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Review of the Seasonal Wastewater Challenges in Baltic Coastal Tourist Areas: Insights from the NURSECOAST-II Project

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Abstract: The NURSECOAST-II project addresses the challenge of managing wastewater in near-coastal tourist destinations around the Baltic Sea, particularly from small treatment plants (<2000 PE) that experience fluctuating flows due to seasonal tourism. These fluctuations make it difficult to meet environmental standards, potentially harming both the environment and tourism. The project has created a GIS-based inventory of small wastewater treatment plants within 100 km of the coast. This inventory includes crucial operational data like flow rates, pollutant levels, and treatment technologies. Initial findings reveal significant discrepancies in data management, regulations, and treatment standards across the Baltic Sea region countries, as EU legislation does not uniformly cover plants under 2000 PE. Key findings highlight that small treatment plants are often undocumented, their environmental impact underestimated, and regulations vary widely. Small plants can significantly contribute to nutrient pollution, affecting the Baltic Sea, particularly in local areas. The data gathered will support local authorities in identifying gaps and improving management strategies. This study stresses the need for harmonized data collection and reporting methods across countries and suggests establishing a unified database accessible to both specialists and the public. The status of the collected data depending on the type of data and country was as follows: 38.11% from Denmark, 46.14% from Estonia, 26.36% from Finland, 15.56% from Germany, 23.47% from Latvia, 34.77% from Lithuania, 14.51% from Poland, and 45.40% from Sweden. Ultimately, this project aims to enhance wastewater management, protect the environment, and improve tourist satisfaction in coastal regions.

Keywords: Baltic Sea region; effluent; governance; legislation; seasonality; tourism; wastewater treatment

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1. Introduction

During the summer months, the coastal regions surrounding the Baltic Sea experience a significant influx of tourists, which amounts to up to 20 times more than local residents. The wastewater infrastructure is normally planned with a safety margin, but in many places, once designed 30–50 years ago, it did not account for the increasing trend of tourists' seasonal flows, as happens in other regions of Europe with high tourist density [1,2]. The Baltic Sea is one of the world's largest brackish water systems, encompassing a surface area of approximately 420,000 km^2 and boasting an extensive coastline of roughly 8000 km. It is bordered by nine countries with a combined population of approximately 85 million inhabitants [3]. Within the Baltic region, countries such as Poland, Denmark, and Germany exhibit the highest population densities along their coastlines, ranging between 11 and 100 persons per km^2 [4]. Of the nine countries with access to the Baltic Sea, Lithuania, Latvia, and Estonia are located entirely within its catchment area. The total Baltic Sea catchment area comprises approximately 1,720,000 km^2, of which nearly 93% is within the borders of the nine HELCOM countries (with Russia), and 7% lies within the territories of five non-contracting Parties (Belarus, Czech Republic, Norway, Slovakia, and Ukraine) [5,6]. However, the largest catchment areas of the Baltic Sea belong to Sweden (25.6% of the total catchment area), Russia (18.3%), Poland (18.1%), and Finland (17.5%). Countries located in the Baltic Sea region are classified as developed [7].

The Baltic Sea is an epicontinental sea with an average depth of 52 m and very limited water exchange due to its shallow depths, absence of tides, low salinity, and location on a tectonic plate. Furthermore, the water is divided into two layers with differing salinity levels, which leads to minimal mixing and results in low oxygen levels in the deeper layer. As a result, pollutants introduced into the sea tend to persist for several years. It is one of the largest brackish water seas in the world, and its salinity, depending on the location, is in the range of 2–20%. The Baltic Sea ecosystem, due to its characteristics, is sensitive and tends to react strongly to the effects of human activity and is affected by pollution, nutrient inputs, including a high level of eutrophication due to nutrient discharge and oxygen depletion in preindustrial times [8–10].

The Baltic Sea region was among the earliest marine areas to urgently address eutrophication in the 1970s, yet it remains the most significant environmental issue in the Baltic Sea today. Despite substantial reductions in phosphorus discharge since the 1970s—particularly from Poland [11]—achieved through various approaches tested under the Helsinki Commission (HELCOM) agreement signed by all Baltic Sea coastal states, phosphorus levels in the Baltic Sea remain high and require further reduction [12].

1.1. Phosphorus Sources in Baltic Sea

Eutrophication remains a significant challenge in the Baltic Sea, driven by the inflow of large nutrient loads [13–15]. Human activities that lead to the export of nutrients to rivers and coastal zones represent a major issue for river catchments and coastal marine ecosystems [12,16].

Nutrients come from various human activities and reach the sea through air emissions and deposition, point source discharges, and runoff from diffuse sources. Additionally, natural background sources also contribute to the overall nutrient load. Nutrients reach the Baltic Sea through rivers, direct discharges along the coast, and atmospheric deposition. Riverine nutrients come from the catchment area and may originate from point sources like industrial or municipal wastewater plants, diffuse sources such as agriculture and scattered dwellings, or airborne deposition on land and water. Natural background sources, mainly from erosion and leakage in unmanaged areas, contribute independently to human activities [12]. Other anthropogenic sources such as agriculture (the dominant one), managed forestry, wastewater from scattered dwellings, storm waters, etc. made up about two third of the total riverine nitrogen and phosphorus load to the Baltic Sea in 2017 [17]. Sewage from ships is also a source of nutrients [10,18]. Recovery from eutrophication is expected to be slow due to the long residence time of phosphorus, among other factors [9].

Tourism is also a significant source of micropollutants in coastal urban areas, and there is a correlation between the presence of micropollutants and tourism indicators. It is crucial to address the release of micropollutants from coastal wastewater treatment plants [19]. Tourism exerts considerable pressure on coastal wastewater treatment systems, which are primarily designed to accommodate the average year-round population [1,2].

Consequently, several issues may arise, as untreated or inadequately treated wastewater can have detrimental effects on human health, the environment, and economic activities. These effects include degradation of water quality in catchment areas, eutrophication, and deterioration of oxygen levels and fish populations in the ecologically fragile Baltic Sea. The attractiveness of coastal areas for tourism is closely linked to the state of the Baltic Sea. Clean beaches and safe, clear water are essential for attracting tourists; however, the environmental impact of tourism must be managed, including the proper treatment of wastewater from tourist destinations. The seasonal influx of tourists and the corresponding variability in wastewater flow rates present challenges for maintaining effective wastewater treatment and protecting the region's environment and the Baltic Sea.

Eurostat [20] also provides data on total discharges of wastewater treatment plants (urban and other)—Table 1, total discharges to marine waters—Table 2, and total discharges to inland waters—Table 3. Complete data is available only for Latvia, Lithuania, and Estonia, while no such data is available at all for Sweden. Only partial data is available for the remaining countries of the Baltic Sea region.

Table 1. Total discharges of wastewater treatment plants (urban and other) in Baltic Sea Region countries.

	Million m^3							
Country	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Poland	-	-	-	-	-	-	-	-
Lithuania	158.98	173.76	195.47	169.43	165.56	165.27	177.91	189.86
Latvia	121.38	113.57	141.13	117.64	119.42	111.75	113.35	113.65
Estonia	-	119.36	120.63	103.39	115.05	117.66	96.33	109.33
Finland	256.00	254.00	267.00	246.00	280.00	282.00	248.50	252.84
Sweden	-	-	-	-	-	-	-	-
Denmark	304.89	310.27	312.93	329.49	321.06	337.51	324.78 (p)	314.7 (p)
Germany	-	10,393.79	-	-	9848.39	-	-	-

- Data not available; (p) provisional.

Table 2. Total discharges to marine waters—all sources in Baltic Sea Region countries.

	Million m^3							
Country	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Poland	-	-	-	-	-	-	-	-
Lithuania	2.83	2.95	3.55	2.97	2.99	3.16	3.54	3.32
Latvia	61.39	60.81	62.07	55.88	57.84	57.20	57.17	56.91
Estonia	70.71	70.35	74.05	63.63	70.94	73.99	70.12	68.02
Finland	-	-	-	-	-	-	-	-
Sweden	-	-	-	-	-	-	-	-
Denmark	-	-	-	-	-	-	-	-
Germany	-	-	-	-	-	-	-	-

- Data not available.

Table 3. Total discharges to inland waters—all sources in Baltic Sea Region countries.

	Million m^3							
Country	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Poland	2122.10	2165.96	2197.66	2191.61	2176.46	2195.15	2254.04	2148.30
Lithuania	246.96	267.65	296.72	268.32	269.09	279.91	292.68	309.14
Latvia	127.06	128.79	133.32	122.87	119.36	117.54	119.53	116.37
Estonia	213.42	53.07	52.65	45.00	47.84	46.66	52.07	49.95
Finland	-	-	-	-	-	-	-	-
Sweden	-	-	-	-	-	-	-	-
Denmark	-	-	-	-	-	-	-	-
Germany	-	-	-	-	-	-	-	-

- Data not available.

As HELCOM reported, the annual inputs of phosphorus to the Baltic Sea area amount to about 38,300 tonnes [5]. In the case of phosphorus and nitrogen loads, the Eurostat website [20] only provides data for three of the eight Baltic countries (Russia is omitted). The average annual amount of phosphorus in 2015–2022 was 0.13 tons per day for Estonia, 3.08 for Latvia, and 6.8 for Lithuania. The values for nitrogen load (tons per day) are 2.33, 20.36, and 42.99 for Estonia, Latvia, and Lithuania, respectively. The data on suspended solids are also available for these three countries. Parameters such as chemical oxygen demand and biochemical oxygen demand are not available for any of the eight Baltic countries [21]. At least 95% of the TP load enters the sea via rivers or as direct waterborne discharges [13].

Enhanced Biological Phosphorus Removal (EBPR) was implemented in five Polish municipal wastewater treatment plants located in northern Poland and discharging wastewater (directly or indirectly) into the Baltic Sea, which is a common practice in Poland. However, the commonly used process in Finland is chemical precipitation of phosphorus [22].

Pollution loads can also be released into the Baltic Sea as a result of failures. One of them occurred in 2019 and again in 2020; it is estimated that 4.8 million m^3 of untreated sewage was released into the Vistula and then into the sea within a few days. Studies have shown a deterioration in water quality at the mouth of the Vistula and the coastal waters of the Baltic Sea (over 400 km from the source). Two and a half weeks after the failure, a 65.7% increase in the water P content was recorded in the waters of the Bay of Gdańsk [23,24].

The patterns for total phosphorus and nitrogen loads differ, though both have decreased over time across the Baltic Sea. Phosphorus reduction has been prioritized due to its key role in eutrophication. Nitrogen has received less focus historically, but this has shifted more recently. The differences are noticeable when comparing inputs across different basins and countries [25].

According to the HELCOM [25] study published in 2018, the trends observed over the evaluated period show a decline in total phosphorus load across the Baltic Sea and most of its basins. Significant reductions occurred in 2014 for the Bothnian Sea and the Gulf of Finland, while the Gulf of Riga showed no noticeable decrease. Country-wise, phosphorus loads generally decreased for Estonia, Germany, Poland, and Sweden, with Denmark showing an early reduction in 1995, and Finland, Lithuania, and Russia experiencing later declines. No clear trends were observed for Latvia.

1.2. Small Wastewater Treatment Plants

Typically, small WWTPs are situated in rural areas with long specific sewer lengths, making wastewater disposal often more cost-intensive than in more densely populated regions [26]. Wastewater discharged from coastal areas of the Baltic Sea often originates from small treatment plants with capacities less than 2000 population equivalents (P.E.).

Population equivalent is a number expressing the ratio of the sum of the pollution load in wastewater to the individual pollution load in household sewage produced by one person at the same time. In Poland, the BOD_5 load from one person is assumed to be equal to 60 g O_2 per 24 h [27]. It is calculated as follows:

$$P.E. = \frac{BOD_5 \frac{kg}{day}}{0.6 \frac{kg}{person \times day}} \tag{1}$$

Additionally, the seasonal variability in wastewater flows complicates the ability to consistently achieve the required effluent quality parameters, potentially compromising the environmental quality of tourist destinations and customer satisfaction.

It is more difficult to maintain the correct treatment parameters of small WWTPs than in the case of large ones, which have more advanced technology to capture the nutrients [13].

Wastewater entering a wastewater treatment plant below 2000 PE must be provided with "appropriate treatment". "Appropriate treatment" means the treatment of wastewater by any process and/or disposal system that allows receiving waters to achieve appropriate quality parameters. Appropriate treatment can include a range of treatment methods, from basic to advanced technology [28]. In small wastewater treatment plants, mainly biological or mechanical treatment combined with biological treatment is used.

Table 4 shows the distribution of WWTPs in Poland in terms of PE and treatment load. Despite the majority of load coming from highly populated urban areas treated by large plants, the majority of plants in PL are the smallest ones, and the legislation around them is often less strict than for larger ones.

Table 4. Wastewater treatment plants breakdown according to PE and load treatment in Poland.

Share of WWTPs	PE	Treated Load
3%	>100,000	60
17%	10,000–100,000	30
30%	2000–10,000	8
50%	<2000	2

Identifying alternative wastewater treatment technologies specifically adapted for tourist areas could significantly reduce nutrient inputs into the Baltic Sea while maintaining the high touristic quality of the given region. This eventually would have a positive effect on the tourism business sector. To achieve sustainable development, it is imperative to consider not only technological and economic factors but also environmental and social dimensions when selecting appropriate wastewater treatment solutions. The protection of freshwater resources is becoming increasingly critical on a global scale. Modern wastewater treatment systems are designed to mitigate the environmental impacts of wastewater. In industrialized nations, central sewer systems transport wastewater from urban areas to municipal treatment plants. However, in rural areas, on-site treatment systems are necessary to prevent pollution of nearby freshwater ecosystems and groundwater [29].

In addition to enhancing wastewater treatment capacity, it is essential to raise awareness about responsible water consumption. Household water use, including activities such as cooking, showering, and drinking, constitutes a significant portion of overall water consumption. In the tourism sector, accommodations, restaurants, harbors, campsites, summer festivals, mobile toilets, and other service providers consume substantial volumes of water and generate corresponding amounts of wastewater. The European Environment Agency estimates that approximately one-third of the European Union's territory faces water stress, either permanently or seasonally [30]. Climate change is anticipated to increase the frequency of water shortages, with droughts becoming more prevalent and precipitation less frequent. Extreme water conditions, such as floods and droughts, will place additional pressure on infrastructure in both urban and rural areas, including those in northern Europe.

1.3. Key Features of the Legal System in the Analysed Countries

Based on the information provided by the project partners, it can be concluded that the wastewater legislation systems in the analyzed countries are structured similarly.

The Urban Waste Water Treatment Directive (UWWTD), also called the Water Directive, is the main legal act in EU countries in water management. The directive regulates the required level of treatment of wastewater before it is discharged into receiving water bodies. It specifies the conditions for the use, treatment, and disposal of wastewater. These requirements vary depending on the size of the agglomeration expressed in population equivalent (PE), the type of sewage receiver, and its sensitivity to eutrophication.

Along with the limits set by the UWWTD, stricter discharge limits were set by HELCOM in the Recommendations of the Baltic Marine Environment Protection Commission 28E/5, based on the agreement of the Baltic Region countries' Ministers of Environment in 2007. According to HELCOM recommendations, WWTPs within the Baltic Sea catchment area must comply with both national legal regulations and HELCOM requirements. These requirements specify minimum reduction levels and allowable values for three key indicators: Biochemical Oxygen Demand over five days (BOD_5), Total Nitrogen (TN), and Total Phosphorus (TP) [31]. HELCOM's standards, along with those of the EU, are designed with consideration of Population Equivalent (PE) values and are regularly updated to enforce stricter reductions in pollutant loads, particularly nutrient discharges, from these treatment plants [32].

National legislation provides for the possibility of establishing different national administrative rules regarding the quality of treated wastewater. The nitrogen discharge requirements in Germany apply to ammonium nitrogen (NH_4^+–N) and total nitrogen (TN), if the wastewater temperature is above 12 °C in relation to the wastewater from the biological reactor of the sewage treatment plant. The temperature criterion may be replaced by a limitation in the summer season from 1 May to 31 October [32]. Swedish legislation has limited the TP limit in water discharges to receivers to 0.5 mg/L. Compared to other EU countries, the approach to BOD is more restrictive, requiring BOD_7 (7-day) marking rather than BOD_5 (5-day) [33]. To encourage nutrient reduction efforts, Denmark has implemented a discharge tax targeting Biochemical Oxygen Demand over 5 days (BOD_5), Total Nitrogen (TN), and Total Phosphorus (TP). This tax enforces the "Polluter Pays Principle", making it mandatory for wastewater treatment plant (WWTP) operators to bear the cost of their environmental impact.

In most cases, the construction of a WWTP requires obtaining a water permit, which specifies treated wastewater quality standards, treated wastewater discharge locations, and the PE of the treatment plant. However, the Swedish system is an exception to this rule. In Sweden, in addition to the water permit (tillstånd), there is a notification obligation (anmälningsplikt). The first one is required for WWTPs in the range of 5 PE to 199 PE. For WWTPs over 200 PE, there is an obligation to notify.

Significant differences exist in how wastewater quality is monitored in the analyzed countries. Typically, the differences concern the number of measurements per year and the types of parameters that are measured. Regarding WWTPs under 2000 PE in the analyzed countries, neither monthly nor quarterly data are collected. The number of measurements per year is determined based on the size of the WWTP, assuming that small plants can carry out fewer measurements. It should be emphasized that some countries do not monitor the smallest WWTPs. In Finland, there is no obligation to monitor sewage treatment plants below 100 PE.

In Poland, the permissible values of pollutants introduced into water are regulated by the Regulation of the Minister of Maritime Economy and Inland Navigation [34]. For treatment plants below 2000 PE, the permissible values are BOD_5—40 mg O_2/L, COD—150 mg O_2/L, Suspended Solids—50 mg/L, TN—30 mg N/L, and TP—5 mg P/L.

In the case of small sewage treatment plants, they must be monitored four times a year, if they meet the requirements—only two. Parameters are also specified in the water permit, which may vary depending on the treatment plant.

Urban Wastewater EU legislation is now to be changed from 2000 PE to 1000 PE: By 2035, urban wastewater will undergo secondary treatment (i.e., the removal of biodegradable organic matter) before it is discharged into the environment, in all agglomerations of the size of 1000 PE or more [35].

The circular economy has been proposed as an effective framework for sustainable water management. The concept of circular water management encompasses the 5R approach: reduce, reuse, recycle, restore, and recover (Figure 1). The NURSECOAST-II project adopts the 5R framework, focusing on small-scale wastewater treatment systems with capacities less than 2000 PE, as well as other measures and technologies aimed at recirculating or reducing nutrient loads, particularly in tourist regions. The fluctuating wastewater flow rates due to seasonal tourism activity pose challenges to wastewater treatment and impose additional burdens on the environment and the Baltic Sea.

Figure 1. Circular water management—5R principles [36].

This study presents the preliminary results of the ongoing NURSECOAST-II project, which aimed to collect, process, cross-validate, and graphically present the data on the amount of pollution discharged from sewage treatment plants, because they can be the source of uncontrolled discharge of nutrients into the Baltic Sea. At the initial stage of the project, data was collected for small sewage treatment plants below 2000 PE, which were located up to 100 km from the coast.

2. Materials and Methods

2.1. Methodology

Project Criteria

For the project, wastewater treatment plants from the Baltic Sea region were selected. The selection criteria were as follows:

- Location of the WWTP within the distance of 100 km from the coastline of the Baltic Sea;
- PE less than or equal to 2000;
- Operating in 2019 and 2021;
- The Baltic Sea is the end receiver of the treated wastewater.

The distance of 100 km from the coastline of the Baltic Sea was determined based on the coastlines of all the Baltic Sea countries, including countries not participating in the project—Russia and Norway (Figure 2). It should be emphasized that the obtained results will vary depending on the geometry of the source layer. For example, the borderline of 100 km from the coastline of the Baltic Sea will be different when the source layer is the coastline of one country, and different when the source layer is the coastline of all the Baltic countries. Figure 3 shows the impact of considering the coastline of Russia (Kaliningrad) and Lithuania on determining the distance of 100 km in Poland. Lastly, the designated boundaries have been adjusted to the boundaries of NUTS 3 level (Nomenclature of Territorial Units for Statistics).

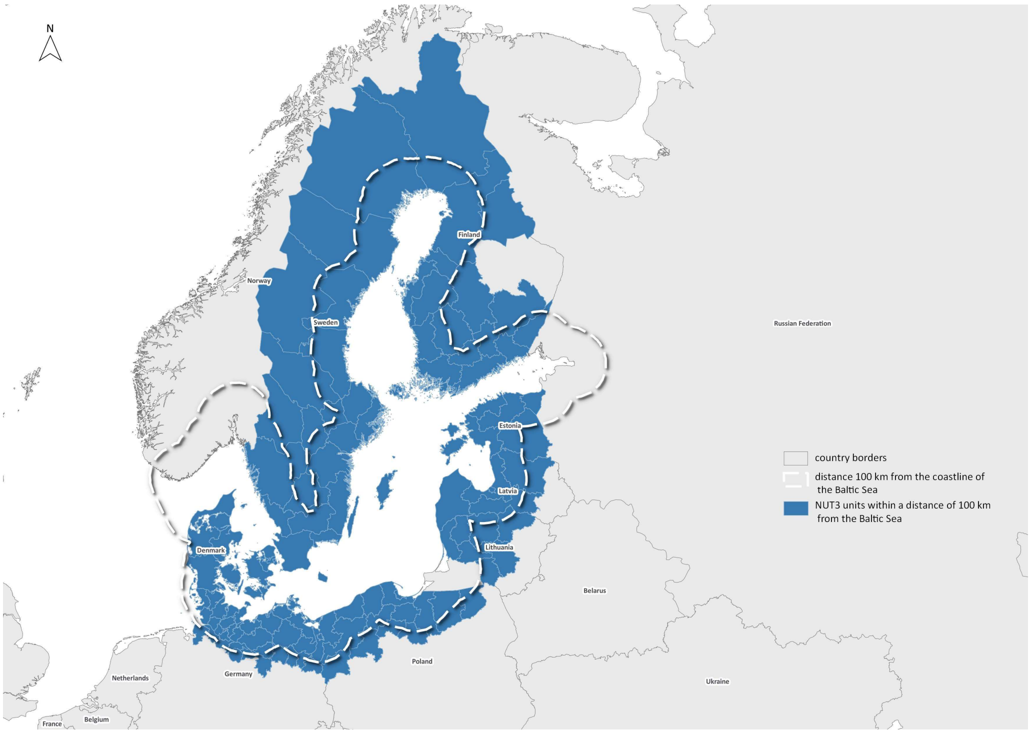


Figure 2. Distance of 100 km from the coastline of the Baltic Sea.

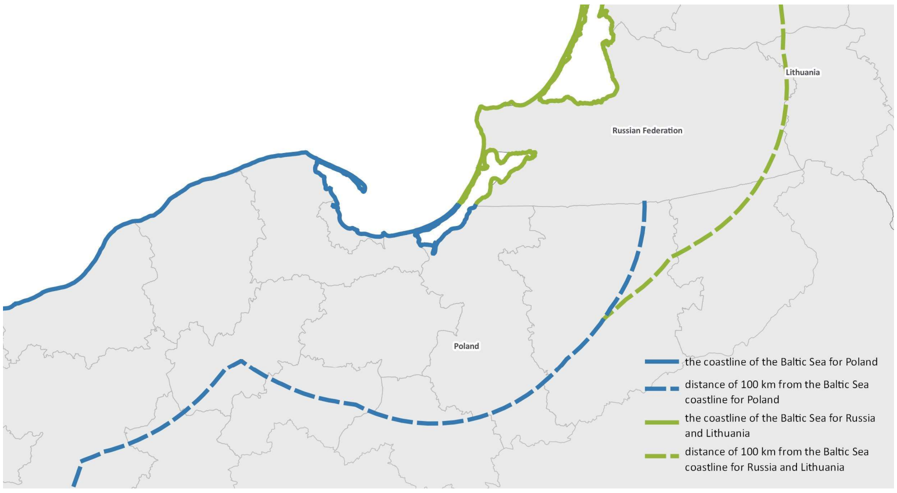


Figure 3. The impact of taking into account the coastline of Russia (Kaliningrad) on determining the distance of 100 km in Poland.

The second criterion was met if, in at least one of the analyzed years, the WWTPs had a value equal to or below 2000 PE. This means that WWTPs that were redeveloped during the analyzed period were also included in the project.

The year 2020 was omitted in the project due to the COVID-19 pandemic, during which countries imposed significant restrictions on domestic and foreign travel. Due to the smaller number of tourists visiting the Baltic Sea regions, the measurements from 2020 would most likely differ significantly from those from 2019 and 2021. The years selected for the project were considered the most reliable.

The fourth criterion concerns the end receiver of treated wastewater. In Denmark and Germany, some WWTPs located 100 km from the coastline of the Baltic Sea discharge treated wastewater to the North Sea, which is closer than the Baltic Sea. Such treatment plants were not included in the project.

Even though the project focuses on the impact of tourism on increasing wastewater production, in most partner countries, it is not possible to select WWTPs that treat wastewater from tourist entities only. Moreover, when analyzing wastewater from municipal WWTPs, not only domestic sewage but also industrial sewage is taken into account. Therefore, until a consistent data collection system is introduced in all partner countries, selecting treatment plants based on the origin of wastewater is impossible.

2.2. Data Collection Procedure

A universal form (spreadsheet) was prepared in cooperation with the project partners. The form was divided into three parts: basic information about the wastewater treatment plant, characteristics of the wastewater discharged to the wastewater treatment plant, and characteristics of the treated wastewater. The data contained in individual sections are shown in Figure 4.

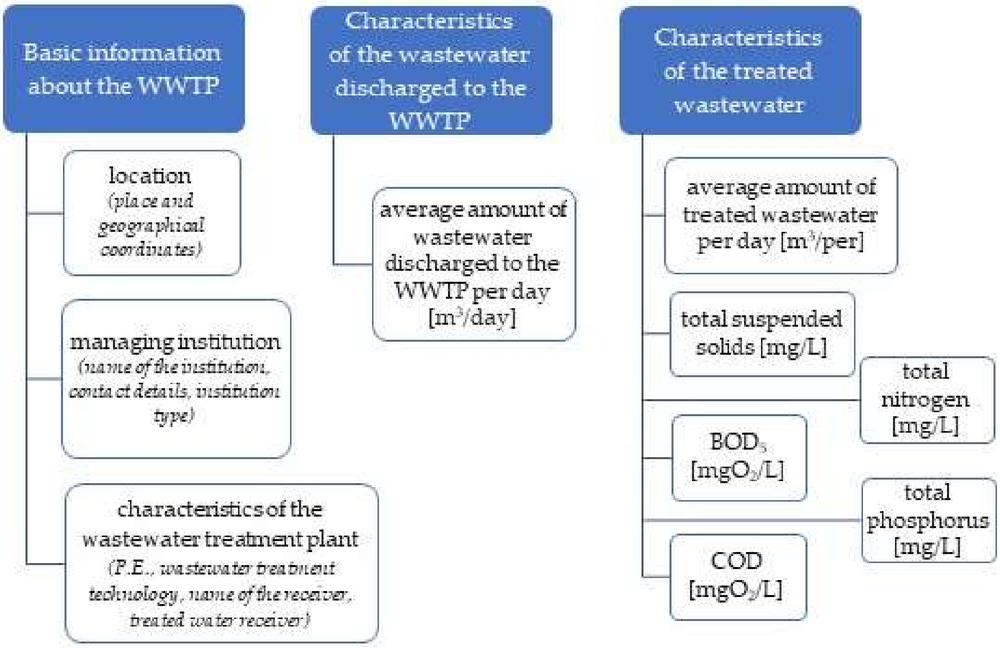


Figure 4. These sections contain the following data.

The data in the second and third parts was collected on an annual, quarterly, and monthly basis, depending on the data available to the partner countries. Partner countries have been given the option to include additional data at the end of the table.

The process of individual data collection began after sending the prepared form to all the project partners. Then the project partners submitted requests for the data to the national or municipal authorities responsible for collecting the data on Wastewater Treatment Plants.

In Poland, two regional institutions are responsible for collecting data on wastewater treatment plants. The first authority is Voivodship Inspectorate for Environmental Protection (WIOŚ) and the Regional Water Management Board part of Polish Waters (RZGW). The areas under the administration of each of the two authorities do not overlap. WIOŚ is working within the administrative borders of voivodship, the RZGW administrates areas whose borders are suited to the water catchment areas. So, there are 7 RZGWs and 6 WIOŚ within 100 km from the coastline of the Baltic Sea, to with requests were submitted.

Data collection in Poland was a long-term process, lasting about six months, due to formal reasons. Two institutions requested additional explanations regarding the purpose of the data collection, while one of them refused to provide the data. One institution reported a lack of sewage treatment plants meeting the project criteria within 100 km from the seashore. In Finland, there is no obligation to monitor sewage treatment plants below 100 PE. Therefore, the data provided from Finland do not include WWTPs below this value.

While waiting for the data in Poland, the project partners collected data in their countries. In the meantime, questions from the project partners were answered, and minor corrections were made. The actual process of verifying the provided data started in mid-June after the data was provided by each of the foreign project partners. It has been observed that there are many discrepancies in the way data is collected in partner countries.

In Poland, most of the data received came from water law permits specifying the upper limit of parameters—normative values, not measurement values. Taking into account the concern for the integrity of the final database, partners were asked to make the necessary corrections and additions to the submitted data, including normative data. After verification of the collected data, in case of errors, partners were asked to make the necessary changes. The last stage of data verification was based on the geographic coordinates of wastewater treatment plants. After entering the data into the GIS program, it turned out that there were large areas without sewage treatment plants. project partners were obliged again to re-check the submitted data and make any necessary corrections. The data collection and processing procedure is presented in Figure 5.

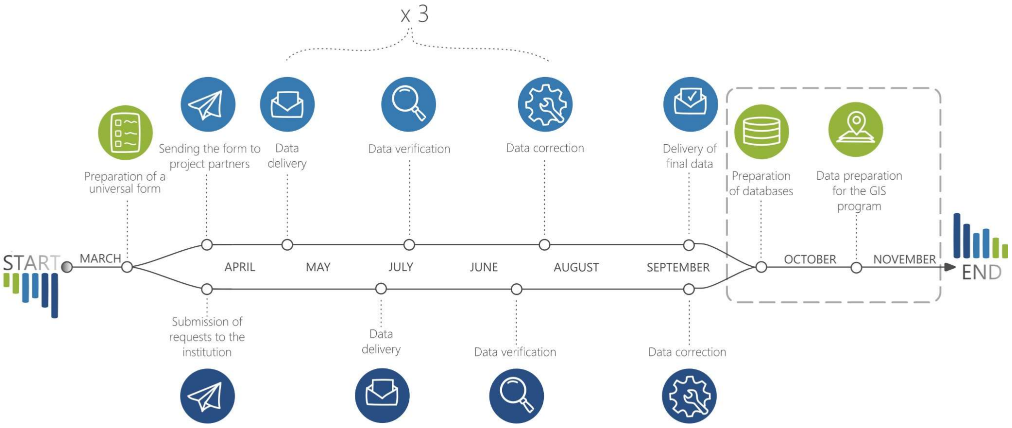


Figure 5. Data collection and processing procedure.

2.3. Data Processing Procedure

After delivering the final data sets to the project partners, two databases were created: one for Poland and one for the project partners. The databases were processed for compatibility with the spatial data visualization program. This process consists of changes in notation to match the notation used in the GIS program and re-organization of the table structure.

Further steps of the data processing procedure were carried out in the GIS program and included, among many others:

- Verifying the format in which the geographical coordinates were provided by the project partners;

- Changing the field type for all columns containing numerical data to enable their visualization on a numerical scale;
- Changing the notation of some values (for example, a value given as "<4" was rewritten as "3.9");
- Data verification (e.g., checking whether the location of the point corresponds to the name of the town indicated in the form or with the plot number).

Due to errors in geographical coordinates, some of the WWTPs were not transferred from the Excel file to the GIS program. When incorrect notation occurred or when coordinates were missing, the program did not include the object in the GIS project. Therefore, in order to include this object, it had to be transferred manually. In such cases, the location of WWTP was determined based on publicly available data, such as satellite photos or maps of technical infrastructure.

A geographic information system (GIS) is a platform for collecting, managing, and analyzing data. GIS integrates many types of data. It allows for analyzing spatial locations and organizing information layers for visualization using 3D maps and scenes. With this unique capability, GIS provides deeper insight into the data, allows for seeing patterns, exploring relationships, and assessing situations, helping users make informed decisions.

The simplest case of analyzing spatial data is visually assessing their distribution based on a traditional map. Visual examples of GIS tools are the maps presented later in the manuscript. GIS-based database of the WWTP could help municipalities plan new investments in non-existing WWTPs, especially if the local nutrients excess–vulnerable zones are mapped.

3. Results and Discussion

3.1. Data Characteristics

None of the authorities to which the request had been submitted provided monthly or quarterly measurement data, and only a few of them provided annual measurement data. Despite the obligation to carry out at least two measurements yearly, access to these data is significantly limited. Most of the authorities did not provide a completed database for WTPs under their authority. Typically, measurement data are collected in paper form in archives, and making it available requires scanning and forwarding thousands of copies. Authorities refuse to provide this type of data due to excessive workload and provide only water law permits or summary tables available on the internet, both of which contain only normative data. As a result, data on WWTPs below 2000 PE collected in Poland are mostly normative and do not reflect seasonal changes.

During the data collection process, significant differences were noticed between the data provided by the authorities. The differences concerned not only the values of parameters or characteristics of the WWTPs but also the number of declared WWTPs. Considering the legal obligation to report these measurement data to both WIOŚ and RZGW, they should be the same. Presumably, the differences resulted from the lack of updating and verification of the data, but it is not possible to clearly determine the reasons for the discrepancies. As a result, it is not possible to collate and compare the received data from the two authorities. To ensure the consistency of the final database, it was decided to show the data from two sources separately.

A significant difficulty in preparing the database for Poland was the lack of a coherent data collection system. Despite the obligation to collect the same data, individual authorities use different methods. For example, authorities in Poland collect location data in six different ways:

- Geographical coordinates of the WWTP in the Polish coordinate system (ETRF2000-PL/CS92);
- Longitude and latitude of the WWTP;
- Plot number of the WWTP;
- Geographical coordinates of the wastewater discharge location in the Polish coordinate system (ETRF2000-PL/CS92);

- Longitude and latitude of the wastewater discharge location;
- Number of the plot where the wastewater is discharged.

The process of verifying location data for several hundred WWTPs would require a significant amount of time, going beyond the project schedule. For this reason, it has been decided to present the location data in the form in which it was provided by the authorities, without any significant changes. Moreover, only one dataset will be used for further analysis and visualizations—a dataset from RZGW. The database from WIOŚ has significant deficiencies and is not suitable for comparing data between countries.

In addition to inconsistencies between authorities described above, there are also inconsistencies in the individual data sets. There were cases in which the values of one parameter were given in different units for each WWTP (e.g., the average amount of treated wastewater was given in m^3/day, in m^3/year, or in m^3 without a time unit). There were also inconsistencies in the form of notation. For instance, the data concerning the receiver of the treated wastewater are presented in an unclear manner, making it impossible to determine which of the listed receivers is the final one. Such cases required selection and additional verification based on publicly available data.

The last issue is the inaccuracy of providing PE data. For many small WWTPs, the exact PE value is unknown. The only information available is the declaration of individual WWTP managers on whether the facility exceeds 2000 PE. If a given WWTP did not exceed 2000 PE, the authorities only provided information "below 2000 PE" without the exact value.

All the project partners provided annual measurements, but only a few of them provided monthly and quarterly data. Due to the limited amount of monthly and quarterly data, seasonal changes in measured parameters will only be shown based on the data from Danmark, Latvia, Poland, and Sweden. After verifying the data, the partners supplemented data sets with normative data.

Since legal systems in the analyzed countries are not coherent, the following discrepancies occurred in the final database:

- Lack of data from Finland on wastewater treatment plants below 100 PE;
- Lack of data from some Swedish municipalities that did not provide data;
- BOD_7 in Finland, Estonia, and Sweden, BOD_5 in the rest of the countries,
- Some of the values do not represent average values but the value from one measurement.

Some data providers did not provide annual data, so the project partners were asked to calculate annual averages from the monthly or quarterly data. This decision has been made in order to obtain a parameter that could be used to compare the results from all countries since most of the partners provided annual data. Unfortunately, this process introduced the risk of computational errors. Some of the values differ significantly, which indicates an error when calculating the averages. In such cases, extreme values were omitted from the visualizations and left in the Excel database.

3.2. Status of Collected Data

The tables below present the status of data collection (Tables 5–8). The number in the table should be understood as the number of objects for which the type of data specified in the column has been provided. These objects will be presented in the project database. The following assumptions have been made in the database:

- For the parameters: average amount of wastewater discharged to the WWTP per day [m^3/day] and average amount of treated wastewater per day [m^3/per], the value "0" was interpreted as a lack of data. Such a value implies that there was an interruption in the operation of a WWTP and a significantly different value is not taken into account in the database.
- If approximate values were provided (for example "<30" or "6.5–6.7"), the upper value of the limit was taken.

- For the PE parameter, when the value has not been precisely determined (e.g., "<2000"), it is considered as a lack of data, but the WWTP is qualified for the project. When the value "<2000" is not provided in the table and the field is left empty, this case is considered as a declaration of the project partner that the PE value for the WWTP is below or equal to 2000 PE, and the WWTP is qualified for the project.

Table 5. Basic information about the WWTP.

Country	WWTPs	Location		Managing Institution		P.E.	Technology	Receiver	
		Place	Coordinates	Name	Type			Name	Type
2019									
Denmark	155	155	155	150	11	155	150	154	155
Estonia	216	216	216	216	216	193	216	216	216
Finland	108	108	108	108	108	92	107	9	9
Germany	102	102	102	102	0	102	30	0	0
Latvia	504	504	504	504	504	504	504	4	4
Lithuania	50	50	50	50	50	50	50	50	50
Poland	486	466	118 *	461	254	299	382	249	484
Sweden	73	73	73	73	73	70	73	72	73
2021									
Denmark	155	155	155	150	11	155	150	154	155
Estonia	10	10	10	10	10	9	10	10	10
Finland	110	110	110	110	110	91	9	9	9
Germany	159	159	159	159	0	159	0	0	0
Latvia	4	4	4	4	4	4	4	4	4
Lithuania	50	50	50	50	50	50	50	50	50
Poland	491	471	113 *	468	259	303	387	249	491
Sweden	73	73	73	73	73	70	73	72	73

* The value shows the number of WWTPs for which the facility coordinates were given, for 415 WWTPS in 2019 and for 413 WWTPs in 2021 the wastewater discharge locations were given.

Table 5 presents data on the number of wastewater treatment plants (WWTPs) across eight countries in the Baltic Sea region for the years 2019 and 2021. It includes information on locations, managing institutions, person equivalents (PE), technology types, and receiving water bodies. The data that was collected are as follows:

- Denmark, Lithuania, and Sweden maintained a stable number of WWTPs between 2019 and 2021. Denmark had 155 WWTPs consistently across both years. Lithuania and Sweden had 50 and 73 WWTPs, respectively, with no changes noted over the two-year period.
- Estonia and Latvia saw a substantial decrease in the number of WWTPs. Estonia dropped from 216 WWTPs in 2019 to just 10 in 2021. Latvia reduced its count from 504 in 2019 to four in 2021. These reductions suggest a potential shift toward fewer, possibly more centralized, and efficient treatment facilities or changes in reporting practices.
- Germany and Poland exhibited an increase in the number of WWTPs. Germany increased from 102 WWTPs in 2019 to 159 in 2021. Poland had a slight increase from 486 in 2019 to 491 in 2021.

Table 6. Analyzed parameters on a quarterly basis.

Country	WWTPs	Qdwavg	Qdtavg	BOD_5/BOD_7	COD	TSS	TN	TP
				2019				
Denmark	155	137 *	0	36 *	123 *	136 *	147 *	147 *
Estonia	216	216	0	216	216	216	216	216
Finland	108	104 *	12 *	104 *	100 *	102 *	102 *	103 *
Germany	102	46	0	46	46	0	46	46
Latvia	504	490 *	490 *	312 *	0	313 *	0	0
Lithuania	50	50	50	50	50	50	48	50
Poland	486	0	27	49	49	49	0	0
Sweden	73	50 *	30 *	63	52	41	58	57
				2021				
Denmark	155	149 *	0	137 *	112 *	125 *	155 *	150 *
Estonia	10	9	0	9	9	9	9	9
Finland	110	102 *	11 *	104 *	103 *	103 *	104 *	104 *
Germany	159	108	0	107	107	0	103	17
Latvia	4	4 *	4 *	4 *	4 *	4 *	4 *	4 *
Lithuania	50	49	50	50	50	48	50	50
Poland	491	0	27	46	46	45	0	0
Sweden	73	53 *	29 *	71	59	37	64	65

* values calculated based on monthly data, or the total quantity in the year.

Table 7. Analyzed parameters on a quarterly basis.

Country	WWTPs	Qdwavg	Qdtavg	BOD_5/BOD_7	COD	TSS	TN	TP
				2019				
Denmark	155	0	0	0	0	0	0	0
Estonia	216	214	2	0	0	213	3	213
Finland	108	0	0	0	0	1	0	0
Germany	102	0	0	0	0	0	0	0
Latvia	504	0	0	0	0	0	0	0
Lithuania	50	0	0	0	0	0	0	0
Poland	486	0	0	14	0	38	1	38
Sweden	73	40	0	25	0	25	1	21
				2021				
Denmark	155	0	0	0	0	0	0	0
Estonia	10	9	0	0	0	9	0	9
Finland	110	0	0	0	0	1	0	1
Germany	159	0	0	0	0	0	0	0
Latvia	4	0	0	0	0	0	0	0
Lithuania	50	0	0	0	0	0	0	0
Poland	491	0	0	14	0	31	8	33
Sweden	73	42	0	24	0	26	4	21

Table 8. Analyzed parameters on a monthly basis.

Country	WWTPs	Qdwavg	Qdtavg	BOD_5/BOD_7	COD	TSS	TN	TP
				2019				
Denmark	155	25	112	0	0	0	28	16
Estonia	216	0	0	0	0	0	0	0
Finland	108	0	0	0	0	0	0	0
Germany	102	0	0	0	0	0	0	0
Latvia	504	0	0	0	0	1	199	1
Lithuania	50	0	0	0	0	0	0	0
Poland	486	0	0	0	1	0	8	0
Sweden	73	40	0	24	1	13	37	5
				2021				
Denmark	155	20	99	0	0	2	23	24
Estonia	10	0	0	0	0	0	0	0
Finland	110	0	0	0	0	0	0	0
Germany	159	0	0	0	0	0	0	0
Latvia	4	0	0	0	0	1	3	1
Lithuania	50	0	0	0	0	0	0	0
Poland	491	0	0	0	0	0	3	0
Sweden	73	40	2	23	1	10	37	9

The table also shows inconsistencies, particularly for Poland, where discrepancies exist in the number of WWTPs between years and across different categories (e.g., locations and managing institutions). The number of locations for Poland in 2019 (466) does not match the total number of WWTPs (486).

Table 5 indicates also variances in technological types used by WWTPs across the countries:

- Poland shows a notable increase in WWTPs employing diverse technologies, from 299 in 2019 to 303 in 2021.
- Estonia's drop in the number of WWTPs is mirrored by a reduction in technology types, indicating potential centralization or technological upgrades.

Some countries like Germany and Latvia show zero or minimal data on managing institutions, indicating potential gaps in data collection or reporting standards. The inconsistencies and large discrepancies in the data, especially for Estonia and Latvia, suggest a need for harmonized reporting and better data management across the region. The data indicate a potential shift toward fewer but more advanced treatment plants, especially in countries like Estonia and Germany. This may suggest efforts to improve efficiency and reduce nutrient loads.

Table 6 presents a quarterly analysis of various wastewater treatment parameters across different countries in the Baltic Sea region for the years 2019 and 2021. The parameters include the number of wastewater treatment plants (WWTPs), average amount of wastewater discharged to the wastewater treatment plant per day (Qdwavg), average amount of treated wastewater per day (Qdtavg), and concentrations of several key pollutants: Biological Oxygen Demand (BOD5/BOD7), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Nitrogen (TN), and Total Phosphorus (TP). The collected data are as follows:

- Denmark and Finland reported high Qdwavg numbers consistently. In 2021, Germany and Latvia saw notable increases in Qdwavg numbers, suggesting better reporting practices. Poland consistently reported zero Qdwavg, indicating possible data collection issues or the absence of quarterly reported data.

- BOD data shows a general trend of stable or slightly increasing values across the years. Denmark and Finland consistently reported BOD values, indicating robust monitoring and treatment capabilities. Germany's BOD data improved significantly from 46 WWTPs in 2019 to 107 WWTPs in 2021, suggesting expanded reporting.
- Collected data of COD are generally consistent, with Denmark, Finland, and Sweden, showing minor fluctuations. Germany's reported COD data increased, indicating an expanded or more detailed reporting system. Latvia had no COD data for 2019 but reported some values in 2021, showing an improvement in data availability.
- The data for TSS are largely consistent, with slight variations across the years. Denmark, Finland, and Sweden provided stable TSS data, reflecting consistent monitoring practices. Germany had no reported TSS data in 2019 and 2021.
- TN data show significant gaps, with countries reporting no values or small amounts for one or both years. Denmark and Finland provided consistent TN data In 2019, indicating good monitoring and reporting systems in 2021.
- TP data are also sparsely reported, with significant gaps for countries like Poland and Latvia. Sweden showed an increase in TP data reporting, suggesting improvements in data collection.

The table highlights significant gaps in data reporting across several countries, particularly for Poland and Latvia. There is a need for harmonized and more comprehensive data collection and reporting practices across the region to ensure accurate assessment and comparison of wastewater treatment performance. Countries like Germany and Estonia have shown significant changes in data reporting, indicating potential improvements in wastewater treatment infrastructure or data collection methodologies. Continued efforts to enhance data accuracy and completeness are essential. The increase in reported parameters for countries like Sweden and Germany suggests a focus on upgrading treatment technologies and expanding monitoring capabilities. These efforts are crucial for improving the quality of wastewater treatment and reducing environmental impacts.

Table 7 shows the availability of quarterly data relative to the number of WWTPs in each country for collected parameters.

The average amount of wastewater discharged to the wastewater treatment plant per day data are generally available for several WWTPs across all countries, except for some gaps in Germany and Finland. Qdtavg (average amount of treated wastewater per day) is similar to Qdwavg; data availability varies, with gaps noted in some countries like Estonia and Latvia. BOD_5/BOD_7 data are available, with some gaps in reporting in countries like Sweden and Finland in 2019. Chemical oxygen demand values are consistently reported with no major gaps. Total suspended solids are also available, although there are minor gaps in reporting for some countries in both years. Total nitrogen availability varies, with gaps noted in reporting for some countries, especially in 2021. Similar to TN, total phosphorus data availability varies, with gaps in reporting observed. As can be seen in the table, quarterly data are available for only a few treatment plants.

Table 8 shows monthly data for the given parameters. As can be seen, many of them are missing and not monitored.

Analyzing the above tables, the status of the collected data based on the data type and year was as follows:

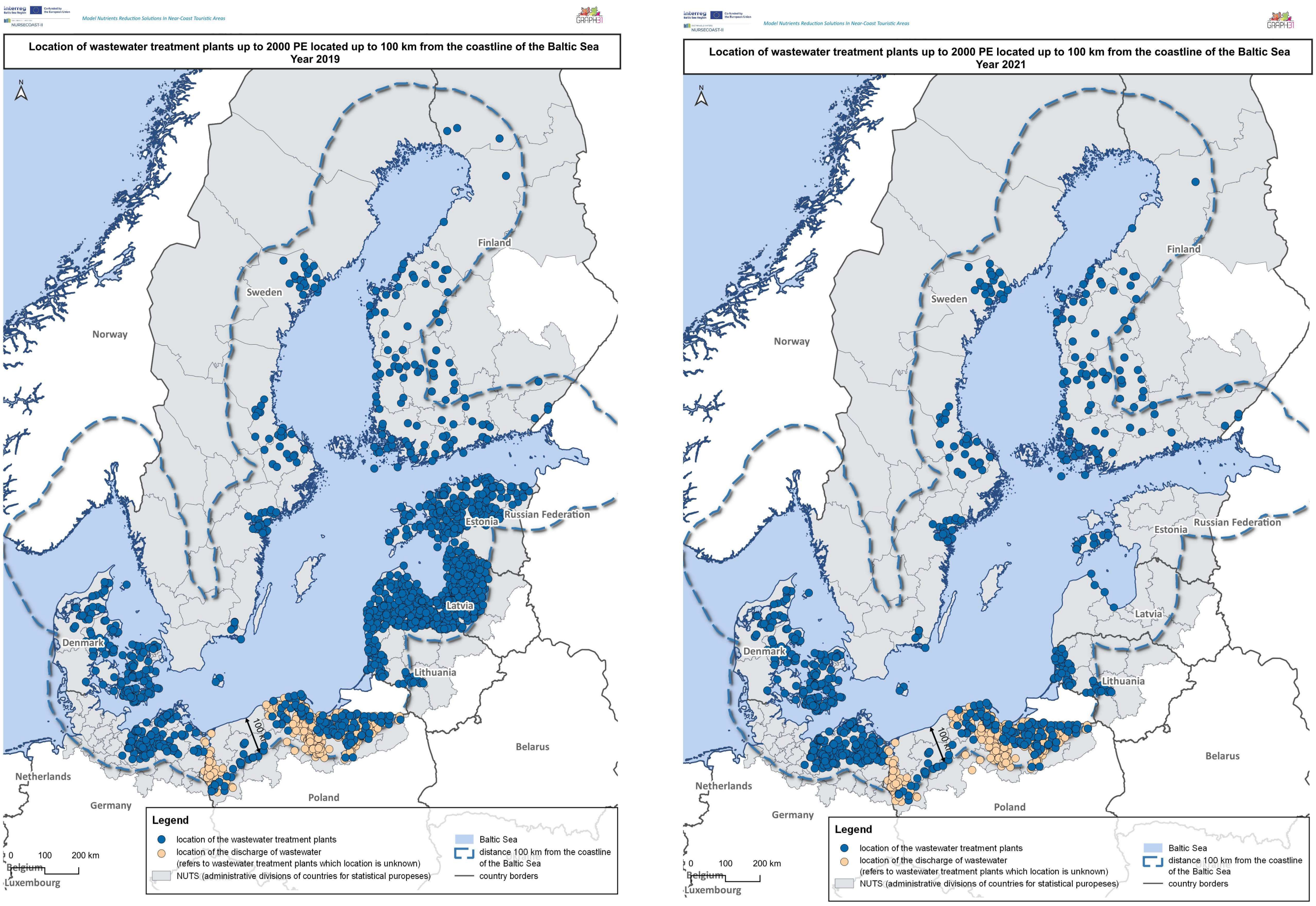
- 45.18%—annual data for 2019;
- 39.00%—annual data for 2021;
- 6.80%—quarterly data for 2019;
- 2.76%—quarterly data for 2021;
- 6.05%—monthly data for 2019;
- 6.46%—monthly data for 2021,

whereas, by country:

- 38.11%—data from Denmark;
- 46.14%—data from Estonia;
- 26.36%—data from Finland;
- 15.56%—data from Germany;
- 23.47%—data from Latvia;
- 34.77%—data from Lithuania;
- 14.51%—data from Poland;
- 45.40%—data from Sweden.

3.3. WWTPs That Meet the Project Criteria

There are 1694 WWTPs in 2019 and 1052 WWTPs in 2021 that meet the project criteria and are presented in the final database. However, some of them were not shown in the map analyses due to the lack of data on the location of the objects. The maps below show locations of WWTPs in 2019 and 2021 (Figure 6). The change in location between 2021 and 2019 is most visible in Latvia, but differences are also visible in Germany and Finland. The situation is mainly dictated by the lack of data.



(**a**) (**b**)

Figure 6. Locations of WWTPs in: (**a**) 2019 and (**b**) 2021.

3.4. Map Analyses

For each of the partner countries, a set of maps illustrating the analyzed parameters was prepared. The collected data for 2019 and 2021 are presented on separate maps. Due to the large number of maps to present, only some of them are presented—for selected parameters, developed for Poland. Other not presented parameters—BOD_5, COD, total nitrogen, and total phosphorus—were compared with data on technology. The remaining maps for Poland are included in the Supplementary Materials.

In-depth analysis of maps is not an easy task. Observations and changes on maps between 2019 and 2021 are mainly related to the lack of data, so in this context, it is difficult to have a discussion. Changes may also be dictated by a change to more efficient technology, but the authors cannot verify this either. Another reason may be a change in the size of the treatment plant above 2000 PE.

Figures 7 and 8 present the locations of WWTPs in Poland meeting the project criteria in the examined years. The disproportion in the number of WWTPs between the western and eastern parts of Poland results from the lack of data in the western part. There are no significant differences in the number of WWTPs between 2019 and 2021. Due to the lack of coordinates of some WWTPs, Poland is the only country in which the locations of some WWTPs are presented based on the location of wastewater discharge. Information on the PE value for a given sewage treatment plant was compared with information on the type of receiver.

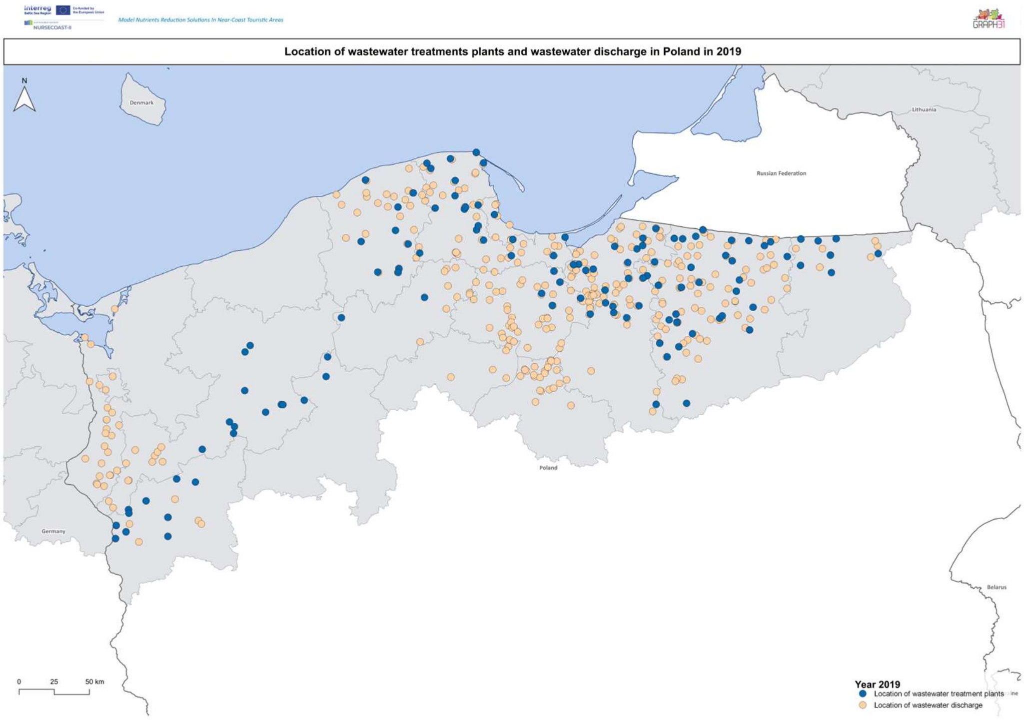


Figure 7. Locations of the WWTPs and wastewater discharge in Poland in 2019.

The maps below (Figures 9 and 10) show the PE of the WWTPs and the type of receiver. There are no significant changes in the PE of WWTPs between 2019 and 2021. Most treatment plants discharge treated wastewater into rivers or in other ways (e.g., into ditches or directly into the ground). There are no dependencies between the PE and the type of receiver.

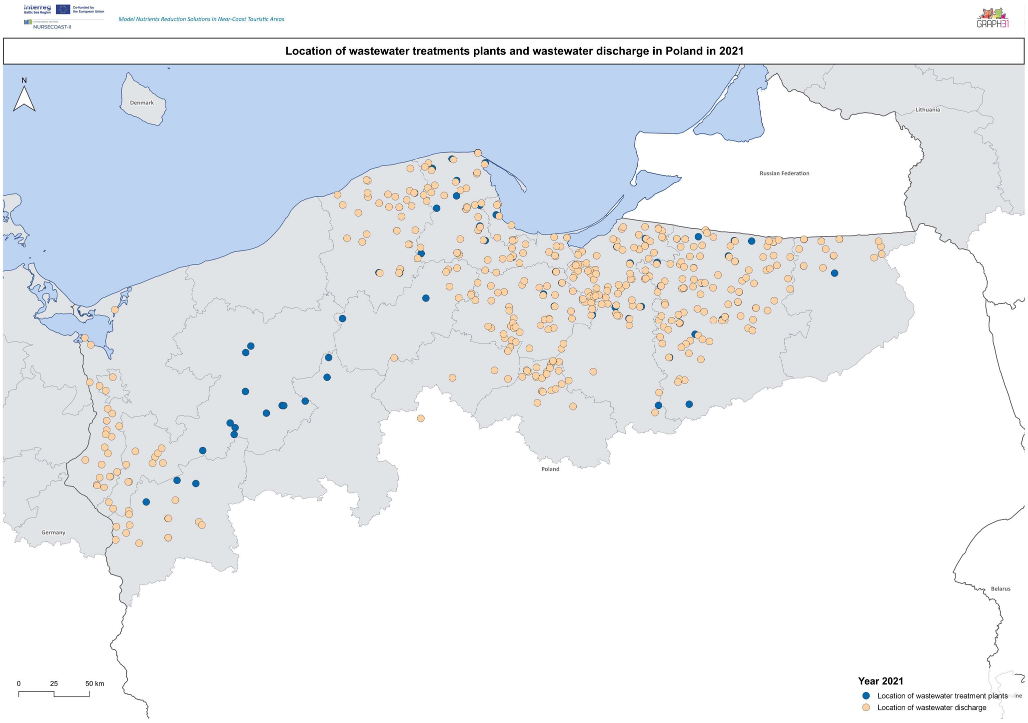


Figure 8. Locations of the WWTPs and wastewater discharge in Poland in 2021.

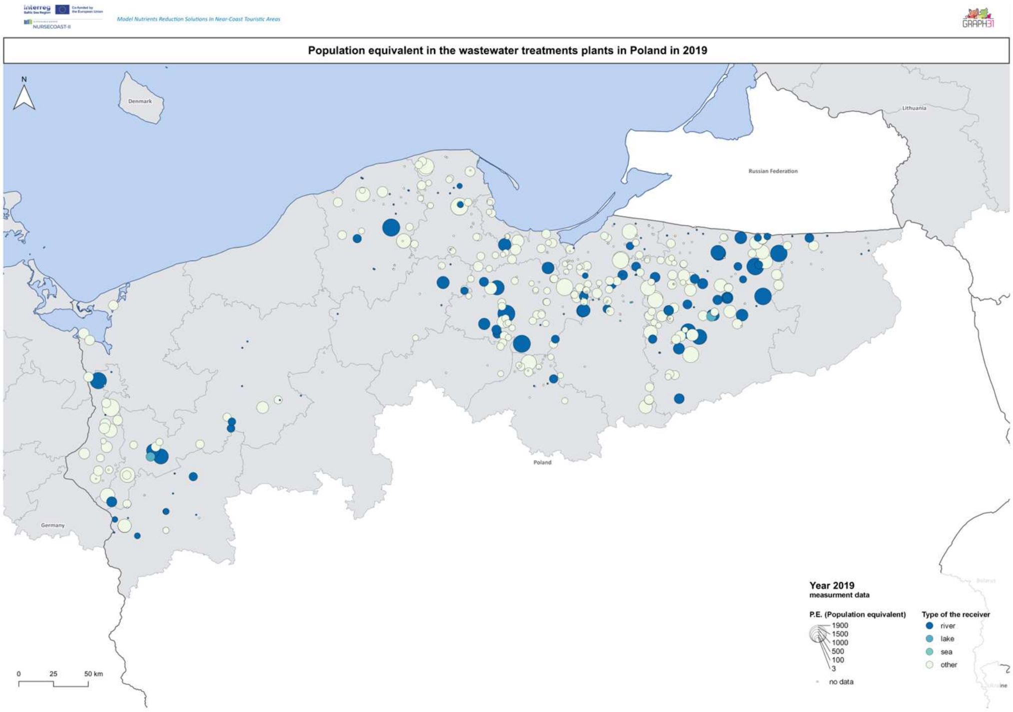


Figure 9. Population equivalent in the WWTPs in Poland in 2019.

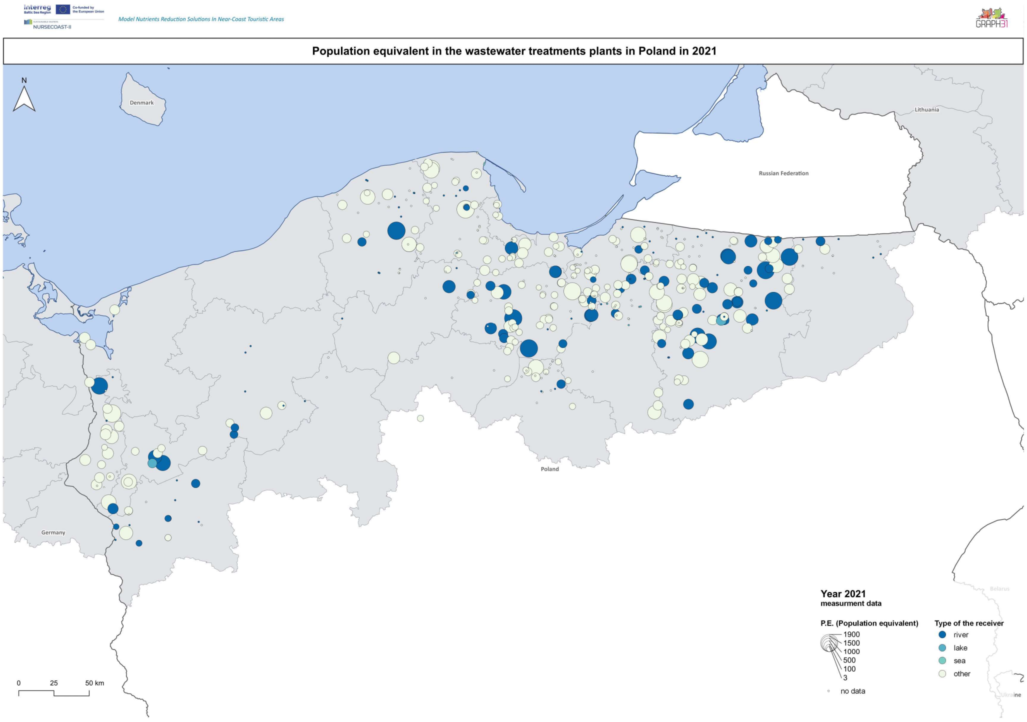


Figure 10. Population equivalent in the WWTPs in Poland in 2021.

The presented maps (Figures 11 and 12) show the amount of treated wastewater in the WWTPs in Poland in the analyzed years. There is a notable difference between the maximum average amount of treated wastewater in 2019 and 2021. For 2019, the maximum amount is approximately 90 m^3 per day, while for 2021, the maximum amount is 13,000 m^3 per day.

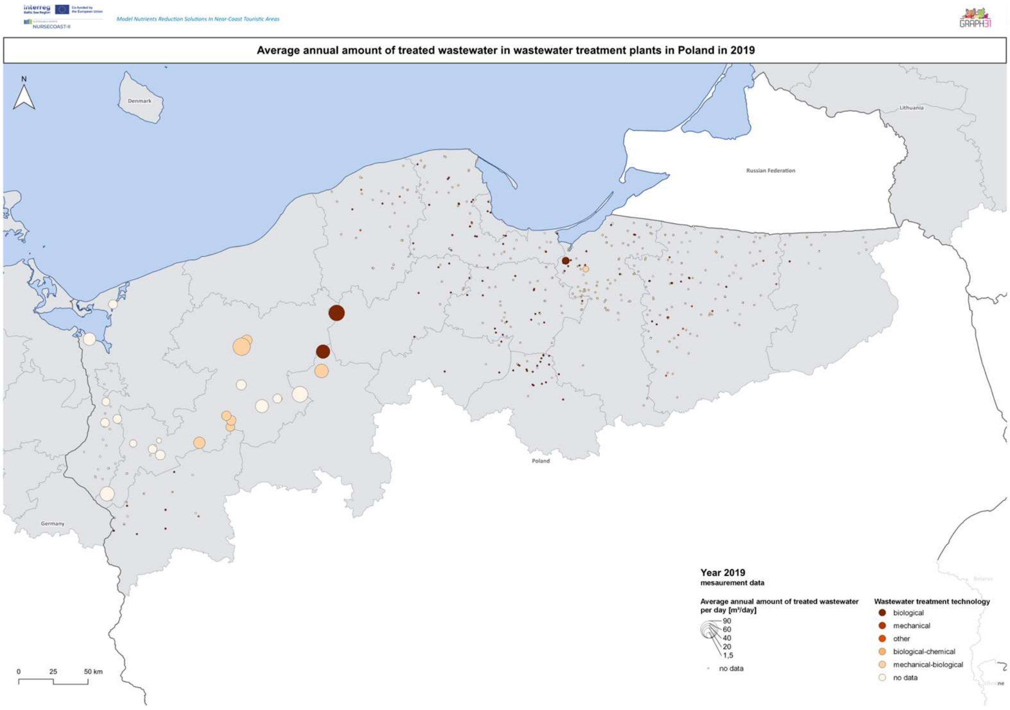


Figure 11. Average annual amount of treated wastewater in WWTPs in Poland in 2019 (measurement data).

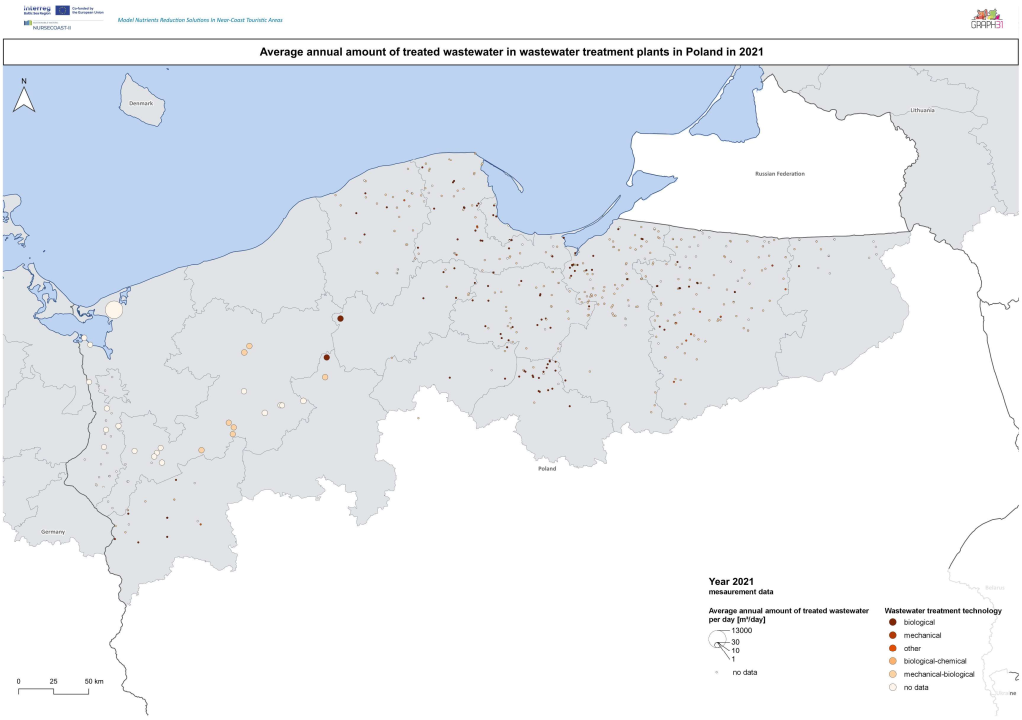


Figure 12. Average annual amount of treated wastewater in WWTPs in Poland in 2021 (measurement data).

The annual amount of BOD_5 (Figure S1) in the treated wastewater of WWTPs in Poland shows significant differences in the marginal parameter values between 2019 and 2021. In 2019, the values range from 3 to 1000 mgO_2/L. In 2021, the values range from 4 to 19 mgO_2/L. Similarly, there is a significant difference in the range of COD (Figure S2) values in 2019 and 2021 (in 2019: 30–4800 mgO_2/L, in 2021: 60–75 mgO_2/L). There is also a notable difference in the range of values between 2019 and 2021. The maximum value in 2019 is nearly 80 times greater than the maximum value in 2021. The noticeable difference between the years compared may be caused not only by the pandemic period but also by technological improvement.

In the case of data on nutrients responsible for eutrophication—nitrogen and phosphorus, there is no data available for most of the WWTPs that met the project criteria. Maps for 2019 and 2021 are provided in the Supplementary Materials (Figure S3 and Figure S4, respectively).

Reducing the P load in the Baltic Sea to meet HELCOM requirements is currently more difficult than before. Diffuse sources are the largest sources of P pollution, including agricultural activities and livestock production, and are difficult to limit and track. On the other hand, point sources of P such as municipal and industrial wastewater are easier to redirect because they are concentrated and usually monitored. From a regulatory perspective, the difficulties arise from the complex regulatory settings, characterized by interconnected, overlapping levels of regulation and flexible legal approaches [37–40].

From a circular economic perspective, it is recommended to maintain phosphorus in the value chain (as wastewater and its fractions, such as sewage sludge and sewage sludge incineration ash and other waste streams) as long as possible, and to further recover and reuse valuable resources, including phosphorus. Such actions can contribute both to the prevention of eutrophication and to the security of raw material supply [8].

The wastewater management sector provided the most comprehensive data on both achieved and remaining reductions in pollutant discharge. The analysis revealed that despite significant advancements, there remains a potential for further reductions in municipal wastewater treatment plants, estimated at approximately 10% of the 2007 HELCOM Baltic Sea Action Plan (BSAP) targets for both nitrogen and phosphorus [17].

Policy and governance are central to transforming the agriculture and wastewater sectors towards increased circularity. The EU Circular Economy Package was adopted in 2018, but most EU policies and regulations are rooted in the age-old linear, resource-to-waste paradigm [41]. Unfortunately, due to the lack of legal and economic drivers, nutrient recovery is still not a common solution, while phosphorus recovery, as well as energy efficiency, are among the main current challenges in the design and operation of wastewater treatment plants (WWTPs) [42]. In order to be able to select the most appropriate strategy to improve this situation, multidimensional and transdisciplinary knowledge is needed. This means that it is necessary to integrate expertise from different disciplines and stakeholders to create an understanding of the entire phosphorus supply chain, taking into account both scientific and technical aspects as well as social and economic implications [43,44]. Additional reduction of nutrients can be realized by upgrading the technology of large municipal wastewater treatment plants across the region to meet HELCOM's nutrient removal standards and by expanding the connection of populations in dispersed dwellings to centralized sewerage systems [17].

The quantity and quality of data collected for the project clearly indicates the lack of resources of environmental protection authorities in examining the impact of small WWTPs on the natural environment of the Baltic Sea. Due to the lack of data, it is not possible to estimate the real impact of small WWTPs on the environment. It is even more challenging to study seasonal changes in the efficiency of WWTPs, because of the lack of monthly or quarterly data.

The Council Directive of 21 May 1991 [28] concerning urban wastewater treatment (91/271/EWG) regulates the rules regarding the treatment of wastewater and monitoring of WWTPS above 2000 PE. The introduction of the Directive was a step in the right direction, but it requires stricter regulations. It should be noted that in October of 2022, the European Commission proposed a Directive concerning urban wastewater treatment (recast) to lower the limit of 2000 PE for wastewater agglomerations to 1000 PE. Thus, WWTPs between 2000 and 1000 PE, which have not yet been covered by the regulations of the Directive, would be subject to monitoring and control. The most beneficial solution from an environmental perspective would be to include all WWTPs. However, taking into account the costs of implementing those regulations, this approach that spreads costs over time should be considered reasonable. The proposal has not yet been adopted.

Preisner et al. [32] reviewed various approaches to wastewater discharge standards. They established quality requirements for discharged wastewater in different countries and grouped them into four main categories:

- Permissible concentrations or reduction efficiency—this approach focuses on setting limits for pollutant concentrations (like BOD, COD, TSS, TN, TP) or establishing reduction efficiency rates at different administrative levels. These must be met during wastewater treatment.
- Uniform quality standards—this method establishes national standards that uniformly apply to treated wastewater throughout the country, ensuring consistency in quality.
- Environmental standards—in this approach, the focus is on maintaining the water quality of the receiving body (rivers, lakes, etc.) to prevent deterioration due to the discharge of treated wastewater.
- Technological standards—this method provides recommendations on the use of specific treatment technologies or processes without necessarily defining limits for pollutants in the treated water.

These approaches show the varying emphasis on pollutant limits, environmental protection, and technological prescriptions depending on national policies.

Preisner et al. [32] also noticed that the climate differences, seasonality factors, type of recipient, and the bioavailability of nutrients are missing in the EU legislation for the Member States.

4. Conclusions

The rules for carrying out measurements and collecting data should be uniform in all European Union countries. It would also be beneficial to maintain a common database, which would significantly facilitate conducting scientific research. This database should be intended for both specialists and citizens to enable easy access to public information.

To conclude, the authors found four main key points of the above inventory:

1. There is neither no treatment data available for WWTPs < 2000 PE in all the project's countries nor data about the number of small WWTPs.
2. Legislation varies in the different project countries because EU legislation does not cover WWTPs < 2000 PE. Treatment requirements vary country by country regarding WWTPs < 2000 PE.
3. There is no sufficient information about the environmental load of the small WWTPs—small WWTS may contribute significantly to the nutrient load of the Baltic Sea, especially locally.
4. The spatial, analytical, and legal analysis of WWTPs across BSR countries uncovered many discrepancies in data accessibility and collection, spatial distribution of the WWTPs, effluent standards, and technological solutions. This could be a good starting point for the local authorities to improve these aspects for the safer management of excess nutrients in the near-coast touristic regions.

There is a pressing need to further harmonize load calculation methods for both riverine inputs and particularly for discharges from wastewater treatment plants and industrial sources. Currently, data from these sources—especially from smaller-scale operations—are not fully comparable or consistent across different regions, and some countries do not include all point source discharges. Thus, harmonizing data collection and load calculation methods for small-scale wastewater treatment plants is crucial to ensure comprehensive and reliable reporting [17,45].

The following recommendations could be given to the local authorities:

1. Local authorities should better monitor the inflow of newly occurring construction permits or residential investments without such a permit in order to quantify the potential excess of wastewater in the touristic regions.
2. Local authorities should also develop individual monitoring plans for WWTPs <2000 PE where tourist flows are not taken into account when planning the wastewater infrastructure, which was often done 30–50 years ago when the tourist sector was not well developed, and people could not afford long holidays.
3. Local authorities should stay in touch with wastewater specialists who could redesign or add plug-in technology to the existing WWTP in order to meet the challenges resulting from seasonal flow and load fluctuations of the wastewater in the summer season.

In the future, a special focus should be placed on seeking already known technologies and adapting them to the changing flow and load. This could be done by both plug-in devices increasing, e.g., the aeration rate (micro- and/or nano-aeration) without the necessity to reconstruct or enlarge the already existing plant. Such a solution could possibly increase the wastewater capacity in an artificial way. Another technology could be a constructed wetland as reeds have a potentially high tolerance to the flow and load changes, reduce the wastewater parameters effectively, and could even allow for further irrigation of certain cultivations. The systems could be single, dual, or hybrid, meaning vertical and/or horizontal systems, parallel systems with interconnecting valves that could direct the wastewater to each or both plant filters placed inside each of the constructed wetlands, depending on the flow variability. Such solutions are also currently being tested within the NURSECOAST-II project in five pilot plants in Poland (1), Denmark (2) and Latvia (2).

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su16229890/s1, Figure S1: Amount of BOD5 (normative data) in the treated wastewater of wastewater treatment plants in (a) 2019 and (b) 2021; Figure S2: Amount of COD (normative data) in the treated wastewater of wastewater treatment plants in (a) 2019 and (b) 2021; Figure S3: Amount of total nitrogen (normative data) in WWTPs in Poland in (a) 2019 and (b) 2021; Figure S4: Amount of total phosphorus in (normative data) WWTPs in Poland in (a) 2019 and (b) 2021.

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