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Comparative Analysis of the Water Policies and the Systems for Ecological Status Assessment of the Running Waters in Bulgaria and South Korea: Case study on Maritsa River and Han River

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Abstract. Rivers are the main resource for water supply in Bulgaria and South Korea, thus the ecological status of the running water bodies is important for the ecosystem integrity, as well as for the health and life standard of the population in both countries. This study presents and compares the water management policies, the water legislations and the systems for ecological status assessment of the running waters in both countries. In Bulgaria, the Ministry of Environment and Water provides the water management policy and the national water legislation is fully harmonized with the European requirements. Korean government has strategically been enforced water management plans since the passing of the Environmental Pollution Prevention Act in 1963. The water quality criteria follow the regulations in both countries - European Union Water Framework Directive (2000/60/EC) in Bulgaria and the Environmental Policy Act and the Water Environment Conservation Act in South Korea. The evaluation of the ecological status of the running waters in both countries is based on biological, physico-chemical and hydro-morphological quality elements, and each criterion is specifically defined. Both classification systems for the status evaluation of flowing water bodies by biological quality element are composed of five-level scales, which makes them relatively comparable. Ecological status evaluation based on the macrozoobenthos, according to the classification systems of the Bulgarian and South Korean water legislations was determined for 30 study sites located in the basins of Maritsa River in Bulgaria and Han River in South Korea. The study showed relatively good comparability of the obtained assessments.

Key words: water resource, water management policy, water quality elements, macrozoobenthos.

Introduction

Water related policies have been changed historically depending on the natural and socio-economic conditions and human demands. In recent years, as the anthropogenic pressure and the climate change impacts are increasing worldwide, the ecologically related approaches and environmentally friendly technologies for sustainable water management are highlighted.

Bulgaria joined the European Union (EU) in 2007. Due to the long transitional period from socialism towards democracy and the innovative changes in the economy structure, the implementation of the regulations is comparatively slow and lengthy. The government has updated regulations in line with the EU Water Framework Directive (WFD) (2000/60/EC) and other key documents in the field of the European water legislation. Currently, the strategic aim of Bulgaria in the water management policy is optimal provision of water in the required quantity and good quality for the population and the economy, and enough natural water for the normal functioning of the aquatic ecosystems (Water Act, 1999). Bulgaria is facing environmental issues in the field of water management due to the country's urbanization, infrastructure development and unsustainable agriculture. Especially, during the economic crisis in 2010, water abstraction increased significantly for industry, production and distribution of electricity, heat and gas, and irrigation (Sharkov, 2017). The main significant pollutants of the surface water bodies are the nutrients (40%) and the organic pollution (25%), and in rivers they come mainly from unknown anthropogenic sources (23%), from urban wastewater (22%) and agriculture (19%) (EC, 2019). Moreover, the insufficient number and capacity of wastewater treatment plants delay the purification of the polluted waters. Thus, the main challenges for the water management in Bulgaria have become the appropriate collection and treatment of urban wastewater, and implementation of proper water protection legislations (Water Act, 1999 and its accompanying regulations).

In the period of 1880s and 1960s, South Korea had poor quality of the surface waters because of the lack of water and insufficient sanitation infrastructures, so people suffered from waterborne infectious diseases (Ministry of Environment (ME), 2017). The water infrastructure was reconstructed according to a post-war restoration project funded by international aids and municipal bonds in 1945-1950s (Choi et al., 2017; ME, 2017). After the Korean War (1950-1953), Korea experienced rapid industrialization, urbanization, and economy growth as well as rapid population increase. The massive scales of the developments straightened and covered many urban streams for the extension of land use. Furthermore, untreated industrial wastewater and sewage discharged directly into the rivers especially in rainy seasons. The remarkable population growth and movements particularly to Seoul (from 2.44 million in 1960 to 8.36 million in 1980) increased the contamination even more (KRIHS, 2012; Choi et al., 2017). That resulted in serious urban stream pollution. In 1991, phenol solution from the storage tanks of an electronic factory leaked to the Nakdong River, and the odour was detected in the tap water. That came as a shock to the public and became a huge social issue (KRIHS, 2012; ME, 2017). It raised the awareness of the water quality protection and the drinking water safety in the public. In the twenty-first century, South Korea have faced increased drought and flood risks caused by the climate change, but also issues related to the aging water infrastructure. The importance of the co-relationships between human and nature are also highlighted, as well as the need of sustainable water management systems.

The paper aims at presenting and comparing the water management policies and the water legislation in Bulgaria and South Korea, as well as the systems for the ecological status assessment of the running waters through a study of model rivers in both countries.

Material and methods

Water management policies in Bulgaria and South Korea

The land area (around 100,000 km^2) and the distinct topography of Bulgaria and South Korea are similar regarding the mountains, which pass through the middle of their territories (Balkan, Pirin and Rila Mountains in Bulgaria, and Taebaek and

Sobaek Mountains in South Korea) and the existence of maritime borders.

Bulgaria is located in the central part of the Balkan Peninsula and is divided into four River Basin Districts (RBDs) for basin management: Danube RBD, Black Sea RBD, East Aegean Sea RBD and West Aegean Sea RBD (Fig. 1) (DANGO, 2014; RBMP, 2016-2021; EC, 2019). The Danube RBD is the largest one (42.5% of the country territory) and is subdivided into eleven unites, which are covering the water catchment areas of Iskar, Erma, Nishava, Ogosta, West of Ogosta, Vit, Osam, Yantra, Rusenski Lom, Danubian and Dobrudjan rivers (DRBMP, 2016-2021). The Black Sea RBD is subdivided into several river basins, which are the basins of Shablenska, Batova, Provadiyska, Kamchia, North-Bourgas rivers (Fandakliiska, Panair dere, Dvojnitsa, Vaya, Drashtela, Hadjiyska, Aheloy, Curbandere, Aitoska, Chukarska), Mandrenski rivers (Rusokastrenska, Sredetska, Fakijska, Izvorska), South-Bourgas rivers (Ropotamo, Dyavolska, Karaagach and Lisovo dere), Veleka and Rezovska rivers (BSRBMP, 2016-2021). The East Aegean Sea RBD is subdivided into four river region units: Tundja, Maritsa, Arda and Byala (EARBMP, 2016-2021). The West Aegean Sea RBD is subdivided into three river basins, which are the basins of Mesta, Struma and Dospat rivers (WARBMP, 2016-2021). The river network, hydro-geographical regions and the main catchment areas are described by Hristova (2012). Bulgaria shares three major river basins with neighbouring countries (Serbia and Macedonia to the west, Greece and Turkey to the south, and Romania to the north) and 84.3 % of the renewable freshwater resources are external inflow from the neighbouring territories (EEA, 2018). Thus, their water resources are interdependent and interconnected.

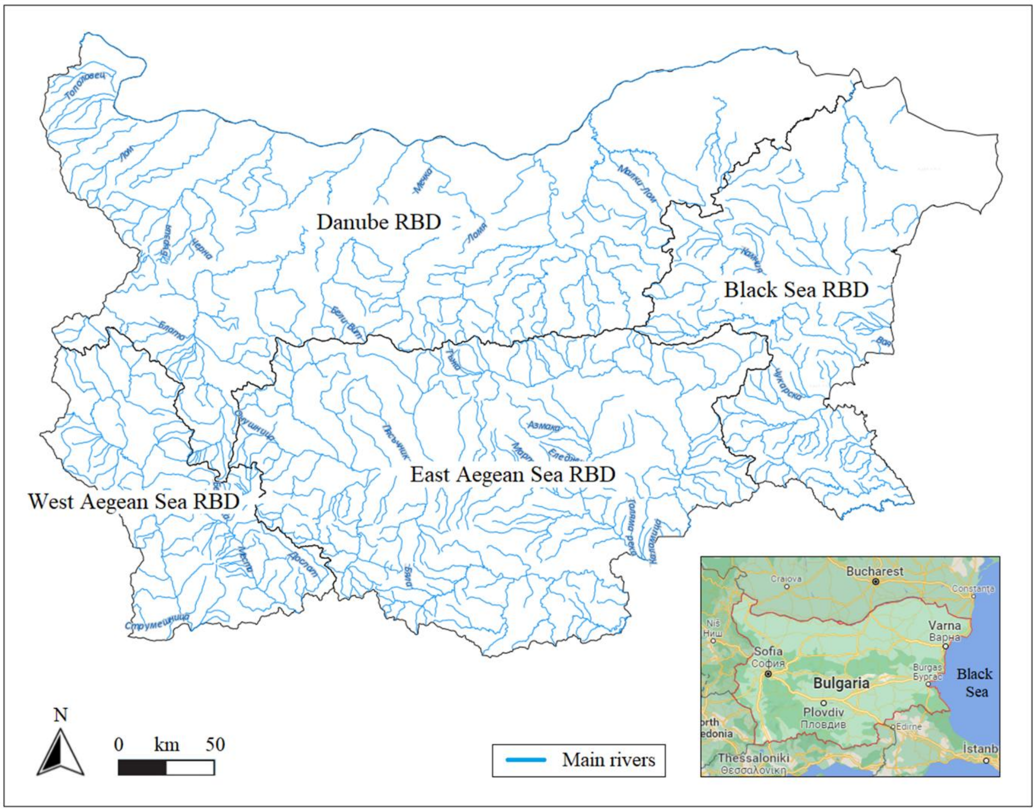

Fig. 1. The four major River Basin Districts (RBDs) in Bulgaria.

In Bulgaria, the Ministry of Environment and Water and the Executive Environmental Agency provide the national water management policy. On a territorial basis, water management is carried out by the four major River Basin Directorates. The first and second River Basin Management Plans (RBMP) have been developed and implemented for the periods of 2010-2015 and 2016-2021. Currently, the third RBMP (2022-2027) is in action. In the recent years, because of climate change and unreasonable human intervention, periods of extremely high tide of water have been observed, causing problems in floodplains and endangering people's lives. In connection with these adverse events, the first Flood risk management plans (FRMP, 2016-2021) had been developed and implemented and the second one is under the preparation. Totally, 16 Regional Inspectorates of Environment and Water monitor the superficial waters and control the wastewaters in their respective territorial scope. The National Institute of Meteorology and Hydrology manages the hydrological and hydro-geological station networks and monitors hydrological and hydro-geological elements.

South Korea is located on the southern part of the Korean Peninsula, which is surrounded by three seas: East Sea, South Sea and Yellow Sea (Fig. 2). About 64% of the territory of the country is covered by mountainous terrains, and most rivers begin from the mountains and flow into the South and Yellow Seas (ME, 2015; Kim et al., 2018). South Korea defines five major River Watershed Regions (RWRs); Han, Geum, Nakdong, Yeongsan and Seomgin, and according to the River Law all rivers in the RWRs are classified in three river types (62 national, 3,773 local and 22,664 small rivers) for efficient management (Fig. 2). The Han RWR is the largest one and the capital city of Seoul is located in it (river length of 514.8 km, basin area of 26,018 km^2; WAMIS, 2021). The Geum RWR is located in the central western area (river length of 395.9 km, basin area of 9,810 km^2; WAMIS, 2021). The Nakdong RWR is located in the eastern part of the country and the total length of the river is the longest (river length of 521.5 km, basin area of 23,817 km^2; WAMIS, 2021). The Yeongsan RWR (river length of 136.0 km, basin area of 3,371 km^2) is located in the south-western area, and the Seomgin RWR (river length of 222.1 km, basin area of 4,897 km^2) is located in the south-central part of the country (WRMIS, 2021).

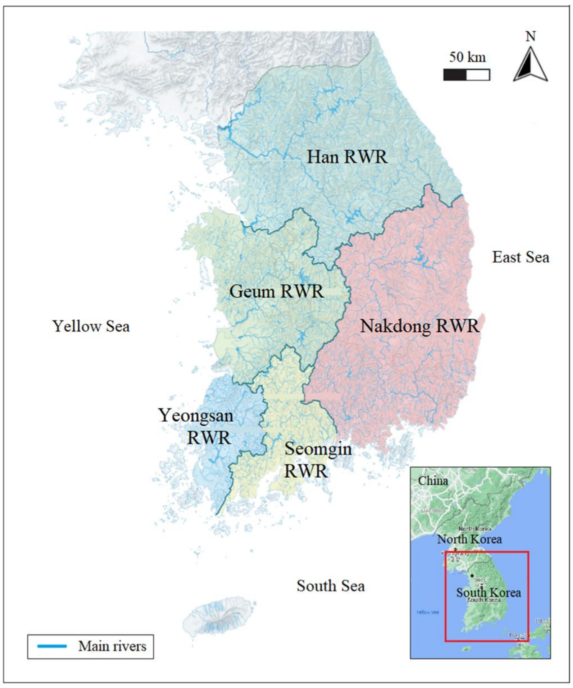

Fig. 2. The five major River Watershed Regions (RWRs) in South Korea.

In South Korea, water management was organised by various water-related ministries until 1990s: Ministry of Environment (ME); Ministry of Land, Infrastructure and Transport; Ministry of Agriculture, Food and Rural Affairs; Ministry of the Interior and Safety; Ministry of Trade, Industry and Energy (Lee and Kim, 2009; KRIHS, 2012; ME, 2017, 2020). The ministries managed and controlled the total 293 of water source protection and special measure areas based on administrative regions; one capital, one special autonomous and six metropolitan cities, and nine provinces including one special self-governing autonomous province (ME, 2021a; MLIT, 2021). However, the administrative district system differs with the RWRs, so conflictions occur between up and down streams in different administrative districts. Moreover, similar plans on same RWRs by various ministries promoted the necessity of the unification of the water management plans for the efficient actions and budget consumptions. Although, the integrations were not straightforward due to the different opinions between the ministries, governments phased to unify them into the ME in the period of 1990-2018 (ME, 2020). In present, the ME is the integrated national water management organisation as the single authority.

Study sites

Two main rivers were chosen for the case study: Maritsa River in the East Aegean Sea RBD from Bulgaria and Han River in the Han RWR from South Korea (Fig. 3). For the purpose of representativeness of the assessment, the sampling sites – 15 in each region, were selected in different river sections along the main rivers and their tributary systems. They represent unaffected reference sites and sites subjected to various types of anthropogenic pressure (Table 1 and 2).

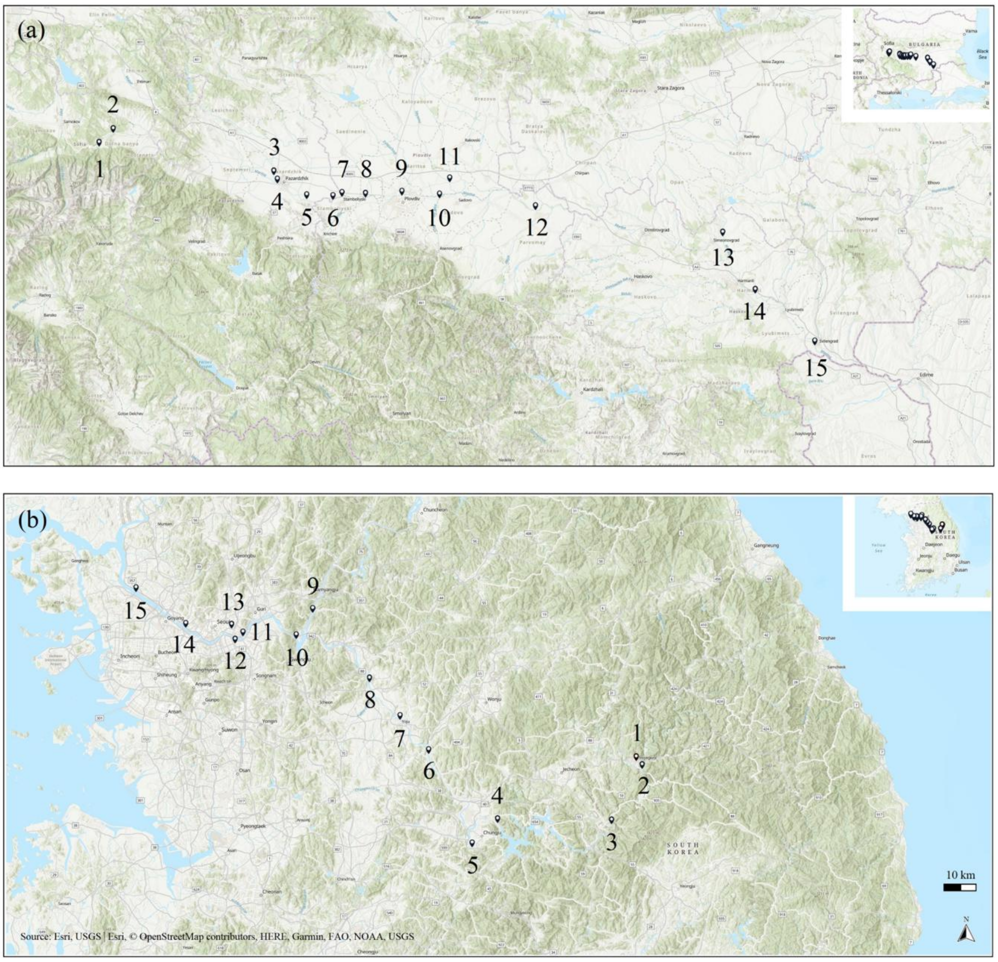

Fig. 3. Maps of the case study sites along Maritsa River in Bulgaria (a) and Han River in South Korea (b).

Table 1. The list and localities characteristics of the 15 case study sites in the Maritsa River Basin.

Site no.	Name of the site	Coordinates (N, E)	Characteristics
1	Maritsa River, Raduil	42.2795, 23.6872	Near the Raduil village (no data for significant anthropogenic pressure, reference site)
2	Maritsa River, Dolna Banya	42.3159, 23.7330	Before the Dolna Banya town (low anthropogenic pressure, mainly from diffuse sources, reference site)
3	Topolnitsa River, Pazardzhik, before estuary	42.2062, 24.2954	Near the bridge for Boshulia village (illegal waste disposal at the banks)
4	Maritsa River, Pazardzhik, Atlantic Motorway Bridge	42.1843, 24.3082	Urbanized area, before the bridge (factories)
5	Maritsa River, Ognyanovo	42.1438, 24.4115	3.7 km downstream from the estuary of Luda Yana River
6	Maritsa River, Govedare	42.1420, 24.5040	Near the village (agricultural land use)
7	Maritsa River, Stamboliyski	42.1498, 24.5349	City centre of Stamboliyski, 1.45 km before the road bridge and weir (agricultural land use and factories)
8	Maritsa River, after Vacha River	42.1477, 24.6174	240 m downstream from the estuary of Vacha River
9	Maritsa River, Plovdiv	42.1536, 24.7450	City centre of Plovdiv (domestic waste disposal at the banks)
10	Chepelarska River, Kemera Old Bridge	42.1456, 24.8772	2.2 km upstream from the estuary (agricultural land use)
11	Stryama River, Manole	42.1874, 24.9131	Representative site for the lower Stryama River, near the Manole village, under the road bridge (agricultural land use, fishing and poaching)
12	Maritsa River, Parvomay	42.1160, 25.2132	Representative site for the middle course of Maritsa River, under the old wooden bridge (significant biogenic and industrial pollution)
13	Sazliyka River, before estuary	42.0478, 25.8702	2.07 km upstream from the estuary of Sazliyka River, near the bridge for Svirkovo and Troyan villages (cow farms, heavy biogenic and organic pollution)
14	Maritsa River, Dositeevo	41.8980, 25.9840	Representative site for the lower Maritsa River, City centre of Dositeevo, after stone weir
15	Maritsa River, Svilengrad	41.7634, 26.1928	Representative site for the lower Maritsa River, City centre of Svilengrad

Table 2. The list and localities characteristics of the 15 case study sites in Han River Watershed Region (RWR).

Site no.	Name of the site	Coordinates (N, E)	Characteristics
1	East River, Yeongwol bridge	37.181944, 128.475556	Representative site for the Upper South Han River (recreational area - resorts, fishing spots, camping sites - on river sides)
2	West River, Palheung Bridge	37.160222, 128.495806	Representative site for the Upper Han River (1.63 km upper - water and sewerage facility, 582 m upper - hydro and nuclear power plant)
3	South Han River, Deokcheon Bridge	37.005528, 128.389167	Representative site for the Dal Stream and Han RWR (no data for significant anthropogenic pressure, reference site)
4	South Han River, after Chungju Dam	37.009222, 127.981806	After Chungju Lake (recreational area at the lake side)
5	Dal Stream, Danwol Bridge	36.941508, 127.899844	Danwol River Beach (livestock logistics centres on the left bank)
6	South Han River, SHR Bridge	37.201889, 127.747556	Representative site for the downstream of Chungju Dam (camping sites at the lake side, a cow farm 1.74 km away from the right bank)
7	South Han River, Yeoju Bridge	37.296722, 127.647889	Parks, gardens, tracking courses on river sides
8	South Han River, Ipo Bridge	37.398083, 127.541389	Representative site for the Ipo Weir (350 m downstream from Ipo Bridge) (camping sites on right side)
9	North Han River	37.594225, 127.341306	Representative site for Cheongpyeong Dam and Han RWR (farms on right side, recreational area on river sides)
10	Han River, after Paldang Dam	37.521394, 127.283339	Representative site for Paldang Dam and Han RWR, before the Paldang Dam with hydro power plant (major water supply to the capital city), Geomdan mountain on left side
11	Han River, Jamsil Railway Bridge	37.528986, 127.097153	City centre of Seoul, representative site for Han River Jamsil, parks on river sides
12	Han River, Tan stream, before estuary	37.510208, 127.070622	City centre of Seoul, Tan stream passes through most uptown areas and flows into Han River, parks on river sides
13	Han River, Cheonggye stream	37.549322, 127.055453	City centre of Seoul, significant urban environment infrastructure in downtown (restored in 2005)
14	Han River, before Seongsan Bridge	37.553022, 126.896244	City centre of Seoul, parks and recreational areas on river sides
15	Han River, Ilsan Bridge	37.651869, 126.721647	Representative site for Han River_Goyang, parks on river sides

Data analysis

Data about the macrozoobenthos collected from Maritsa River in July 2021 (Varadinova et al., 2022) and from Han River (WEIS, 2022) in September - October 2021 were used.

Two indices: Biotic index (BI) (Cheshmedjiev & Varadinova, 2013) and Benthic Macroinvertebrate Index (BMI) (Guidelines, 2019-52) were calculated for the biological quality assessment based on the macrozoobenthos. For the calculation of the BMI, 190 indicator species have been defined with saprobic values (s) and indicator weight values (g). The index is calculated according to the formula:

$$\mathrm{BMI} = 4 - \frac{\sum_{i=1}^{n} si\ hi\ gi}{\sum_{i=1}^{n} hi\ gi}\ x\ 25$$

i: number assigned to the species,
n: number of indicator species,
s_i: saprobic value of the species i,
g_i: indicator weight value of the species i
h_i: frequency of the species i.

The value of h changes from 1 to 5 according to R_i (1 (> 80%), 2 (60% < ~ ≤ 80%), 3 (40% < ~ ≤ 60%), 4 (20% < ~ ≤ 40%) and 5 (≤ 20%)). The R_i is calculated as a percentage of the ranking of the abundance (1, 2, 3 .... in the order of the highest abundance) for each appeared species (Guidelines, 2019-52).

The assessments of the ecological status of all study sites were done according to the Bulgarian (Regulation H-4/2012) and the Korean (Water Environment Conservation Act (WECA, 2022, Article 9) water legislations. Data about the ecological status assessment of Maritsa River, according to the Bulgarian legislation, published by Varadinova et al. (2022), were used in this article.

Results and Discussion

Comparative analysis of the water legislation in Bulgaria and South Korea

Although water management is organized differently, restrictive water legislation is implemented in Bulgaria and South Korea, which aims at the water resources conservation, as well as the preservation of its quality.

Since Bulgaria's accession to the EU, the water legislation of the country has been fully harmonized with the European one. The Water Act has been adopted in accordance with EU WFD (2000/60/EC). Bulgaria has been included in two Ecoregions (7 Eastern Balkans and 12 Pontic Province) and both surface (running and standing) and underground water bodies have been identified and characterised in accordance with national river typology (Cheshmedjiev et al., 2013). Achieving good (ecological and chemical) status of the waters in the country has been defined as a main goal. Gradually, the relevant ordinances concerning various aspects of water protection have been adopted. Regulations have been developed for water monitoring, characterisation of the superficial waters, quality of drinking and bathing water, emission standards for the permissible content of harmful and dangerous substances in wastewater discharged into water bodies, for preservation of waters from pollution by nitrates from agricultural sources, for groundwater protection and others (Water Law). Areas with a special status of water protection according to the European (Directive 92/43/EEC; Directive 2009/147/EC) and national (Protected Areas Act, 1998; Biodiversity Act, 2002) legislation have been introduced. The Regulation H-4/2012 of the surface waters characterisation and its amendments and additions plays a key role to define the quality elements, methods for sampling, analysis and assessment of the ecological status of the surface water bodies in Bulgaria.

The geographical, economic and political features contribute to the major difference in the water resource management approach in Bulgaria and South Korea. Bulgaria efforts on the harmonious cooperation with neighbouring countries which are not members of the EU to maintain and protect the water quality from industrial, agricultural, and domestic waste pollutants. The Bulgarian government has made bilateral agreements and partnerships in several international conventions such as the Convention on Co-operation for the Protection and Sustainable Use of the River Danube, the Convention on the Protection of the Black Sea against Pollution and the Convention on the Protection and Use of Transboundary Water courses and International Lakes (RBMP, 2016-2021).

Korean government has strategically been enforced legislation on water environment to protect water quality and provide safe drinking water. The water-related policies have been evolved from pollution control to cleaner production and eco-efficiency management highlighting the importance of the environmental issues. In 1963, the Environmental Pollution Prevention Act was imposed as the first water related law to protect people's health from industrial wastewater. During the period of 1970-1980s, many urban rivers were covered or reformed, and their channels were straightened for the needs of transportation infrastructure and rapid urbanization in accordance with the River Management Policy. However, as the issues of environmental degradation of rivers raised, Ecological Stream Restoration Project (ESRP) has implemented to restore urban rivers by replacing artificial infrastructures with natural conditions in 1987 (ESRP, 2020). This enhances the self-purifying capacity of the rivers, improves the water quality, and provides better habitats for aquatic flora and fauna. In 1990, WECA (1990) was implemented in order to manage the complex environmental problems more effectively. In line with the ESRP, the 'Four Major River Restoration Project' was enforced to secure the water resources and to enhance the water quality of the rivers; the Acts on the River Watershed Management and Community Support were enacted for Han RWR in 1999 and for Nakdong, Geum and Yeongsan RWRs in 2002 (Kim et al., 2007; KRIHS, 2012; WEPA, 2012; Choi et al., 2017). Until 2019, about 97 of water-related plans existed by seven ministries in accordance with 29 Acts. Since the ME became the central government administration, the ministry has defined a new Water Management Act (WMA, 2019). The Act focuses not only on the unification of the water managements but also on the extended applications of the present legislations, which used to be applied mainly for major RWRs, for more comprehensive and effective achievements. In accordance with the WMA, the first National Water Management Plan (NWMP) (2021-2030) and the Comprehensive Watershed Management Plan (2021-2030) are in action.

Assessment of the ecological and chemical status of the surface waters in Bulgaria and South Korea

Bulgarian authorities follow the EU WFD for the assessment of the ecological and chemical status of surface waters. The ecological status is evaluated by biological, physico-chemical and hydro-morphological quality elements. Five obligatory biological quality elements are used – phytoplankton, phytobenthos, macrophytes, macro-zoobenthos and fish. For each element, specific indices have been developed with corresponding type-specific scales for assessing the status (Regulation H-4/2012). The evaluation is expressed as 'Ecological Quality Ratios (EQR = observed value / reference value) and is performed through a five-step type-specific classification scale (high, good, moderate, poor and bad status) (Table 3). The ratio has a numerical value that varies between zero and one, which expresses high status. The classification guidance separates three levels in the biological assessment: the quality element level, the parameter level, and the status classification. The main conclusion is that the WFD requires classification of water bodies at the quality element level, and that the worst of the relevant quality elements determines the final classification (the "one out, all out" principle) (Van de Bund & Solimini, 2007). The physico-chemical quality elements for rivers include basic parameters dissolved oxygen (DO), conductivity, pH, nutrients ($N\text{-}NH_4$, $N\text{-}NO_3$, $N\text{-}NO_2$, total nitrogen (TN), $P\text{-ortho-}PO_4$ and total phosphorus (TP)) and biological oxygen demand (BOD), and specific pollutants (Regulation H-4/2012). The assessment is characterised with a three-step scale (high, good and moderate status). Hydro-morphological quality elements determine the status 'good' (native or unaffected conditions) or 'deviations from natural conditions' (CIS-WFD, 2003). The physico-chemical and hydro-morphological quality elements play a supporting role in the ecological assessment of the water bodies. The chemical status of the water bodies is set in the Regulation on environmental quality standards for 45 priority substances and specific pollutants (Directive 2013/39/EU), and the criteria is whether 'good' or 'failing to achieve good' status (Regulation of 09.11.2010) (Table 3). In this way, the general status of a surface water body is determined by its worse ecological or chemical status.

In South Korea, the water quality standards are classified into surface, ground, coastal and drinking waters based on the Environmental Policy Act (EPA, 2022) and the WECA. For the surface water in rivers, there are two quality standards – one of them is applied for 'Conservation of the Living Environment (CLE)' and the other one is for 'Protecting Human Health' (EPA, Article 2). In terms of the CLE, the water status in rivers is determined by biological, hydro-morphological, and physico-chemical quality elements, and hazardous chemical materials, same categories as in Bulgaria.

Table 3. The ecological and chemical status and the quality elements for surface water assessment of the rivers in Bulgaria (The colour-code of each status classification is indicated).

	Ecological status			Chemical status
Quality elements	Biological (incl. macrozoo-benthos)	Physico-chemical	Hydro-morpho-logical	Priority substances /specific pollutants
Grade	High	High	Good	Good
	Good	Good	Deviation from the natural conditions	Failing to achieve good
	Moderate	Moderate		
	Poor			
	Bad			

The biological and hydro-morphological quality is surveyed and evaluated in accordance with the Guidelines No. 2019-52. The indices based on the quality elements are Trophic Diatom Index (TDI), Benthic Macroinvertebrate index (MBI), Fish Assessment Index (FAI), Riparian Vegetation Index (RVI) and Habitat and Riparian Index (HRI) (Table 4). Each element quantitatively evaluates the ecosystem health into five grades (very good (A), good (B), average (C), poor (D) and very poor (E). The colour-coding of the ecological status classification is the same in both countries (Table 3 & 4). The physico-chemical quality is characterised with eight elements which are pH, BOD, Chemical Oxygen Demand (COD), Total Organic Carbon (TOC), Suspended Solids (SS), DO, TP and Coliforms, with seven grades (very good ($\mathrm{I_a}$), good ($\mathrm{I_b}$), somewhat good (Ⅱ), average (Ⅲ), somewhat poor (Ⅳ), poor (V) and very poor (Ⅵ)) (Table 5). For the measurement, Water Environment Measurement Network monitors the physico-chemical quality elements monthly at 691 sites and the biological quality elements at 3,035 sites (TDI, BMI and FAI are twice a year, RVI and HRI are once a year) on rivers (ME, 2021a-297). Currently, advanced water quality standards including water quantity and waterside environment (history, culture, scenery etc.) are preparing for the 2nd NWMP (2031-2040).

Table 4. The biological and hydro-morphological quality elements and the criteria for Conservation of the Living Environment in rivers in South Korea (The colour-code of each status classification is indicated).

Grade		TDI	BMI	FAI	RVI	HRI
Very good	A	≥ 90	≥ 80	≥ 80	> 65	> 80
Good	B	≥ 70	≥ 65	≥ 60	> 50	> 60
Average	C	≥ 50	≥ 50	≥ 40	> 30	> 40
Poor	D	≥ 30	≥ 35	≥ 20	> 15	> 20
Very poor	E	< 30	< 35	< 20	≤ 15	≤ 20

Table 5. The physico-chemical quality elements and the criteria for Conservation of the Living Environment in rivers in South Korea (The colour-code of each status classification is indicated).

Grade		Elements								
		pH	BOD	COD	TOC	SS	DO	TP	Coliforms (groups/100mL)	
			(mg/L)						Total	Fecal
Very good	I$_a$		≤ 1	≤ 2	≤ 2		≥ 7.5	≤ 0.02	≤ 50	≤ 10
Good	I$_b$		≤ 2	≤ 4	≤ 3			≤ 0.04	≤ 500	≤ 100
Somewhat good	II	6.5-8.5	≤ 3	≤ 5	≤ 4	≤ 25	≥ 5.0	≤ 0.1	≤ 1,000	≤ 200
Average	III		≤ 5	≤ 7	≤ 5			≤ 0.2	≤5,000	≤ 1,000
Somewhat poor	IV		≤ 8	≤ 9	≤ 6	≤ 100		≤ 0.3	-	-
Poor	V	6.0-8.5	≤ 10	≤ 11	≤ 8	No floating garbage, etc.	≥ 2.0	≤ 0.5	-	-
Very poor	VI	-	> 10	> 11	> 8	-	< 2.0	> 0.5	-	-

Current water quality status and future of the water management in Bulgaria and South Korea

Water management should be considered in two aspects: improving water quality and sustainable use of the water resources. These are especially important against the background of the growing needs of people and the increasing impacts of the global climate change.

Bulgaria is obliged by the European Structural and Investment Fund (ESIF) rules and should improve the necessary infrastructures to comply with the Urban Waste Water Treatment Directive. The government has increased the number of wastewater treatment plants (79 pcs in 2010 to 174 pcs in 2019; EEA, 2021), and the compliance levels have increased in recent years (90-100% in the improvement of surface water quality in EU; EEA, 2016 & 2018).

According to the RBMPs reports, Bulgaria has improved the water quality overall in rivers. The high or good ecological status in the four RBDs have increased from 43.2% in the 1st to 52.6% in the 2nd RBMP (WISE). The assessment of the main physico-chemical indicators (DO, BOD, ammonium, nitrogen, and phosphates) showed that the water bodies had on average 66.9% of high or good ecological status (1996-2019), with the lowest values in the Black Sea RBD (51.2%) and the highest ones in the in Danube RBD (74.6%) (Table 6) (EEA, 2021). The assessment of the main biological quality elements (phytoplankton, macrophytes, phytobenthos, benthic invertebrates and fish) showed that on average 62.7% of rivers had high or good ecological status (Table 7) (EEA, 2021). Despite of the achievements, further improvements are required because of the low values of some quality elements (Table 6 and 7). Thus, strategic documents are developing such as the National Strategy for Management and Development of the Water Sector and the Action Plan until 2037, and the Implementation of Directive 91/271/EEC on the treatment of urban wastewater. In addition, a new classification system has been proposed and the scales for the biological status of different types of water bodies have been specified. A system for evaluation of the status by hydro-morphological quality elements is also to be developed. The government is forcing conservation laws and environmental regulations for effective water management and efficient spending of available finances.

Table 6. The percentages of the water bodies with high or good status according to the main physico-chemical indicators in the four major RBDs in Bulgaria for the period of 1996-2019 (EEA, 2021).

Physico-chemical indicators		**DO**	**BOD**	**Ammonium**	**Nitrogen**	**Phosphate**
RBDs	Danube	86	77	85	61	64
	Black Sea	57	53	46	50	50
	East Aegean Sea	84	53	74	75	53
	West Aegean Sea	90	68	81	80	51

Table 7. The percentages of the water bodies with high or good status according to the main biological indicators in the four major RBDs in Bulgaria based on the 2nd RBMP report.

Biological indicators		**Phyto-plankton**	**Macro-phytes**	**Phyto-benthos**	**Benthic invertebrates**	**Fish**
RBDs	Danube	50	72	76	67	61
	Black Sea	57	73	85	57	56
	East Aegean Sea	38	65	72	45	71
	West Aegean Sea	-	77	60	67	57

The implementation of the water management policy has improved water quality and ecosystem integrity of surface waters overall in South Korea. Especially, the BOD decreased significantly from maximum 130 mg/l in 1981 to 20 mg/l in 1995, and during the recent decades it has maintained average values of 1 mg/l (ME, 2021a). However, other elements have not improved as much as the BOD.

In the basis of the WECA (Article 9-2), the government defines targeting grades for physico-chemical quality elements at 35% of very good (Ia), 43% of good (Ib), 13% of somewhat good (Ⅱ), 10% of average (Ⅲ), and 1% of somewhat poor (Ⅳ) of all rivers in RWRs (ME Notice No. 2018-6). However, for the period 2016-2020, the assessment based on the physico-chemical quality elements showed that 63.7% of rivers were in a very good (Ia) or good (Ib) status, which is lower than the targets (ME, 2021b) (details in Table 8). The lowest value was in the Geum RWR (59.9%) and the highest one was in the Nakdong RWR (66.1%). The assessment of the biological and hydro-morphological indicators showed that overall 40.0% of rivers in RWRs were in a very good (A) or good (B) status (TDI: 38.3%, BMI: 52.0%, FAI: 42.1%, RVI: 33.5% and HRI: 30.7%) (ME, 2021b) (Table 9). The lowest value was in the Geum RWR (32.3%) and the highest one was in the Han RWR (43.6%). Thus, in order to improve the water quality in RWRs, the government is investigating not only a highly advanced water management system but also doing structural changes. For example, the 'Four Major River Restoration Project' restored 1,813 rivers from 1987 to 2015, as a result, the percentage of ecologically degraded rivers of total rivers decreased from 55% in 2009 to 35% in 2015 (ESRP-MLP, 2016-2020; ESRP, 2020). The project is continuing with Comprehensive Mid- (2020) to Long-term (2025) Plan (ESRP, 2020). Also, weirs in the RWRs are gradually opening since 2017 for the restoration of natural conditions (ME, 2020). The most significant changes are an increase in flow rate and a decrease in residence time, and consequently a significant decrease in tidal flow. However, the water quality did not improve significantly after the weir opened, and the cause is analysed by external variables (precipitation and upstream pollutants). Therefore, long-term monitoring is required for the effectiveness of the weir openings in the water quality.

Table 8. The percentages of the rivers with very good or good status according to the physico-chemical quality elements in the five major River Watershed Regions (RWRs) in South Korea for the periods of 2016-2020 (ME, 2021b).

RWRs	Quality Elements								
	pH	BOD	COD	TOC	SS	DO	T-P	Coliforms (groups/100mL)	
								Total	Fecal
Han	95.3	64.1	52.5	65.7	97.2	100	46.1	24.7	45.6
Nakdong	98.6	76.7	32.3	49.8	98.2	100	57.7	37.3	44.6
Geum	99.6	46.1	34.3	44.1	88.5	100	99.1	12.4	15.1
Yeongsan and Seomgin	100	65.9	37.8	49.6	91.1	100	33.3	43.2	46.2

Table 9. The percentages of rivers with very good or good status according to the biological and hydro-morphological quality elements in the five River Watershed Regions (RWRs) in South Korea for the period of 2016-2020 (ME, 2021b).

RWRs	Elements				
	TDI	BMI	FAI	RVI	HRI
Han	43.9	58.7	51.2	25.4	38.7
Nakdong	49.0	56.3	46.2	29.6	27.1
Geum	24.1	40.3	31.4	38.2	27.8
Yeongsan and Seomgin	36.0	52.6	39.5	41.0	29.4

Bulgaria and South Korea aim to achieve and maintain at least good ecological status of rivers. For the recent five years (2016-2020), both countries showed average achievements – 16th (50.5%) and 14th (51.8%) place among 30 countries, although the specifications of the criteria are different, the main quality elements are the same (Fig. 4). These are higher than the average to the countries, 2nd RBMPs (44.0% of all rivers, WISE).

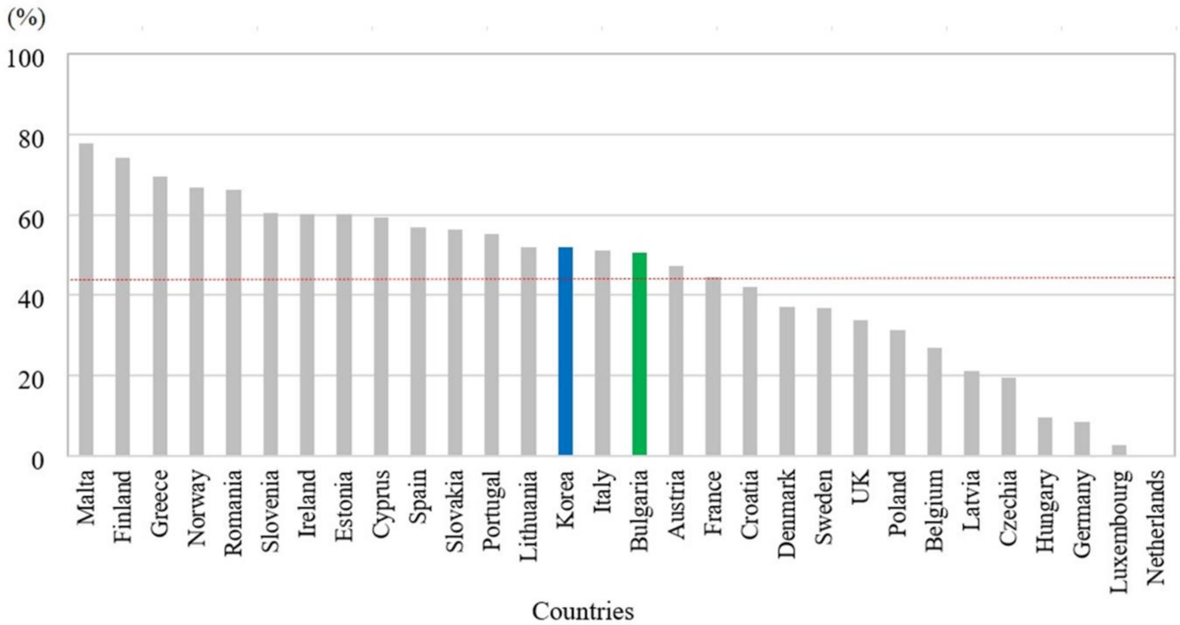

Fig. 4. The percentages of high/very good or good ecological status in rivers in European countries and South Korea for the periods of 2016-2020 (the red dash line indicates the average value for all the countries; the data are based on 2nd RBMPs reports (WISE) and ME (2021b).

Comparison of ecological status assessment in Bulgaria and South Korea: Case study of Maritsa River and Han River

Both classification systems for the status evaluation of running water bodies by biological quality element are composed of five-level scales (Tables 3 and 4), which makes them relatively comparable. Ecological status assessment of the study sites located in the basins of Maritsa and Han rivers according to the classification systems of the two water legislations

(Bulgaria and South Korea) is presented in Table 10.

In total, the ecological status of Maritsa River evaluated by two classification scales coincides at seven sites: sites 2, 3, 8 and 11 – good; site 10 and 15 – moderate / average; and site 13 – bad / very poor. The assessment of the status of Han River shows a match at eight sites: sites 2 and 3 – high / very good; sites 6 and 12 – moderate / average; sites 8, 13 and 14 – poor; and site 15 – bad / very poor. There is a discrepancy in the ecological status of Maritsa River by one class at 8 sites: at three sites (1, 7 and 14) lower, and at four sites (4, 5, 6 and 12) higher status, and only at site 9 the condition is higher by two classes in accordance with the Korean water legislation. The ecological status assessment of Han River differs at seven sites: at four sites (5, 7, 9 and 11) by one class lower, at two sites (1 and 4) by one class higher, and at site 10 by two classes lower according to the Bulgarian water legislation.

Table 10. Ecological status assessment of the study sites in Maritsa and Han rivers based on the macrozoobenthos according to the Bulgarian and Korean water legislations in 2021 (The colour-code of each status classification is indicated).

River	Maritsa River		Han River	
Assessment	Bulgarian water legislation (Varadinova et al., 2022)	Korean water legislation	Bulgarian water legislation	Korean water legislation
Site 1	High	Good	High	Good
Site 2	Good	Good	High	Very good
Site 3	Good	Good	High	Very good
Site 4	Moderate	Good	Moderate	Poor
Site 5	Moderate	Good	Good	Very good
Site 6	Moderate	Good	Moderate	Average
Site 7	Good	Average	Moderate	Good
Site 8	Good	Good	Poor	Poor
Site 9	Moderate	Very good	Moderate	Good
Site 10	Moderate	Average	Poor	Good
Site 11	Good	Good	Bad	Poor
Site 12	Moderate	Good	Moderate	Average
Site 13	Bad	Very poor	Poor	Poor
Site 14	Moderate	Poor	Poor	Poor
Site 15	Moderate	Average	Bad	Very poor

Both assessments determined one and the same ecological status almost at the half of the sites in both rivers, and only one level of discrepancy for most of the rest. The assessment of the condition of the rivers by the two classification systems shows that the Bulgarian assessment scale is stricter for both rivers. The number of sites with good or high ecological status determined according to the values of the BI used in Bulgaria is less in both rivers (6 in Maritsa River and 4 in Han River) than the number of sites with the same status, but defined through the Korean BMI (10 in Maritsa

River and 7 in Han River) (Table 10). It should be noted that the ecological assessment of the conditions in Bulgarian rivers is being determined according to type-specific scales, in which the boundaries between individual classes are determined in terms of the type of running water body (Regulation H-4/2012). Unlike Bulgaria, Korean assessment does not apply river types and reference sites for the evaluation. The biological quality assessment of running waters in South Korea is based on defined indicator species with their own index values and only those species are used for the evaluation (Guidelines, 2019-52). However, the species composition of the macrozoobenthos, and the indicator species depend on the complex action of the specific environmental factors in the river habitats. In this case study, 40 out of 110 taxa found in the Maritsa River survey were not included in the calculation of BMI, while only 2 taxa from Han River were excluded. However, at site 4 in Maritsa River where all taxa were used in the calculation, the status differ by one class. On the other hand, 6 taxa with total abundance of 60 individuals at site 3 and 8 taxa with total abundance of 532 individuals at site 8 in Maritsa River were excluded, but the two assessments determined the same status. This case study demonstrated that the calculation approaches of the assessment methods are of essential importance in determining of the ecological status. Thus, in Bulgaria, the evaluation of the BI is based on taxa, which belong to certain indicator groups, differing in degree of sensitivity. The calculation of the South Korean index (BMI) is based on the saprobic values and indicator weights of each individual species.

Conclusion

Despite of the specific differences in the water legislation in Bulgaria and South Korea, the basic national policies in the field of surface running waters are aimed at protection and sustainable use of the limited water resources affected by the growing freshwater requirements and global climate change. Both countries apply scientifically based methods in the water resources management and basin approach for comprehensive and integrated water management taking into account the specifics of the geographical locations. The ecological status of rivers (water bodies) in Bulgaria and South Korea is evaluated by the same groups of quality elements - biological, physico-chemical and hydro-morphological. The results from the study of Maritsa and Han rivers showed that the assessments based on one of the key biological quality elements macrozoobenthos and made according to the classification systems of Bulgarian and South Korean water legislations determined the same or similar ecological status. More detailed studies based on long data set received from more rivers in the two countries has to be conducted in order to receive more reliable results.

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