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Danube Delta: Water Management on the Sulina Channel in the Frame of Environmental Sustainability

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Abstract

The Danube Delta is the newest land formed by both transporting sediments brought by Danube River, which flows into the Black Sea and by traversing an inland region where water spreads and deposits sediments. Diurnal tidal action is low (only 8–9 cm), therefore the sediments would wash out into the water body faster than the river deposits it. However, a seasonal fluctuation of water level of 20 cm was observed in the Black Sea, contributing to alluvial landscape evolution in the Danube Delta. The Danube Delta is a very low flat plain, lying 0.52 m above Mean Black Sea Level with a general gradient of 0.006 m/km and only 20% of the delta area is below zero level. The main control on deposition, which is a combination of river, wind-generated waves, and tidal processes, depends on the strength of each one. The other two factors that play a major role are landscape position and the grain size distribution of the source sediment entering the delta from the river. The Danube Delta is a natural protected area in the South-Eastern part of Romania, declared a Biosphere Reserve through the UNESCO “Man and Biosphere” Programme. Water is a determining factor for all the human settlements in the Biosphere Reserve, the whole Danube Delta being structured by the three branches of the Danube (Chilia, Sulina and Sfantu Gheorghe (Saint George)). Our case study is focused on the Sulina branch, also named Sulina Channel, which offers the shortest distance between the Black Sea (through Sulina Port) and Tulcea (the most important city of the Danube Delta from economic, social and cultural points of view) for both fluvial and marine ships. The improvement of water resources management is the main topic of this chapter, in terms of water quality indicators, which will be presented in twenty-nine monitoring points, starting since a few years ago and updated to nowadays. During the study period, significant exceedances of the limit value were detected in case of nitrate-N (3.9–4.6 mg/L) at the confluence (CEATAL 2) with the Saint George branch and in the Sulina Channel after the Wastewaters Treatment Plant (WWTP) discharge area, as well as near two settlements, namely Gorgova and Maliuc. The higher concentrations of Nitrogen-based nutrients were caused by the leakage from the old sewage systems (where these exist) and the diffuse loads.

Keywords: Danube Delta Biosphere Reserve; water quality indicators, surface water monitoring, Sulina channel between Tulcea and Sulina port, water resources management

1. Introduction

Water quality is a highly important issue that should concern all of us, taking into consideration that our health is directly dependent on the water sources. At the core of the Water Framework Directive (2000/60/EC) [1] is an integrated approach for sustainable water management in river basin district.

After the Volga River which is the largest river in Europe, the Danube River is second, with a basin surface of 801,463 km² covering more than 10% of the territory that belongs to nineteen countries [2]. The main course of the Danube River passes through ten countries (Germany, Austria, Slovakia, Hungary, Croatia, Serbia, Romania, Bulgaria, the Republic of Moldova, Ukraine) and four capitals (Vienna, Bratislava, Budapest, Belgrade) (**Figure 1**).

Due to its geological and geographic conditions, the Danube River Basin is divided into three main parts: The Upper Danube, the Middle Danube and the Lower Danube [2]. The Lower Danube „risk” is generated by the nutrient pollution and hazardous substances (including persistent organic compounds such as pesticides and petroleum products) and is in large part due to hydro morphological alterations [2].

The Danube River is the collector of all discharges from upstream countries, affecting the quality of the Danube Delta waters and the Black Sea coast. The EU Marine Strategy Framework Directive aimed at achieving or maintaining a Good Environmental Status (GENs) by 2020 in the territorial waters of the EU Member States [4]. The water quality in the Danube Delta is the result of complex processes having the genesis in the whole river basin, but local factors lead, inside the Delta, to specific differentiation for the Danube branches, delta lakes and in general for each ecosystem. The entire deltaic ecosystem complex of the Danube has been

Figure 1.
The main course of the Danube River (adapted from [3]).

declared a Biosphere Reserve and a UNESCO site since 1991, but, nevertheless, the works of arranging the main in order to reduce the length and increase the flows necessary for navigation, as well as digging various secondary on the entire surface of the delta had a negative impact on the global ecosystem of the delta, as they changed the natural environments, disrupting the reproduction of fish, intensifying the erosion of the banks and the deposition of alluvium [5]. Other works carried out especially during the communist period aimed at draining wetlands and transforming them into agricultural land (over 100,000 hectares), intended for crops, forest plantations or fish farming. As a result of these changes, with the increase in pollution and eutrophication of Danube waters and the intensive exploitation of fishing in the absence of regulations, the fish stocks have visibly decreased [3, 5].

The Danube Delta is the newest land formed, starting since more 12000 years ago (a relatively new delta) by the sediments that are transported by the Danube River before discharged into the Black Sea. Therefore, the Danube Delta has a size and respectively a shape, controlled by the balance between the watershed processes that supplied the sediment, and the receiving basin processes that redistribute, isolate, and export these sediments [6]. Water is a determining factor for all human settlements of the Biosphere Reserve of Danube Delta and therefore its quality plays a key role for the development of the local communities.

The course of the Danube has a dynamic character, which although satisfactory at a certain stage, can be influenced by human activities determining an evolution towards an unsatisfactory quality. Based on previous studies, the following main classes of pollutants were identified:

- Nutrients based on nitrogen (mineral i.e. nitrates, nitrites, ammonium and organic i.e. amino acids, peptides, proteins, urea, etc.), and based on phosphorous (mineral: orthophosphates and organic: organic phosphates (as phospholipids and nucleotide phosphates), phosphatides, etc.) which lead to the increasing of water eutrophication potential;
- Petroleum substances, which form large surface films on the waters, as a result of intensification of port activities and river traffic;
- Specific pollutants with persistent character and high toxicity: heavy metals (copper, zinc, iron, manganese, etc.), organochlorurate pesticides (i.e. terbutylazine, metolachlor, acetochlor, atrazine, etc.) and benzimidazole fungicide (i.e. carbendazim, etc.), used for the protection of agricultural crops.

The main pressure on the surface water bodies, and not only, is exerted by human activities like discharging untreated or insufficiently treated wastewater into natural emissaries, a practice that must be stopped, in order to protect the water resources.

The water resources represent the hydrological potential formed by the surface waters and groundwaters in the natural regime or under hydrotechnical arrangements, which ensures the supply for multipurpose water uses (drinking water preparation, irrigation of cultivated plants, use as process/industrial water, use in fish farming (aquaculture), or for leisure/sport/tourism and respectively as a means for river transportation). Human health and the environmental protection and wastewater treatment are the main challenges for a healthy environment, both in urban and rural areas and, especially in protected areas of the Danube Delta.

The uncontrolled discharge of the wastewater endangers the population health and the environmental quality, and these could be tackled by improving the monitoring system of surface water quality.

The water supply sources in the Danube Delta settlements are mostly represented by surface water, but also, in isolated cases, by groundwater. The Danube with its arms and the adjacent and the lakes of the Razim and Babadag Complexes represent the surface water sources, while the underground sources are represented by some random drilling of small and medium depth [7]. According to the data presented in the Environmental Quality Report related to the monitored area [8], only 60% of the rural population consumes drinking water of high/medium depth or spring water, which falls within the parameters stipulated by regulations in force; 10% consume water directly from the Danube; 20% consume well or shallow water that does not fall within the regulated values, and the remaining 10% of the rural population consumes treated water that is not compliant with the terms of potability from a microbiological point of view.

The main anthropogenic activities (e.g. agricultural and fish farms), including tourism and fish poaching, frequently involve some discharges (in terms of detergents, domestic waste, agricultural fertilizer, animal manure, and oil products) in the water of Sulina Channel, which lead to the enrichment of its content with dissolved nutrients. Such nutrients are especially Nitrogen and Phosphorous based, promoting the growth of algae and other aquatic plants, which take oxygen from the water, causing the death of fish and bringing again an additional contribution to the water pollution and finally the eutrophication process occurs. Eutrophication is known as a major environmental issue for the management of water resources, affecting the full exploitation potential.

In order to avoid the installation of the eutrophication process, this should be stopped in its early stage of development, by specific measures starting with the monitoring of both nutrients concentration and algae development in water (usually with optical measurements for the colored pigments from the algae structure (e.g. Chlorophyll, Phycocyanin, etc.)).

Based on the above mentioned aspects, the first objective of the present study is to reveal the evolution over time of the water quality indicators especially in terms of nutrients (Nitrogen and Phosphorous forms) on one of the 3 branches through which the Danube is discharged into the Black Sea, trying to correlate the natural factors with the anthropogenic ones that have recently led to the destabilization of the ecological balance, having a negative impact both on the environment and on the conservation of the traditional heritage of the local communities and of the authentic elements specific to the protected areas of the Danube Delta.

Another objective of this chapter is to review, in the last part, the most important data involved in the improvement of the water management (focused on drinking water preparation and wastewater treatment) in the main human settlements located along the Sulina Channel, in order to be further correlated with the water quality, using of some dedicated software solutions, assuring the environmental sustainability and the primary water needs of the local inhabitants.

1.1 The deltaic morphology of the Danube River and their ecosystems before the discharge into the Black Sea

The Danube Delta is an environmental buffer between the Danube River and the Black Sea, filtering out the pollutants and enabling both adequate water quality conditions and natural habitats for fish in the delta and in the environmentally vulnerable shallow waters of the north-western Black Sea [2].

As it is known, a river Delta is a form of land created by the sediment deposition, as a result of the river water loaded with fluvial sediment, when this leaves the riverbed, before purging into other waters with slower or stagnant movement [9].

The Danube Delta was formed in two stages: a pre-deltaic one (geologically located in the Pleistocene, being marked by climate change) and a deltaic one (started 12000–15000 years ago), in which the territory is no longer submerged and on which we focused our attention in the present chapter, although probably 40% of the actual Delta has been built in the last 1000 years [10]. Therefore, the modern Danube Delta began to form after 4000 BC, in a Gulf of the Black Sea, as a result of rising water levels in the Black Sea and the development of a sand deposit that partially blocked the discharge of the Danube, so the initially formed delta advanced outside the estuary blocked by sediments, after 3500 BC, building several successive lobes: St. George I (3500–1600 BC), Sulina (1600–05 BC), St. George II (0 BC) and Chilia or Kilia (1600 CE - present). Thus, several internal lobes were formed in the lakes and lagoons that border the Danube Delta to the north (Chilia) and to the south (Dunavatz). Most of the alluvium in the delta resulted from soil erosion associated with degraded biomass in previous millennia in the Danube basin, thus causing the expansion of its surface in the form of lobes [10, 11].

The Danube Delta formation was dependent on many factors, including the marine wind waves from the Black Sea (up to 7 m high), and plays an important role in coastline defense and drinking water supply for local communities [12]. Thus, the Danube Delta was formed by both transporting sediments brought by water that flows into the sea and by traversing an inland region where water spreads and deposits sediments. Diurnal tidal action is low (only 8–9 cm); therefore, the sediments would wash out into the water body faster than the river deposits it. However, a seasonal fluctuation of water level of 20 cm was observed in the Black Sea, contributing to alluvial landscape evolution in the Danube Delta. The delta formation is a long process (in a permanent metamorphosis) in which the amount of sediment carried by water should be significant, and due to the decrease of water velocity (as a result of the flow section increasing), alluvium deposition is achieved which contributes to the building of a deltaic system [13].

The Danube Delta is a very low flat plain, lying 0.52 m above Mean Black Sea Level (MBSL) with a general gradient of 0.006 m/km, and therefore the hypsometry is limited to a very narrow range of values. The maximum difference in altitude is 15 m and is given by the highest point (–12.4 m) of the Letea dunes and the lowest lake bottom (–3 m) from the marine part of the delta. Compared to the Black Sea level, only 20.5% of the delta area is below 0 m. The rest (79.5%) is above 0 m, the most of which (54.6%) is in the range of 0–1 m above MBSL. If the 1/2 range (18.2%) and that of below 0 m are added to this range, more than 93% of the delta area is within the 3 m range of hypsometry [14].

Deltas are typically classified according to the main control on deposition, which is a combination of river, wind-generated waves, and tidal processes [15], depending on the strength of each [16]. The other two factors that play a major role are the landscape position and the grain size distribution of the source sediment entering the delta from the river [17]. In wave dominated deltas, wave-driven sediment transport controls the shape of the delta, and much of the sediment emanating from the river mouth is deflected along the coast line [15].

The relationship between waves and river deltas is quite variable and largely influenced by the deep water wave regimes of the receiving basin. With high wave energy near shore and a steeper slope offshore, waves will make river deltas smoother. Waves can also be responsible for carrying sediments away from the river delta, causing the delta to retreat [12]. For deltas that form further upriver in an estuary, there are complex yet quantifiable linkages between winds, tides, river discharge, and delta water levels [18, 19].

In the case of the Danube Delta, initially there was a triangular bay of limanic type that stretched over a distance of 180 km, in which low-amplitude tides do not

significantly contribute to the process of sediment removal, and coastal currents and transport of sedimentary materials have led to the deposition of a significant amount of alluvium. The Danube flows into the Black Sea causing complex interactions between sediments carried by its huge flow rate and marine dispersal forces that create complex configurations with competing morphologies, i.e. influenced by the river versus wave and by deposition instead of erosion, which materializes in the formation of plain-type relief forms with low monotonous ridges or covered by transgressive dune fields, which are a common feature of deltaic lobes influenced by waves [20]. Climate and environmental changes played also an important role in the Danube Delta formation [21, 22].

The inflow rate of the Danube into the Delta is $6,350 \text{ m}^3/\text{s}$. The Danube Delta is located mostly in Dobrogea - Romania (82% - 3446 km^2) and partially in Ukraine (18% - 732 km^2) (**Figure 2**).

The Danube Delta covers a total area of $4,178 \text{ km}^2$, which makes it the second largest and best preserved of the European deltas [23].

As early as 1856, in the Danube Delta, a series of works began to arrange the navigable, which aimed mainly at correcting the meanders in order to shorten the distances between the main localities under the coordination of Sir Charles Augustus Hartley, Civil Engineer (1825–1915: the Father of the Danube). He was designated as designer and executor of these works by the European Commission of the Danube. In this sense we can mention 1862 as the beginning of the first correction works (cutting the bends and meanders of the watercourse, consolidating the banks and dredging the riverbed/bottom of the water) carried out on the Sulina Channel, which continued until 1902 and maintained until nowadays in order to maintain navigation on the channel. Therefore, the length of the Sulina Channel was reduced from 92 to 71 km, and its flow was two times increased, making it suitable for

Figure 2.
Satellite view of the Danube Delta (adapted from [23]).

navigation with both large fluvial ships and respectively with maritime boats [24, 25].

The type of global ecosystem found in the Danube Delta (considered as a young region in continuous development), is the Pannonian steppe of Eastern Europe, with Mediterranean influences. It consists of 23 specific natural ecosystems, mostly aquatic due to the rejuvenation of wetlands, along with existence of terrestrial ones, between which a swampy strip is interposed, easily flooded by authentic flora and fauna provided with means of adaptation to the aquatic or terrestrial environment, depending on the season or on the hydrological regime.

The Danube Delta, located on the main migration routes of birds, is a unique place in Europe [2], due to the conditions offered by the development of an extremely diverse flora and fauna, with many rare species. Thus, the Danube Delta, through its nesting and hatching conditions, attracts birds from six major Eco-regions of the world, over 320 species of birds gathering here during the summer, of which about half are hatching species, and the rest are migratory. During the winter, there is an impressive population of over one million individual birds (swans, wild ducks, etc.) [26].

The flowing water ecosystem is characterized by a fairly well-oxygenated environment, rich in plankton, and numerous species of fish, such as carp, pike, perch, catfish and freshwater sturgeon, which is found in all arms of the Danube and a series of their channels in which the water circulation is visible.

Another ecosystem typical for the Danube Delta is that of stagnant water, which is found in many lakes, as well as in various ponds, streams and, being characterized by a rich floating flora and submerged rootless floating plants, which have a negative effect on aquatic bioproductivity.

Another widespread ecosystem in the Danube Delta is the one represented by swampy and floodable areas, characterized by reed plants (surrounding lakes and slowly invading the water surface), floating reed islands and vegetation represented by rush, alternating with other species, offering ideal land for reproduction and nesting for a very large and varied population of birds, some of which are very rare.

Shoreline ecosystems refer to the land on the riverbanks in the delta, mostly represented in the past by willow (*Salix alba*, *Salix fragilis*, *Salix purpurea*, *Salix petandra*, *Salix triandra*, etc.), that was more recently cut and replaced with Canadian poplars. The characteristic ecosystems of forests are of mixed oak type (*Quercus robur*, *Quercus pedunculiflora*) with various trees (*Fraxinus pallisae*, *Ulmus foliacea*, *Populus tremula*), shrubs (*Prunus spinosa*, *Crataegus monogyna*, *Rosa canina*, *Berberis vulgaris* etc.) and climbing plants reaching up to 25 m (*Vitis sylvestris*, *Hedera helix*, *Humulus lupulus*, *Periploca graeca*) that grow in sand dune areas.

2. Case study: water quality status in the Sulina Channel and perspectives for a better water management

Once the Danube reaches Pătlăgeanca village, in Romania, it forks at CEATAL-1 (Chilia) into two branches: to the North - the CHILIA arm and to the South - the TULCEA arm. At Sfântu Gheorghe Fork (CEATAL-2), the Tulcea arm is divided into two other arms: the SULINA Channel and the SFANTU GHEORGHE branch (Figure 3).

At the contact between freshwater and seawater, certain physico-chemical and biological processes take place, which led to the emergence of an ecosystem that is very different from the classical ones, called by specialists the "pre-delta": Musura Bay, north of Sulina and Sfântu Gheorghe Gulf are considered the most representative examples for this type of ecosystem.

Figure 3.
*The branches of the Danube on the territory of Romania (adapted from [23]). 1-CEATAL-Patlageanca;
 2-CEATAL-Sfantu Gheorghe.*

The dimensional characteristics of the Sulina Channel are: length of 71 km, 50 m maximum width, 18 m maximum depth and 7.32 m minimum depth. This Danube arm is regularized and channeled, being maintained for the maritime navigation of seagoing vessels with a draft of up to 7 m, under the management of the Lower Danube River Administration (AFDJ) based in Galati (the biggest city on the Danube on Romanian territory) [28]. It can be observed that the Sulina arm, which is also denominated as Sulina Channel, is the shortest and straightest arm of the Danube, flowing directly into the Black Sea near the town of Sulina (**Figure 4**), the easternmost settlement in the European Community.

The regularization of the Danube Delta and the appearance of the Sulina Channel meant the opening of the Romanian space to the Black sea, being considered an opportunity for economic development of Romania, based on the implementation of their own projects.

It can be considered that the transformation of one arm of the Danube crossing the Delta, into a navigable channel for heavy ships, in the same time with keeping the specific features of the unique delta in Europe, was a right decision for better water management on the international river, which is subject to the needs of the human community while preserving the biodiversity characteristic of delta-specific ecosystems.

2.1 Some actual and historical data on the water quality on the Sulina Channel

For the settlements located along the Sulina Channel (**Figure 4**), the water from the Danube River is the main source for drinking water preparation. Surface water can only be used as drinking water after its treatment in the drinking water treatment plants. The raw water captured from the Danube is subjected to the water purification procedure through a series of successive processes such as: decantation, flocculation, filtration and chlorination, followed by the temporary storage of drinking water and sending to the consumers, through the drinking water distribution networks.

Figure 4.
The Sulina Channel with populated settlements (adapted from Google maps). Red circle-main settlements; blue circle-small settlements belonging to Maliuc; green circle-small settlements belonging to Crisan.

In order to assure the best water management in the frame of environmental sustainability, the domestic wastewater must be collected from the consumers through sewage networks and pumped to wastewater treatment plants, where the water quality indicators are adjusted to the prescription values to allow the discharge of the treated waters into the natural emissary in accordance with the Romanian Legislation [7], harmonized with European Legislation [1]. The treatment of the domestic wastewaters is usually assured by successive combination of the mechanical, physico-chemical and biological processes, which are designed to have a treatment capacity (m^3/h) in relation to the number of the city inhabitants (from which the wastewaters is collected), that should ensure the water quality before discharge into the natural emissary, also represented in our case by the Sulina Channel.

Maintaining a better quality of water in the Sulina Channel is closely linked to the ensuring of sustainability for the water resources management in the Danube Delta settlements, in accordance with the Integrated Strategy for Sustainable Development of the Danube Delta [8] and with the proper management of the Danube Delta Biosphere Reserve [27].

Even if the Sulina channel is formed in fact at the CEATAL 2 Sfântu Gheorghe by splitting the Tulcea Channel in 2 arms (Sfântu Gheorghe and Sulina), the last section of Tulcea Channel from Tulcea Harbor to CEATAL 2 (with 2 sampling points) was included in our monitored area, as well. In other words the Sulina Channel runs from Tulcea via Crisan and Sulina to be further discharged into the Black Sea, and therefore the most of the sampling points were only accessible by boat. These are numbered for the three different monitoring areas, which are presented in **Figure 5**. Area 1 is illustrated in **Figure 6**, located upstream and downstream, respectively, of Sulina city, up to the sea.

Area 2 (**Figure 7**) is located around Crisan, while area 3 (**Figure 8**) is located around Maliuc (Maliuc and Gorgova are not shown on the map in **Figure 8**).

Some of the obtained results carried out according to the recommended methodology [28] during the summer monitoring campaign (July–August 2019/2020) are presented as the average values in **Figure 9**.

The Sulina channel was considered to have an entrance (namely input) at sampling point S8 from **Figure 8** (CEATAL 2- Saint George/Sfântu Gheorghe), and

Figure 5.
Overview map of the sampling areas.

Figure 6.
Sulina – Sampling area 1. (Sample 1 – Sulina after the old light tower on the Sulina side; Sample 2 – Sulina after the old light tower opposite of Sample 1; Sample 3 – Side channel at the outskirts of Sulina by the large floating crane; Sample 4 – Sulina after Sample 3 by horse pasture; Sample 16 – Sulina drinking water treatment plant; Sample 17 – Sulina port; Sample 18 – Sulina WWTP after the old light tower; Sample 19 – Sulina WWTP discharge tube; Sample 20 – After the discharge of BUSURCA channel; Sample 21 – After Sulina weather station; Sample 22 – BUSURCA Channel near the beach; Sample 23 – Black sea at the beach; Sample 24 – Black sea at the end of Sulina channel; Sample 25 – Sulina city - artificial channel (Busurca); Sample 26 – Sulina city – artificial channel at the intersection with interior channel).

Figure 7.
Crisan – Sampling area 2. Sample 5 – Crisan camping Main street no. 122; sample 6 – Crisan intersection with old Danube Vis-à-Vis of camping (north); sample 7 – Crisan intersection with CARAOMAN Channel south by camping; sample 12 – Crisan intersection with CEAMURLIA Channel, Main street no. 612; sample 13 – Crisan WWTP; sample 14 – Crisan WWTP docks; sample 15 – Intersection old Danube between Crisan and Sulina.

Figure 8.
Maliuc-Gorgova-Tulcea – Sampling area 3. Sample 8 – Sulina channel before intersecting Tulcea channel & St. George channel water level station; sample 9 – St. George channel; sample 10 – Tulcea channel; sample 11 – Tulcea harbor; sample 27 – Gorgova; sample 28 – Maliuc; sample 29 – Partizani.

Figure 9. The water quality data in the sampling points 1–29 ((a) nutrients concentration based on nitrogen and phosphorus, respectively; (b) organic load content expressed as COD).

respectively an exit (namely output) after Sulina city S21 from **Figure 6**. In case of nutrient loading, high concentration values for nitrate-N were measured at point S9 in the St. George Canal (4.3 mg /L), at point S13 and S14 after the Wastewaters Treatment Plant (WWTP) discharge point in the Sulina Channel (3.1 mg/L and 3.3 mg/L) and at point S27 and S28 near Gorgova and Maliuc (4.4 mg/L and 4.6 mg/L). Also around Sulina City the measured values exceed the limit values [29].

The following historical data related to the nutrient concentrations based on nitrogen and phosphorus are presented in **Figure 10(a–d)**. The points from the graph represent the year average values calculated based on trimestrial

Figure 10.
Historical evolution of nutrient (N, P) concentration at the input (a, b) and output (c, d) of Sulina channel, neglecting the most polluted places from Sulina City. (a) N-based nutrients - Input Channel; (b) P-based nutrients - Input Channel; (c) N-based nutrients - output channel; (d) P-based nutrients - output channel.

measurements (usually 4–6 measurements carried out at different months of the year, from spring to autumn).

As a general statement, the input is usually more polluted as visually observed (e.g. due the anthropogenic activities in the Tulcea municipality) than the output (after Sulina city, before discharge into the Black Sea). This aspect can be explained on the basis of self-treatment phenomenon and on the basis of the dilution with clean water resulted from the adjacent channels, where the vegetation acts as a self-treatment system. However, some exceptions appear due to some anthropogenic activities around the Sulina city as well, as can be seen in **Figure 10**.

This study tried to point out some particular aspects of the environmental management in the monitored area, by scanning it with a higher resolution (many sampling points correlated with the visual observation from the field) in comparison with the dedicated sampling points of the water management plan, which included in our case CEATAL 2 - Sf. Gheorghe (as the channel input) and Sulina-discharge in the Black Sea (as the channel output), without intermediary sampling points.

According to **Figure 4**, the human communities are concentrated in the following main settlements located along the Sulina Channel; Sulina city, Crisan commune and Maliuc commune. For each of them, the management of the water resources will be further presented, in order to improve it in the context of environmental sustainability, according to the EU recommendations on the improvement of river basin management [30]. As it was mentioned earlier, the water management includes several components. Among these we will further focus on the drinking water preparation and wastewater treatment in the main human settlements located along the Sulina Channel, providing the most relevant data requested for further using dedicated software solutions in order to satisfy the water needs of the local inhabitants, in the frame of environmental sustainability.

2.2 The main human settlements in the Sulina Channel

2.2.1 The town of Sulina

The town of Sulina (location geographical coordinates: 45° 9' 34" N - 29° 39' 10" E) is one of the three settlements located along the channel that bears the same name. Sulina channel crosses Sulina town, dividing it in two sides, as it can be observed in **Figure 11**, Neighboring areas: to the North – C.A. Rosetti commune; to the South – Sf. Gheorghe; to the West – Crisan, to the East – the Black Sea [31]. Most of the administrative territory is located on the right bank of the Sulina channel, displaying a perfectly ordered street distribution, in orthogonal grid, consisting of 6 streets parallel to the Danube, with transversal streets almost perpendicular to the longitudinal ones (**Figure 12**).

The town of Sulina is dominated by a strong rural character, having less than 50% of its total area built up and used for various purposes, the remaining 50% being defined by vacant land. At national level, Sulina is part of the category of cities with decreasing population, more than 40% between 1989 and 2012. The demographic decline started since 1994, when, out of a total of 5,432 inhabitants registered at the end of 1993, approx. 1,400 inhabitants left the city. At the end of 2020, the city of Sulina has a total population estimated at 4,000 inhabitants [31, 34]. The activities carried out by the population of Sulina fall into the following categories: fishing and economic activities specific to the fishing profile, dismantling and specific manufacturing economic activities, naval transport, public transport (naval and terrestrial), agriculture, telecommunications, trade, tourism. The

Figure 11. Illustrated information about Sulina City. Geographical location (adapted from [31]). Access routes to Sulina (adapted from [32]). Existing water network and proposed extension (adapted from [33]). Overview of Sulina city (adapted from [32]).

Figure 12.
Aerial view images of Sulina City [31, 34].

administrative territory of Sulina is part of the Danube Delta Biosphere Reserve (RBDD), established in 1993 by the Romanian Law No.82.

The altitude is the lowest in Romania, on average 0.31 m, and the climate is temperate - continental; the year maximum absolute temperature was 37.5°C (August 20, 1946) and the absolute year minimum temperature was –25.6°C (February 9, 1929). The total administrative area of the city is about 32956 ha.

Sulina has a special status as a city, being considered a port both on the Danube and at the Black Sea. It has port constructions along the city seafront, which allow the mooring of maritime ships and of those that serve the local traffic of goods and passengers. This settlement is connected to the rest of the country only by water: the Sulina channel to Tulcea, the Black Sea to Constanta and the channels that cross the Danube Delta, to the surrounding localities, with the amendment that sometimes you can drive on the dam between Sulina and Sfântu Gheorghe, using off-road vehicles (tractor, sport utility vehicle, or even motorcycle in certain periods) (**Figure 11**).

However, port activity also comes with negative impacts, especially in terms of environmental pollution, actively participating in the phenomenon of global warming and the degradation of water quality, flora and fauna.

About 95% of the administrative area of Sulina is covered by water (ponds). The hydrological network consists mainly of the Sulina Channel (fragment of the maritime Danube), Musura bay, Roșu, Roșuleț, Lumina, Vătafu, Rotund lakes and numerous gorges and canals. Due to the low altitude, the groundwater is at shallow depths [35]. The water management in Sulina City is schematic illustrated in **Figures 13 and 15**.

The water management works on the territory of Sulina aim at: ensuring the navigation, ensuring the necessary water for various uses (especially for drinking water), protection against floods and land improvements. The town of Sulina is part of the group of localities for which investments were financed for the rehabilitation and expansion of the drinking water systems and the domestic wastewater sewage system, using European funding through the Large Infrastructure Operational

Figure 13.
The water management in Sulina City.

Program (POIM) and Sectoral Operational Programme Environment (POS Mediu 2007–2013, 156/N/23.08.2007) [35].

2.2.1.1 The water management in Sulina City (drinking water treatment plant)

The construction of the drinking water treatment plant of the Sulina city (**Figure 14**) began in 1886 and was completed in 1905, with funds provided by the Dutch Royal House, taking into consideration that the Sulina City was a very important transportation link on international waters, hosting at that time the European Commission of the Danube.

The access of unauthorized persons is restricted inside the water treatment plant, but the water distribution tower can be admired by tourists, as the tallest building in Sulina, so a visible objective from a great distance.

The drinking water treatment plant, together with the Water Tower is still operational today (after modernization based on the European project) and is an important part of the local industrial cultural heritage.

Figure 14.
Drinking water treatment plant with the distribution tower in Sulina City.

Figure 15.
 The most important water sampling points in Sulina City which request a continuous water quality monitoring system (with online data transmission [30]) in order to assure the environmental sustainability.

In the city of Sulina, the water supply source is the Sulina channel, from which the water is captured to be decanted, filtered and treated with chlorine for disinfection in order to meet the quality parameters before distribution to the population. The water plant provides a water flow rate of 64 L/s, covering the current water needs of the city [31, 35].

The drinking water distribution network (**Figure 11**) has a length of approximately 32 km and serves all consumers on the right bank of the Sulina Channel and some of those on the left bank. There is no adduction of treated water in the water supply system of Sulina. Drinking water produced in the drinking water treatment plant is distributed directly from the plant, through a water distribution tower (presented in **Figure 14**). In 2018, the drinking water distribution network included: 1156 home connections; 37 connections to flats in apartment buildings; 90 connections to small business companies; 20 connections to public institutions; 970 is the number of homes that benefit from drinking water in their indoor space [35].

2.2.1.2 The water management in Sulina City (wastewater treatment plant)

Prior to the implementation of the Sectoral Operational Program (SOP), in Sulina there was already a sewage network for domestic wastewater discharge and a meteoric water network which collected the water fallen on the quay surface, which was also used for the discharge of domestic wastewater in the Danube. The total length of the rainwater network utilized as well as a domestic wastewater network was 4.1 km and facilitated the discharge of untreated wastewater for a number of 1394 inhabitants (1197 inhabitants in apartment buildings and 197 inhabitants in houses). Since 2019, the sewage network has a total length of 20.3 km and includes a treatment plant that was extended and modernized in the previous programming period of EU funding through a European project, implemented by the Aquaserv SA water company. The water management infrastructure also includes flood protection dams [35].

2.2.2 The commune of Crisan

Crisan commune is located in the center of the Danube Delta and is crossed by the Sulina Channel on the east–west direction. It comprises three villages: Crisan, Caraorman and Mila 23 (**Figure 16**). The neighbors are: the communes of Chilia Veche and C.A. Rosetti (North), Sfantu Gheorghe commune (South), Murighiol and Maliuc communes (West) and Sulina city (East). The administrative area of the commune is of 38,333.85 ha, and the total urban area is of 389,587 ha. The total population of the commune is of 1237 inhabitants [36].

The settlement of Crisan is the capital of the commune with the same name. It is a linear village, developed on both banks of the Sulina Channel, the houses of the inhabitants lining up along the Danube for a distance of over 5 km. It is considered a starting point for the visitor’s trips, both to the North (to Mila 23, Matita, Letea) and to the South (to Caraorman, Litcov, Roșu - Roșuleț). Mila 23 village develops on the right bank of the Old Danube, being crossed by multiples that discharge the excess water into the main channel and from here into the Old Danube. The village of Caraorman is located between the Sulina Channel and Sfantu Gheorghe branch of Danube on the Caraorman maritime ridge.

2.2.2.1 The water management in Crisan commune

Two of the three component settlements of Crisan commune - Crisan and Mila 23 - have partially solved the drinking water supply issues, and *for Caraorman, the drinking water supply system is under construction*. Crisan and Mila 23 villages have a centralized water supply system, which consists of: water intake (capture), adduction pipe, water treatment and pumping station, water storage tanks, water distribution networks [7].

Figure 16.
Settlements in Crisan commune (adapted from Google maps).

No settlement belonging to the Crisan commune actually has the sewage network system as operational; Crisan and Mila 23 being in the process of completion/commissioning, and Caraorman is in the project phase. The settlements of Crisan and Mila 23 have a sewage system and a treatment plant, built, but not functional, due to the non-existence of connections between them (started to be partially implemented last year) and the lack of authorization for the electricity transformation station which should bring the necessary power supply for the wastewater treatment plant (kept in conservation).

Caraorman does not have a sewage system and a treatment plant yet. Domestic wastewater from homes and socio-cultural objectives is discharged into drainable basins, many of them using dry toilets.

Ensuring the evacuation of domestic wastewater in the commune of Crisan is one of the major, acute and difficult to solve problems [7, 35].

2.2.3 The commune of Maliuc

Maliuc commune is located in the eastern part of Tulcea County, in the first western third of the Danube Delta, being crossed by the Sulina Channel on the east - west direction (**Figure 17**). It comprises five villages: Maliuc, Gorgova, Vultur, Partizani and Ilganii de Sus (**Figure 18**). Its neighbors are Pardina commune (North), Nufăru, Mahmudia, Murighiol and Beştepe communes (South), Tulcea town (West) and Crisan commune (East). The administrative area of the commune is of 25962.02 ha, and the total urban area of 315.62 ha. The total population of the commune is of 1060 inhabitants [37].

Maliuc is the capital of the commune, located about 25 km from Tulcea and situated on the left bank of the Sulina Channel. Vultur settlement is located on the right bank of the Sulina Channel at approx. 3.44 km from the commune capital. Gorgova is the village located on the right bank of the Sulina Channel at approx. 4.22 km from the commune capital. The village of Ilganii de sus is located on the left bank of the Sulina Channel at approx. 13.63 km from the commune capital. The village of Partizani is located on the right bank of the Sulina Channel at approx. 13.51 km from the commune capital.

Figure 17.
Maliuc commune (adapted from Google maps).

Figure 18.
Settlements in Maliuc commune (processed on Google maps support).

2.2.3.1 The water management in Maliuc commune

Of the five settlements belonging to Maliuc commune, three - Maliuc, Partizani and Gorgova - are provided with centralized water supply systems [7, 27, 37]. The villages of Partizani and Gorgova have modern water purification stations, which consist of: water intake (capture) from the Sulina Channel, adduction pipe, module type of water treatment and pumping station, water storage tanks, water distribution networks [7, 37].

A large part of the population in Maliuc commune is supplied with water from underground sources, the total length of the supply network being of 17 km, the rest of the inhabitants getting water from their own sources (wells with a depth of 2–6 m). The village of Maliuc is provided with sewage network, mostly in a damaged state, which takes wastewater from consumers and discharges it into the Danube. No settlement in the Maliuc commune has a domestic wastewater treatment plant. It is necessary to refurbish the existing sewage networks and to set up new domestic sewage networks, pumping stations and sewage treatment plants for each settlement. The discharge of wastewater into the recipient of the area must be done with the provision of sanitary water protection areas in the Sulina Channel [38].

3. Discussions

The Danube Delta is a natural protected area in the South-Eastern part of Romania, declared a Biosphere Reserve through the UNESCO “Man and Biosphere” Programme, where the water is a determining factor for all the human settlements, including these located on the Sulina Channel. However, the eutrophication process based on the increasing of nutrients concentration started in a few locations due to the increasing of the anthropogenic activities. The improvement of water resources management especially related to the drinking water preparation and wastewaters treatment, based on the water quality indicators, which were screened during the summer of 2019/2020 in a twenty-nine monitoring points distributed along the

Sulina Channel, and compared with historical data obtained since a few years ago, is the main topic of this study.

Nutrient pressures in the Danube catchment come from both point and diffuse sources, reflecting the different drivers [39]. The results of the water quality study on the Sulina Channel (at 29 sampling points) show that the values of nitrate-N concentration are outstanding after the WWTP discharge point of Sulina and near the settlements of Gorgova and Maliuc, which could be caused by the leakage of the aging drain pipes. It should be emphasized that the inhabitants of Maliuc obtain drinking water from shallow, 2–6 m deep drilled wells, due to the risk of exceptionally high nitrate concentrations in surface waters, and therefore a special attention should be paid to the drinking water quality monitoring. Residents living along the Sulina Channel that engage in fishing and agricultural activities, bring an additional significant impact on the nutrient load of the surface waters. These findings show that the major point source is the wastewater (insufficiently treated and untreated) and the main diffuse source is the run-off of agricultural fertilizers [39]. The ICPDR modeling studies [39] suggest that in the Danube catchment 86% of nitrogen emissions and 71% of phosphorus emissions now come from diffuse sources.

In order to have an overview on the water quality status in different locations along the Danube River, including the monitored area of this study (highlighted in Bold), the average concentrations for the selected indicators (nutrients and organic load (COD)) during (2013–2018), are presented in **Table 1** [40, 41].

These data belong to the historical data and represent the 6 years average (calculated based on the annual average between 2013 and 2018); some of these were determined by the coauthors of this chapter [28]. It is observed that the water quality has a better quality in the Middle Danube basin in comparison with the Lower Danube basin, where the Sulina Channel is included with 2 sampling points

Name of the sampling point	COD dichromate (mg/L)	NH ₄ -N (mg/L)	NO ₂ -N (mg/L)	NO ₃ -N (mg/L)	Total N (mg/L)	Ortho-phosphate-P (mg/L)	Total P (mg/L)
Vámosszabadi (Hungary-Slovakia border)	7.97	0.05	0.01	1.74	1.25	0.04	0.09
Esztergom	8.71	0.05	0.02	1.77	2.38	0.05	0.12
Upstream of Budapest	11.5	0.06	0.01	1.93	2.61	0.02	0.08
Downstream of Budapest	11.95	0.06	0.01	1.92	2.06	0.02	0.09
Dunaföldvár	11.39	0.06	0.01	2.01	2.54	0.04	0.10
Paks	11.26	0.05	0.01	1.65	2.18	0.05	0.11
Hercegszántó (Hungary-Croatia border)	11.03	0.05	0.01	1.72	2.23	0.05	0.11
CEATAL 1 Chilia	14.50	0.12	0.02	1.55	5.21	0.05	0.12
CEATAL 2 Sfântu Gheorghe	14.00	0.13	0.02	1.20	5.69	0.05	0.11
Sulina	13.89	0.15	0.02	1.09	6.67	0.04	0.11

The highlighted values in Bold are related to the studied area i.e. Sulina Channel.

Table 1.
The average concentrations for the main water quality indicators (nutrients and organic load (COD)) during (2013–2018) in different sampling points distributed along the Danube (from Slovakia to Danube Delta).

(CEATAL 2- Sfantu Gheorghe and Sulina- at the Black Sea). This could be explained taking into consideration the pollution generated by the anthropogenic activities, especially brought by the tributary rivers from the Romanian territory, which are more polluted than the Danube River. In order to support this information we will present a very recent study [41], including the map of the Lower Danube basin with 15 sampling points (related to both Danube River and respectively in the tributary rivers at the discharged points), which is presented in **Figure 19**.

This study presents a complex methodology for assessing water quality based on WQI (Water Quality Index), applied at 15 monitoring points from the Lower Danube and Romanian tributaries for a period of 10 years. The water quality has improved in time at the most sampling points, but some of the Romanian tributary rivers are more polluted than the Danube and still require efforts to improve wastewater treatment from urban agglomerations [41].

Based on the same database [41], in order to have an overview on the water quality discharged into the Black Sea by Danube Delta trough each branch (Chilia, Sulina, Sfantu Gheorghe), including the monitored area of this study (highlighted in Bold), the average concentrations for the selected indicators (nutrients and organic load (COD)) during (2013–2018) are presented in **Table 2**.

Figure 19. CORINE land cover map of the monitored area in the lower Danube with representation of the sampling points (01–15): 01-Bazias, 02-Pristol, 03-Gruia; 04-Jiu; 05-Olt; 06-Oltenita; 07-Arges; 08-Chicium; 09-Ialomita, 10-Siret; 11-Prut; 12-Reni; 13-Chilia (at the Black Sea); 14-Sulina (at the Black Sea); 15-Sfantu Gheorghe (at the Black Sea); Danube River—Black points, tributary rivers—Blue points [41, 42].

Name of the sampling point	COD dichromate (mg/L)	NH ₄ -N (mg/L)	NO ₂ -N (mg/L)	NO ₃ -N (mg/L)	Ortho-phosphate-P (mg/L)	Total P (mg/L)
Chilia (at the Black Sea) [41]	14.78	0.10	0.02	1.10	0.04	0.10
Sulina(at the Black Sea)	13.89	0.15	0.02	1.09	0.04	0.11
Sfantu Gheorghe (at the Black Sea) [41]	14.41	0.10	0.02	1.09	0.04	0.09

Table 2. The average concentrations for the main water quality indicators (nutrients and organic load (COD)) during (2013–2018) corresponding to discharge into the Black Sea for each Danube branch, including Sulina Channel (original data, highlighted in bold).

A very good correlation of ± 0.01 mg/L was found between our results and these reported by [41], for all water quality indicators, except the value for NH₄-N which was higher with 0.05 mg/L and for Total-P which was higher with 0.01 mg/L.

In order to have another overview on the international context related to the water quality status in different similar locations from other European Deltas, a comparison will be focused on the Volga River, which runs through Russia, having a length of 3530 km, cradling more than half of the important Russian cities in the Volga basin, including the capital of Moscow [43], as it is presented in **Figure 20**. The Volga River is discharged into the Caspian Sea, through a huge Delta (10,400 km²) with a classic triangular shape, formed by many channels, from which Nikitinsky Channel was selected to be presented in comparison with Sulina Channel.

Figure 20.
The Volga River basin, with Nikitinsky Channel, located in the western part of the Volga Delta.

Name of the sampling point	COD dichromate (mg/L)	NH ₄ -N (mg/L)	NO ₂ -N (mg/L)	NO ₃ -N (mg/L)	Ortho-phosphate-P (mg/L)	Total P (mg/L)
Sulina Channel (at the Black Sea)	13.89	0.15	0.02	1.09	0.04	0.11
Nikitinsky Channel	29.63	—	—	—	—	—

Table 3.
Comparative water quality in Sulina and Nikitinsky Channel.

Name of the sampling point	NH ₄ -N (mg/L)		NO ₂ -N (mg/L)		NO ₃ -N (mg/L)		Total N (mg/L)		Ortho phosphate-P (mg/L)		Total P (mg/L)	
	Min	Max	Min	Mean	Min	Max	Min	Max	Min	Max	Min	Max
Volga Delta at the Caspian Sea [46, 47]	—	—	—	—	0.007	0.140	0.147	3.640	0.004	0.025	0.066	0.103
[48]	0.390*	**	0.020*	0.04***	—	0.950	—	—	—	0.090	—	—
[49]	—	0.350	—	0.047	0.209	—	—	—	—	—	—	0.444
<i>*Maximum Permissible Concentration (MPC) - Characteristics of the surface and sea water quality in Russia.</i>												
<i>**The occasional maximum concentrations ranged between 3.9–4.4 mg/L, while the annual mean concentration is lower than 0.39 mg/L.</i>												
<i>***The annual mean concentration is around 0.04 mg/L, while the occasional maximum concentrations ranged between 0.2–0.3 mg/L.</i>												

Table 4.
Nutrients concentration in the Volga at discharge in the Caspian Sea.

This was a difficult task because the sources of information for water quality was varied (generally not systematic and not comprehensive) and the measurements were insufficient both temporally and spatially to characterize the nutrients concentrations, and therefore the measurements were focused especially on pollution generated by the dissolved metals (heavy metal ions) and organics (in terms of oil products, phenols, etc.) in water, due to the sampling efforts, expenses, and low levels reported elsewhere in the recent literature. However, some information related to the organic content (in term of COD) in Nikitinsky Channel was relatively recently reported in [44], as it is presented in **Table 3**.

In comparison with the Sulina Channel the organic pollution in Nikitinsky Channel is more than twice, but is hard to draw a general conclusion, taking into account that the characterization of water column concentrations at any single time does not provide much information other than a screening, since concentrations vary rapidly with currents. It was therefore decided to place more effort on characterizing sediments, which could provide a more historical perspective about the pollution. In this respect more data related to the priority pollutants in sediments were comparatively reported in different zones of the Volga and Danube delta in comparison with the Rhine delta [45]. However, even in this paper no data about the nutrients pollution, but as a general conclusion of the three deltas that Winkels [45] investigated – the Volga, Rhine and Danube, the Volga was the cleanest, followed by Danube.

The Hydrometeorology Service in the soviet time performed a routine monitoring of the water and sediments in the part of the Caspian Sea, including the Volga Delta area. The coverage was quite comprehensive, consisting of shore-normal transects around the coast. There are some concerns about the reliability of some of these data and about methodology, particularly with ammonia, phenols, and heavy metals, tacking into consideration that the above mentioned pollutants are quite difficult to be measured in the water. At present, the Hydrometeorology Service are not providing the same level of measurement, and quality-controlled data are sparse for the past decade. These data were carefully collected from the literature and harmonized in order to have the same units and to be easily compared with EU standards. Some representative data are centralized in **Table 4**, even if there are some uncertainties in these values.

As a general overview the concentrations of nutrients in Volga and in Danube (Sulina Channel) are in the same range, but their annual mean concentrations in Volga are 2–3 times higher than in Sulina Channel, with occasional very high values. However, no evidence of widespread eutrophication in the Caspian Sea, though some deltaic and lagoonal areas are slightly eutrophied.

4. Conclusions

The flow of the Danube with an increased contribution of alluvium in the Black Sea gave birth, in time, to the Danube Delta, which is a plain in formation, advancing by 40 square meters in the sea each year. The Danube Delta was formed in two major stages, of which a pre-deltaic stage (prehistoric corresponding to the glacial period) and a deltaic stage, which includes several phases: the gulf phase (at the beginning of the postglacial era, about 10,000 years ago) and the lagoon phase (fluvial - lacustrine, 9,000 years ago when a maritime cord was formed between the strips of land advancing into the seawater due to the currents in the Black Sea, which brought alluvium from coastal erosion and those from the Dniester, Dnieper and Bug discharge areas), followed by other successive phases of the formation of secondary deltas, which in turn have undergone changes due to sea level rise and

alluvial blockage of the Sulina Channel. From the relief point of view, the Danube Delta consists of ridges and islands, swamps, ponds, streams, countless small and large lakes, being the first in Europe as a protected area with swampy territories and wetlands, which is home to unique ecosystems hosting hundreds of flora and fauna species.

In order to avoid health risks for the population in the Danube Delta, it is necessary to assure a continuous monitoring of the drinking water quality by regional operators who ensure the water supply, as well as the monitoring of water quality from the wells. Potential sources of surface water pollution, like direct or uncontrolled discharge of untreated wastewater, must be eliminated, as well as for soil and groundwater pollution, through the occurrence of leaks in sewage networks. In settlements where there is no water supply system, it is necessary to build and expand such a system to provide the population with the necessary drinking water.

From the settlements located along the Sulina channel, only Maliuc, Crisan and Sulina have sewage systems and domestic wastewater treatment plants, but not completely in function, and therefore there are still many issues related to the wastewater management in terms of domestic wastewater canalization, treatment and discharge.

Existing treatment plants involve only mechanical stage treatment, using grates, desanders, septic tanks, grease separators and decanting spaces.

All settlements in the monitored area must have centralized sewage systems that collect wastewater and domestic water throughout the entire locality, as well as treatment plants. Increasing the degree of wastewater treatment, refurbishment and improvement of the treatment process require the implementation of the following measures:

- controlled discharge of domestic wastewater in emissaries;
- improving and making the treatment process of wastewater discharged by economic agents more efficient;
- rehabilitation and extension of sewage networks and old wastewater treatment plants;
- establishment of new sewage networks and treatment plants in all settlements;
- proper treatment of the sludge from wastewater.

In order to respect the Danube Delta Biosphere Reserve, a permanent concern is required from the local authorities, from the Romanian state authorities for: new sources of financing and new investors; accountability of the responsible actors.

The entire deltaic ecosystem of the Danube has been declared a Biosphere Reserve and a UNESCO site since 1991, but, nevertheless, destruction and pollution continue unhindered. The lack of efficient protection mechanisms and of appropriate fines make the upstream pollution of the Danube, private concessions of water surfaces, illegal constructions, races with high speed boats that disturb the birds, poaching without limit, chaotic burning of reed surfaces to remain the main and serious still unsolved problems of the Danube Delta in order to ensure environmental sustainability.

In order to improve the water management in terms of water quality, the implementation of an automated water quality monitoring system on a passengers ship, could provide an early warning message to the water authorities and stakeholders responsible with the water management on the Sulina Channel.

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