Overview of Water Resources, Quality, and Management in Baltic Sea Countries

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Abstract Recently, the region around the Baltic Sea has experienced stringent inter-governmental agreements and actions to regulate water resources among the Baltic countries. The region has also been influenced by various industrial, agricultural, and human activities, as well as several anthropogenic and natural inputs. In this context, multiple researchers have focused their work on understanding the water status and management among the Baltic Sea countries. The aim of this chapter is to represent a summary of the recent number of documents, states, and funding sponsors that contributed to the publications of "Water status in Baltic Sea countries". This survey is retrieved from the Scopus and Web of Science databases from 2001 to 2019. Further, the chapter gives an overview of the water status and standards of some Baltic Sea countries that control the environmental features within the region. The essential suggestions and findings are summarized in the recommendations and conclusions sections.

Keywords Baltic sea · Environmental condition · Literature survey · Water action plan · Water resources

1 Introduction

The Baltic Sea region consists of several EU and non-EU member states, viz., also known as developed and developing countries, such as Denmark, Poland, Germany, Finland, Sweden, and Russia [1]. Surface water and groundwater resources differ widely among these countries due to the existence of various rivers, lakes, streams,

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dams, drains, reservoirs, and aquifers [2]. These water resources control the water quality condition and the ecological and aquatic processes of the Baltic Sea [3]. Various anthropogenic and natural factors, in turn, affect the environmental conditions of related countries, which strongly connect to the water quality of the sea [4]. Moreover, in the past 10 years, several wastewater treatment plants, sewerage collection systems, and infrastructure projects have been constructed to handle a large amount of wastewater in the Baltic Sea region [5].

Due to the importance of the Baltic Sea resources, a number of studies have recently been conducted to cover the water status of the Baltic countries [6]. In addition, more studies have been performed to evaluate the ecosystem and water management within the Baltic region [7]. Although some Baltic countries have considerably succeeded in achieving the water-quality standards, various challenges still remain [8]. For this purpose, water and regulatory authorities attempt to raise consumer concerns and public awareness of water scarcity [9].

In this context, the current chapter gives an overview of the water status and features for the Baltic Sea countries. This objective is attained based on a systematic literature review method and an analysis of relevant documents and reports about the Baltic Sea Basin. Most information is collected from peer-reviewed journals available in the Web of Science, Scopus, and Google Scholar databases. Some recommendations that could be used to improve the Baltic Sea quality are considered. Lastly, a summary of the essential conclusions and perspectives for further researches is demonstrated.

2 Information from Scopus Database

Figure 1 shows the number of documents retrieved from the Scopus database using the research keywords "Water", "Baltic", and "Countries" (https://www.scopus.com/search/form.uri?display=basic). The total number of published documents was 140 during 2001–2010, which increased to 186 documents from 2011 to 2019 (Fig. 1a). The documents were managed by several publishers such as Elsevier, Taylor and Francis, Springer, and Wiley. During 2011–2019, the top countries that participated in the "Baltic Sea region" publications were Sweden, Finland, Poland, Estonia, Denmark, Latvia, Germany, and Lithuania with 47, 37, 32, 29, 28, 27, 25, and 25 documents, respectively (Fig. 1b). Hence, Sweden holds the highest national collaboration statistics. About 69.4% of the documents were an article type, followed by 14.5, 7.5, and 5.9% for conference papers, book chapters, and review manuscripts, respectively (Fig. 1c). The documents were funded by the European Commission, Academy of Finland, California Environmental Protection Agency, Norges Forskningsråd, and other sponsors (Fig. 1d). The peer-reviewed and highly reputable international journals include Agriculture, Ecosystems and Environment, Marine Pollution Bulletin, Ambio, International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management (SGEM), and Environmental Science and Pollution Research. These journals focus on the following areas (a) biological

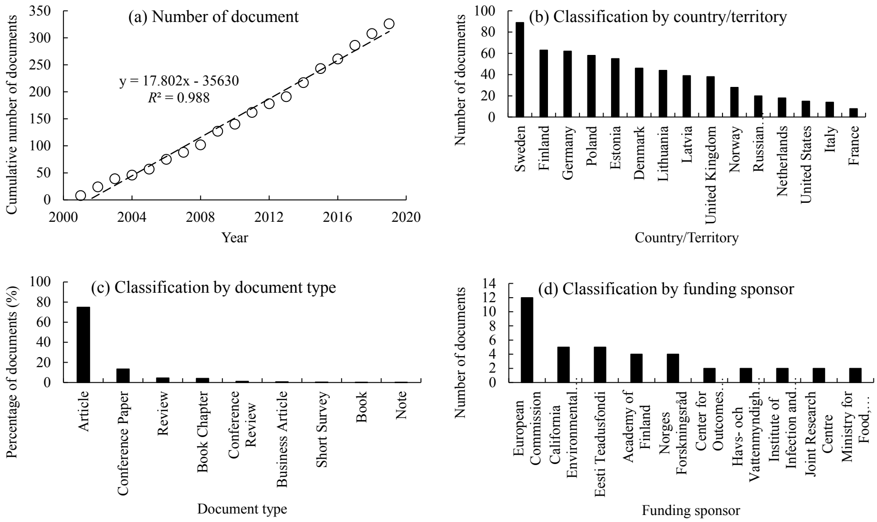

Fig. 1 Statistics of documents retrieved from Scopus database using research keywords "Water", "Baltic", and "Countries" during 2001–2019: **a** Cumulative number of documents, **b** Classification by country/territory, **c** Document type, and **d** Funding agency

and physical characteristics of agroecosystems, (b) global environmental changes including air pollution, climate change, and agricultural systems, (c) land, air, and water relationships, (d) aquatic biology and ecology, (e) environmental analyses and monitoring, and (f) environmental microbiology.

3 Information from Web of Science Database

The total number of documents obtained from the Web of Science (WOS) database using the research keywords "Water", "Baltic", and "Countries" is displayed in Fig. 2 (https://www.scopus.com/search/form.uri?display=basic). The cumulative number of published documents was 83 during 2001–2010, which considerably elevated to 243 documents from 2011 to 2019 (Fig. 2a). The publications were managed by various publishers such as Elsevier, Taylor and Francis, Springer, and Wiley. During 2011–2019, the main countries that contributed to the "Baltic Sea region" publications were Sweden, Finland, Germany, Poland, Estonia, Denmark, Lithuania, and Latvia with 75, 53, 44, 38, 36, 34, 32, and 28 documents, respectively (Fig. 2b). Similar to the Scopus database, Sweden retains the top national collaboration country. Almost 81.5% of the documents were an article type, whereas proceeding paper, review, and news item reported 9.1, 9.1, and 0.3% of the total documents, respectively (Fig. 2c). The major funding agency was European Union (EU) followed by Swedish Environmental Protection Agency, Academy of Finland, Ministry of Education and

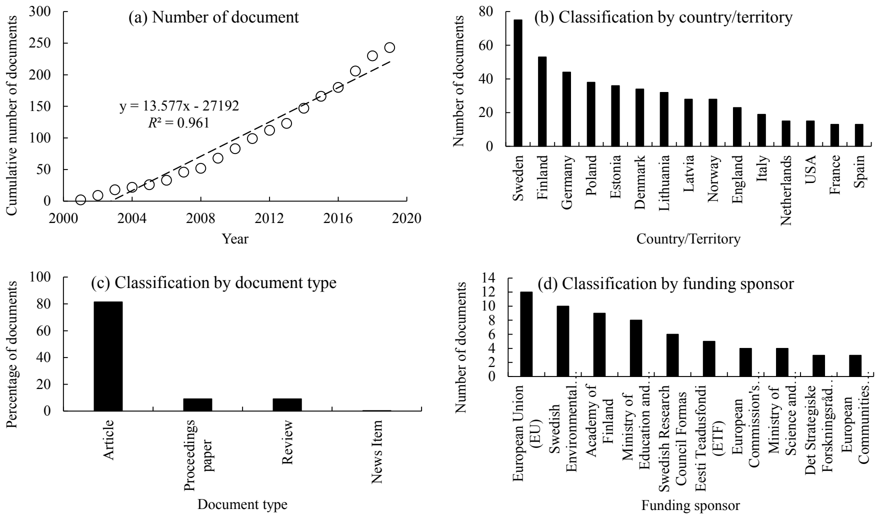

Fig. 2 Statistics of documents retrieved from Web of Science (WOS) database using research keywords “Water”, “Baltic”, and “Countries” during 2001–2019: **a** Cumulative number of documents, **b** Classification by country/territory, **c** Document type, and **d** Funding agency

Research Estonian, Swedish Research Council Formas, Eesti Teadusfondi (ETF), European Commission’s Joint Research Centre, Ministry of Science and Higher Education Poland, Det Strategiske Forskningsråd (DSF), and European Communities (EC) (Fig. 2d). The peer-reviewed and highly ranked international journals that handled these publications include Marine Pollution Bulletin, Agriculture Ecosystems Environment, Ambio, Hydrobiologia, Ecological Economics, and Water Science and Technology. These journals focus on the following subjects (a) biological study in limnology and oceanography, (b) atmospheric sciences, (c) environmental engineering and biotechnology, (d) valuation of natural resources, (e) economic-ecologic interaction and harmony, and (f) policy, strategy, and management considerations of water quality.

4 Baltic Sea Overview

The Baltic Sea is recognized as a large brackish water body and a semi-enclosed sea located between central and northern Europe [10]. It is relatively shallow with an average depth of about 54 m, in which the sea depth significantly varies due to the presence of sills that control the sediment transportation and deposition situations [11]. The Baltic Sea is also known as a separate marine region characterised by a unique and large ecological system. It is linked to the North Atlantic and the North Sea via the Danish straits [3]. Recently, intensive anthropogenic and natural influences have seriously threatened the ecological situation of the sea. The destructive anthropogenic causes include solid waste, agricultural activities, petroleum products, and industrial and municipal wastewater. The main natural inputs are inadequate water exchange, biological processes in the aquatic environment, atmospheric processes, and large river discharges, introducing multiple pollutants into the sea [12]. The main environmental issues in the Baltic Sea comprise overfishing, deterioration of biological diversity and habitats, and eutrophication [13]. Furthermore, some coastal ecosystem services have been damaged because of dissolved oxygen depletion, fish kills, and the spread of toxic algal blooms.

5 Baltic Sea Region Overview

As reported by Manzhynski et al. [14], the Baltic region contains several countries that can be classified into (a) new EU countries such as Lithuania, Estonia, and Poland, (b) highly developed countries including Sweden, Germany, and Denmark, and (c) countries having large social and economic impacts on the region (e.g., Belarus and Russia). Russia, Lithuania, Estonia, and Latvia can also be defined as developing countries located in the Baltic Sea region, as reported in another work by Chang et al. [15]. These countries share different topographic, historical, social, political, and economic positions. The water quality and management of nine states in the Baltic Sea Region have been explored by Nainggolan et al. [5] and Vigouroux et al. [16].

The drainage basin of the Baltic Sea region covers about 1,720,270 km^2, which can be separated into two regions [17], viz., northern boreal and southern areas that drain into the Gulf of Bothnia and the rest of the Baltic Sea, respectively. The area of the drainage basin is considered four-folds the sea area, holding about 110 million people [18]. The catchment area of the Baltic Sea has unique topographic and biological characteristics, and it is surrounded by essential ecological boundaries. It contains around 200 rivers, which in turn increase the nutrient (phosphorus and nitrogen) loads and eutrophication issues due to surface runoff [19]. Moreover, the catchment area retains dense human activities and land-based practices, resulting in the release of huge quantities of domestic wastes into the sea [6]. Moreover, most of the Baltic countries are highly industrialized, and they are associated with major sources of water pollution in Northern and Eastern Europe. The sources of contamination include industrial facilities, sewage treatment plants, toxic air emissions, and marine aquaculture farms. As a result, the water quality of large parts of the central and coastal Baltic Sea area has been severely deteriorated over the last century [8].

6 Baltic Sea Regulations Overview

A series of international collaborations and European agreements have been agreed by the governmental authorities to secure the long-term protection of environmental quality. The national actions have also been adopted to obtain healthy ecosystems around the Baltic Sea region and to meet major challenges influencing the marine eutrophication [5]. For instance, the coastal countries of the Baltic Sea and the European Community declared the Helsinki Commission (HELCOM) Baltic Sea Action Plan (BSAP) in November 2007 to protect the marine environment of the Baltic Sea ecosystem [10]. The BSAP has been adopted and implemented to target the reduction of the nutrient loads from land into the Baltic Sea at various spatial and temporal scales [4]. The amounts of nitrogen, phosphorus, heavy metals, and chemicals should comply with international ecological standards. Moreover, the industrial wastewater discharged into the Baltic Sea should be significantly reduced or prevented [12]. However, due to the significant differences in the catchment features, socioeconomics, environmental legislation, land use/land change, and geosciences along the Baltic Sea region, the regulation and management of environmental issues are still challenging [12].

7 Water Status of Some Baltic Countries

Understanding the water status of the Baltic Sea region is an essential step as the relevant countries are strongly associated with sea quality.

7.1 Sweden

Sweden contains important streams, lakes, rivers, and waterfalls, which are valuable for most human activities. In Sweden, daily water consumption was about 183 litre per person in the years 2015 and 2016 [20]; however, the consumption of bottled water is minimal. Näsman et al. [21] mentioned that the drinking of bottled water was 10.8 L/person/year in 1993 and increased to 24.4 L/person/year in 2014. The Swedish Brewery's Association's [22] lists the status and statistics of drinking water in Sweden during the past 10 years. Sweden protects the quality of the Baltic Sea by avoiding the release of high nutrient loads and organic compounds into the sea [23]. This objective is achieved by developing nitrogen and phosphorus removal technologies into the wastewater treatment plants. The Baltic Sea action plans implemented to improve the water status in Sweden and to meet the international requirements and standards are given by the Swedish Environmental Protection Agency (http://www.swedishepa.se/).

7.2 Germany

In Berlin (Germany's capital), the total annual rainfall amounts to 570 mm [24]. Germany contains about ten main river basins, including Schlei-Trave, Rhine, Elbe, Weser, Danube, and Maas [25]. In Germany, there are approximately 9900 surface water bodies, which comprise 9070 rivers, 710 lakes, and 74 coastal waters [26]. The ecological status of 10, 30, 34, and 23% of these water bodies can be defined as 'High', 'Moderate', 'Poor', and 'Bad' quality, respectively; however, <3% are classified as 'Uncertain'. Germany also contains about 1000 groundwater bodies, which are considered important sources of drinking water. About 62% of groundwater bodies have attained 'High' status, regarding the quantitative (e.g., stability of groundwater levels) and chemical (e.g., pollutants) conditions [26]. The 'Low' to 'Moderate' water quality at some locations could be linked to the noticeable reduction in groundwater level and nitrate inputs from agriculture [26]. The presence of unfavourable and toxic constituents in the drinking water of Germany is summarized in a study by Umweltbundesamt [27]. The available water supply and water use in 2010 were approximately 188 billion m^3, representing 82.4, 11.0, 3.6, 2.7, and 0.3% for unused, thermal power plants, mining and manufacturing industries, public water supply, and remaining industrial and agricultural practices (https://www.umweltbundesamt.de/publikationen/). Around 33.1 billion m^3 of water were supplied from groundwater and surface waters to private house-holds in 2010. Germany also contains nearly 10,000 wastewater treatment plants, treating a total of 10 billion m^3 of wastewater [25]. Additional details of the wastewater treatment facilities and water services in Germany can be found in previous studies [9, 28].

7.3 Denmark

Copenhagen (Denmark's capital) has an annual rainfall of 525 mm [24], and the average water consumption in Denmark was about 158 L/person/day in 2015 and 2016 [29]. HOFOR, which provides water supply and sanitation services to about 90% of Copenhagen's population, is the main utility company in Denmark. Denmark has relied on over 30 years of aquatic action plans to solve the challenges of water quality, policies, and management. The strategies aim at reducing the pollutant levels, mainly nutrients, in water bodies [30]. Denmark does not have large rivers, and hence, a high portion of Danish drinking water comes from groundwater [31]. However, the quality of groundwater is influenced by chemical and toxic contaminants from the agriculture sector. Moreover, Danish people attempt to utilize most of the rainwater via the application of domestic roofs, rainwater harvesting systems, permeable urban infrastructure, and collection and storage tanks. The collected rainwater can be used after partial treatment for flushing, laundry, washing, and irrigation. For this purpose, the Danish government has reasonably increased the environmental awareness of the society and the public to maintain and push forward the "Green Space Branding" strategic plan [32].

7.4 Estonia

Tallinn is Estonia's capital, having an annual rainfall of 690 mm [24]. Tallinna Vesi (Tallinn Water) is the main water utility company in Estonia, offering water, wastewater, and sanitation services to about 90% of Tallinn's customers. Surface water, particularly the two Estonian lakes (Ülemiste and Raku), contributes to the most drinking water requirements [31]. However, the people of Estonia consumes a low amount of water, i.e., approximately 100 L/capita/day [33].

7.5 Poland

Poland is considered one of the Baltic Sea countries, having relatively poor water resources with low quantity and quality [34]. Almost 99.7% of the whole Polish territory is situated in the Baltic Sea drainage basin [35]. About 54 and 34% of the region of Poland belong to the drainage basins of the Vistula River and Oder River, respectively. A small area is covered by catchments of short rivers that discharge directly into the Baltic Sea. The freshwater resources in Poland are stored in lakes (almost 10,000 lakes in northern Poland) and reservoirs (in the southern part) [36]. The average annual freshwater resources in Poland was estimated as 59.9 km^3 (2000–2015). The entire amount of consumable groundwater resources coming from quaternary aquifers was 17.7 km^3/day in 2015. The available quantity of water per capita is 1600 m^3 per year; compared to 5000 m^3/capita/ year for most European countries [7]. The annual precipitation in Poland varies between 500 mm towards the central and northern regions (the lowlands) and 1200 mm at the southern mountainous regions, with an average value of around 600 mm. River water increases (excess water) in the spring, while it reduces (water deficits) during the autumn and winter seasons. The quality of surface water in Poland is negatively impacted by various anthropogenic factors, which have been reported by Szalinska [37].

7.6 Iceland

Recently, Iceland has developed national guidelines considering the principles of the World Health Organization (WHO) and the International Water Association (IWA) to maintain the concept of "Water safety plan" [38]. The Icelandic drinking water regulations include improvement of utility performance, protection of all water resources, regulation on public health, and supply of safe and acceptable drinking water [39]. Ministry of Industries and Innovation, Ministry for the Environment and Natural Resources, Ministry of Welfare, and Ministry of the Interior handle these objectives. Iceland comprises several freshwater resources in terms of rivers, lakes, ponds, and springs [2]. Drinking water is mostly obtained from aquifers in porous basaltic rocks [40], and about 95% of drinking water comes from groundwater [41]. Fresh groundwater withdrawals are treated by filtration followed by UV disinfection. The Icelandic water resource systems provide about 600 thousand m^3 of freshwater per person per year. Iceland includes almost a number of 31 water utilities that serve 81% of the residents [42].

7.7 Russia

Given the size of the Russian landmass, the water quality in Russia varies spatially due to different domestic and international consequences [43]. In Russia, the water supply system is strongly associated with various domestic (households), energy, irrigation, and industrial applications [44]. The main rivers in European Russia include Mezen, Onega, Lower Volga, Northern Dvina, and Don [45]. However, the freezing of rivers may damage hydraulic structures, roads, and bridges, as well as can cause multiple engineering problems [46]. The ice phenomenon in Russian rivers can also inhibit seasonal navigation on the rivers, raise the water levels, and cause flooding. Telichenko et al. [47] suggested green spaces and sustainable landscaping options to manage stormwater problems in Russia. The water status in Russia is also influenced by a number of dams and reservoirs such as Osa River Dam, Irigan Dam in Dagestan, Chirkeiskaya Dam, Cheboksary Dam, Kama Dam, and Bratsk Reservoir [48]. A large part of the Russian people employs household filters or utilizes bottled water to obtain a high quality of drinking water. Due to the installation of metering and modern plumbing systems, the water demand by Russian households has reduced from 300–380 to 180–200 L/person/day.

8 Recommendations

The current chapter gives an overview of the recent publications regarding the water status of the Baltic countries. Based on the literature survey, several recommendations should be considered:

(a) Small, remote, and rural communities should be supported by adequate infrastructure projects, minimum leakage systems, and wastewater collection structures.
(b) Advanced methods of wastewater treatment, with providing adequate training for staff, should be considered to meet the water quality standards regarding organics, nutrients, and anion and cation constituents.
(c) Stakeholders, decision-makers, and public and private ownership should engage under the water authorities of Baltic countries to maintain the "Water-Energy-Food nexus" strategy.

(d) Advanced water metering systems should be broadly implemented to sustain water reforms and tariffs.
(e) Promote the application of water safety projects, as well as maintenance and renewal of infrastructure.
(f) Conduct risk assessment studies and incorporate guidance on materials used for small water supplies and utilities.

9 Conclusions

This chapter aims at giving an essential overview of the water resources and conditions of the Baltic Sea countries. This objective is revealed based on the findings retrieved from the Web of Science and Scopus databases. It is concluded that:

(a) Intensive anthropogenic and natural inputs have seriously threatened the ecological situation of the Baltic Sea countries.
(b) Recently, research studies evaluating the ecosystem and water management within the Baltic region have considerably increased due to the importance of the Baltic Sea resources.
(c) During 2011–2019, the total number of publications reported using the keywords "Water", "Baltic", and "Countries" was 186 and 243 according to the Scopus and Web of Science databases, respectively.
(d) The available surface water and groundwater resources vary broadly among the Baltic countries due to the existence of multiple rivers, lakes, streams, dams, drains, reservoirs, and aquifers.
(e) A series of international activities and European agreements have been established by the governmental authorities to secure the long-term protection of the environmental quality in the Baltic region.
(f) The developed Baltic countries such as Sweden, Germany, and Denmark have adequate water resource management systems; however, some countries such as Lithuania, Estonia, and Poland still have some water resource challenges.

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