estimation and calculation of trim and stability of the ship in undamaged and damaged condition, [20, 21, 22, 23, 24, 25, 26, 27]. An energy balance analysis of the ship was also made in order to select the diesel generators that could power the electric propulsion motors as well as all other electrical systems on the ship including the sorting plant.

After passing through the various steps of the design spiral, the basic parameters of the ship shown in Table 2 were obtained.

Table 2. Basic parameters of a waste sorting ship

Length overall, m	74.0
Length between perpendiculars, m	69.1
Beam, m	17.0
Draft (maximum), m	2.4
Gross tonnage	2540
Engine power, kW	2 x 250

The three-dimensional computer model of the ship's hull is shown in Figure 2.

Figure 2. Three-dimensional model of the ship's hull

The ship was designed as a Ro-Ro cargo ship, with the intention to transport unit cargo in the form of bales, for the navigation area 6. The ship was designed as a twin-propelled ship, with two diesel-electric drives and Z-drive azimuthing thrusters as a means of propulsion. The electric motors of the company Tema d.o.o. from Pula, Croatia were selected, each with an individual power of 250 kW [28]. The selected speed of the ship was 10 knots, while the range was estimated at 1200 nautical miles, which allows a larger number of rounds for waste collection from the considered islands. The rules and regulations according to which the ship is designed are the rules of the Croatian Register of Shipping and other regulations applicable to ships flying the flag of the Republic of Croatia. Figure 4 shows the midship section and Figure 5 shows the general arrangement plan of the waste sorting ship.

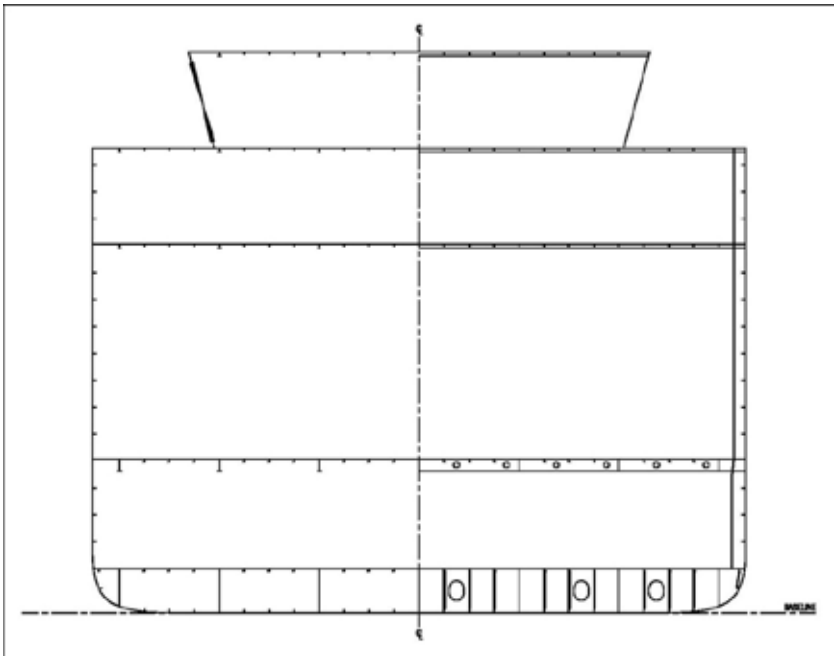

Figure 4. Midship section

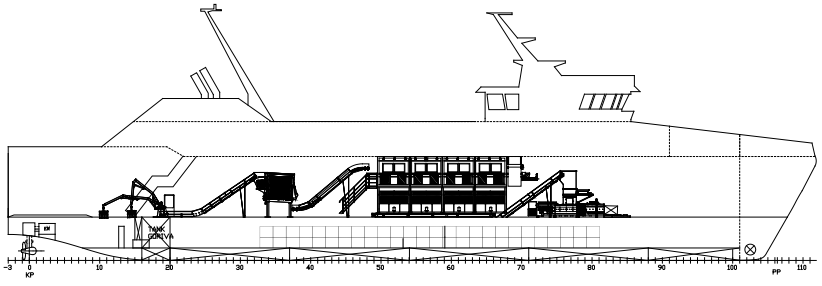

Figure 5. General arrangement plan

5. Conclusion

In this paper, the preliminary design of the waste sorting ship is presented. Preliminary design is the first phase of a ship design process in which the basis of the design are laid, and in which these basis are examined in terms of feasibility. After analyzing the process of sorting, transport and disposal of waste, a solution that could replace the plants located on the islands of Cres, Lošinj, Krk and Rab as the largest islands in the PGKC was offered.

The solution of a waste sorting ship could significantly reduce the facilities located on the islands. Currently, all waste from these islands due to lack of landfills on the islands of Primorje-Gorski Kotar County goes from transshipment stations by truck to the County Center for Waste Management Marišćina, which requires a large transport capacity of companies in charge of waste management on these islands and leads to high costs. The sorting ship can take over both this transport and sorting of mixed municipal waste, provided that bio-waste is separated at the "door", i.e. each household must separate the bio-waste and dispose it in a designated container.

The mission requirements of a ship were defined so that the ship can call to all existing ports already used for ferry lines between the island and mainland. The preliminary design shows that the idea of a ship for sorting mixed municipal waste from the Croatian islands is fully feasible.

However, the presented idea of collecting waste on the islands is narrowly focused on the ship, which is only one of the links in the entire logistics chain of collecting mixed municipal waste from islands. To complete the considered idea, bringing of waste collected on a particular island to the ship, the order of port calls around the islands, the number of calls on the islands during a week or month, then selection of a place for unloading baled waste as well as the best possible economic solution, in terms of the minimum cost for ship's operation should be additionally analyzed.

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