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APPLICATION OF WATER QUALITY INDEX METHODS FOR THE ASSESSMENT OF WATER QUALITY IN KOSOVO, REVIEW

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EXTENDED ABSTRACT

A livello globale è in costante aumento la preoccupazione per la qualità delle risorse idriche utilizzate per il consumo umano, la preparazione degli alimenti, l'agricoltura, la fauna acquatica e, più in generale, per la tutela della salute pubblica e degli ecosistemi acquatici. La composizione chimica delle acque superficiali dipende principalmente dalle fonti di alimentazione e dal regime pluviometrico annuale, ma risulta frequentemente modificata dalle attività antropiche. In particolare, le acque superficiali sono esposte a un'ampia gamma di inquinanti, derivanti dagli scarichi di acque reflue domestiche, dalle fonti di inquinamento diffuso, dall'uso di fertilizzanti chimici, letami e pesticidi in agricoltura, nonché dalle attività industriali e minerarie, dai rifiuti di estrazione, dall'uso indiscriminato degli alvei e delle sponde fluviali, dai cambiamenti di uso del suolo e dai processi di erosione accelerata.

La scarsa qualità dell'acqua rappresenta un problema di rilevanza globale ed è responsabile di numerose patologie, principalmente associate alla presenza di microrganismi patogeni e contaminanti tossici. Inoltre, l'insufficiente disponibilità di risorse idriche determina condizioni igieniche inadeguate a livello domestico e personale, aumentando il rischio di infezioni idrotrasmesse. Al contrario, la disponibilità di acque di buona qualità è essenziale per la fisiologia umana e costituisce un presupposto fondamentale per il benessere delle popolazioni e per uno sviluppo socio-economico sostenibile.

In tale contesto, la valutazione della qualità delle acque superficiali, e in particolare dei corsi d'acqua, assume un ruolo centrale e deve essere considerata un processo continuo e prioritario, soprattutto in presenza di crescenti pressioni antropiche, dello sviluppo agricolo e industriale e degli effetti del cambiamento climatico. A livello europeo, la Direttiva Quadro sulle Acque 2000/60/CE promuove un approccio integrato alla conservazione, al miglioramento e all'uso sostenibile delle risorse idriche, sottolineando l'importanza di strumenti affidabili per il monitoraggio e la valutazione dello stato qualitativo delle acque.

Tra i metodi più utilizzati a livello internazionale per la valutazione della qualità delle acque vi è il Water Quality Index (WQI), introdotto negli anni Sessanta e successivamente sviluppato in numerose formulazioni. Attualmente sono disponibili oltre venti metodi di calcolo del WQI; tra questi, i più applicati risultano il CCME-WQI, il NSF-WQI e il WA-WQI (o MWQI). Tali metodi consentono di sintetizzare un elevato numero di parametri chimici, fisici e biologici in un unico valore numerico di facile interpretazione e comunicazione, offrendo al contempo una buona flessibilità nella selezione dei parametri in funzione delle condizioni locali.

Il presente lavoro propone una revisione sistematica della letteratura scientifica relativa all'applicazione dei metodi WQI per la valutazione della qualità delle acque superficiali nella Repubblica del Kosovo. La qualità delle acque risulta influenzata sia da fattori naturali sia antropici, in un contesto climatico caratterizzato da clima continentale e mediterraneo modificato, con precipitazioni medie annue comprese tra 595 e 809 mm. Anche le condizioni geologiche, con affioramenti che spaziano dal Proterozoico al Quaternario, incidono significativamente sul bilancio idrico, in particolare attraverso le formazioni carbonatiche, che rappresentano il principale tipo di acquifero del Paese.

Nonostante le differenze nei criteri di classificazione della qualità dell'acqua, i metodi NSF-WQI, CCME-WQI e WA-WQI si sono dimostrati efficaci nel contesto kosovaro, evidenziando le peggiori condizioni qualitative nel bacino del fiume Lepenc e le migliori nel bacino del fiume Ibër. L'utilizzo del WQI costituisce pertanto uno strumento utile di supporto alla pianificazione e alla gestione dei bacini idrografici, alla definizione delle politiche ambientali e al conseguimento degli obiettivi di sviluppo sostenibile dell'Agenda 2030, con particolare riferimento all'SDG 6 "Acqua pulita e servizi igienico-sanitari".

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ABSTRACT

At a global level, there is concern about the quality of water used for drinking, food preparation, irrigation, aquatic fauna and other components related to the life cycle, public health and aquatic ecosystems, while efforts to keep its quality under control continue. The European Parliament established a framework for action in the field of water policy, known as the Water Framework Directive 2000/60 EC. This directive emphasizes the need for an integrated approach to the conservation, improvement and sustainable use of water resources. A method for assessing water quality, called the Water Quality Index (WQI), was firstly applied in 1965, and it was then modified by other authors over decades. Other methods for calculating the WQI were developed and advanced, and today they have reached up to 20 WQI methods. These methods have today found widespread use throughout the scientific community worldwide to assess the quality of surface and groundwater. This review presents the findings gained by the use of water quality index methods on the quality of surface waters in different parts of the territory of the Republic of Kosovo. Both natural and human factors affected the quality of surface waters in the territory of Kosovo, which is characterized by Continental and Modified Mediterranean Climate, whith average precipitations ranging from 595.2 mm to 809.1 mm. Besides the precipitations, the hydraulic balance of the country is also impacted by the geological formation that outcrop which belong to an time interval that extends from Proterozoic to Quaternary. The highest (0.5 to 0.8) infiltration rate belong to the carbonate rocks (limestone, dolomite, marbled limestone) which represent the most important aquifer type. This paper aims to bring a systematic review of the written and electronic literature which was collected from a wide range of reliable scientific databases and through an analysis of the WQI methods applied for water quality assessment and the WQI data obtained, tried to present a complete view of the surface water quality in the hydrographic network of the Republic of Kosovo. Apart from differences in water quality classifying ranges of the used WQI methods (NSF-WQI, CCME-WQI and WA-WQI), they were successfully applied for the evaluation of the water quality in Kosovo and revealed that the worse quality waters (low WQI values) belong to the Lepenc River Basin, while good quality waters (high WQI) to the Ibër River Basin.

Keywords: *methods, Water Quality Index, Kosovo*

INTRODUCTION

The European Union's Water Framework Directive 2000/60 (WFD, 2000/60) created a political mechanism for the management of water resources throughout the European Union. Member states, candidates and potential EU members are obliged to undertake measures to meet the requirements of the WFD and to create institutional mechanisms for drafting legal frameworks and strategic documents. In addition, the countries have to implement the plans for river basin management and monitoring, controlling and reporting on the state of water resources based on the WFD 2000/60 requirements, as well as based on the concept of integrated water resources management. The Water Framework Directive 2000/60 emphasizes that the elementary unit for integrated water resources management is the river basin, and also emphasizes the need to monitor the quality of surface and groundwater and maintain a good status of waters based on the limit values set by the surface water directive. As part of efforts to become part of the EU, the Republic of Kosovo (KDI, 2008) has created institutions, legal framework, strategic documents and plans that support and are in harmony with the Water Framework Directive. The Regional River Basin Authority, the Kosovo Environmental Protection Agency-Hydrometeorological Institute (see link: https://mmphi.rks-gov.net/) of the Republic of Kosovo are currently the responsible institutions for the management, monitoring and reporting of environmental indicators, including indicators (National List of Environmental Indicators) for water resources (KEPA, 2022). The Hydrometeorological Institute (see link: https://ihmk-rks.net/?page=2,1) carries out monitoring (among other things) of surface waters throughout the hydrographic network of the Republic of Kosovo.

Water quality assessment is the foundation of water environment managemet and protection (Yang *et alii*, 2023).

Study area Republic of Kosovo-the Republic of Kosovo is located in Southeastern Europe (Western Balkan country), in the center of the Balkan Peninsula, between the coordinates 41° 50' 58'' to 43° 15' 42'' north latitude, 20°01'02'' to 21° 48' 02'' east longitude (ISP, 2010). It has an area of 10,905.25 km2 (KAS, 2026) in which 1,586,659 million inhabitants live (KAS, 2024). The lowest altitude above sea level is 273.5 m (Komatina *et alii*, 1984) and the highest is 2,565 m (ISP, 2010) while the average altitude is about 700 m (Komatina *et alii*, 1984). The territory of the Republic of Kosovo (Fig. 1) is relatively rich in surface and groundwater, and the largest amount of them belong to the Dukagjin Plain (western Kosovo). The territory of the country is divided into five watersheds: Drini i Bardhë, Ibër (includes the Sitnicë and Llapi River basin), Morava e Binçës, Lepenc and Plavë (Fig 1).

Surface waters emerge from the territory of the Republic of Kosovo to neighbouring countries at four points (Vërmicë, Pllavkovë, Dheu i Bardhë and Hani i Elezit) discharging water to three seas: Adriatic, Black Sea and Aegean (IH, 1983; ISP, 2010). The hydrographic network is represented by rivers of Drini i Bardhë, Ibër, Moravë e Binçës, Lepenc, Plavë and their tributaries of Lumbardhi River of Pejë, Prizren, Deçan, Klinë River, Mirushë, Toplluhë, Sitnicë, Llap, Kriva Rekë, Drenicë, etc. (Labus, 1979; IH, 1983; Çadraku, 2014; Pllana, 2015; MESPI, 2020; Çadraku, 2023; Çadraku *et alii*, 2023). Surface

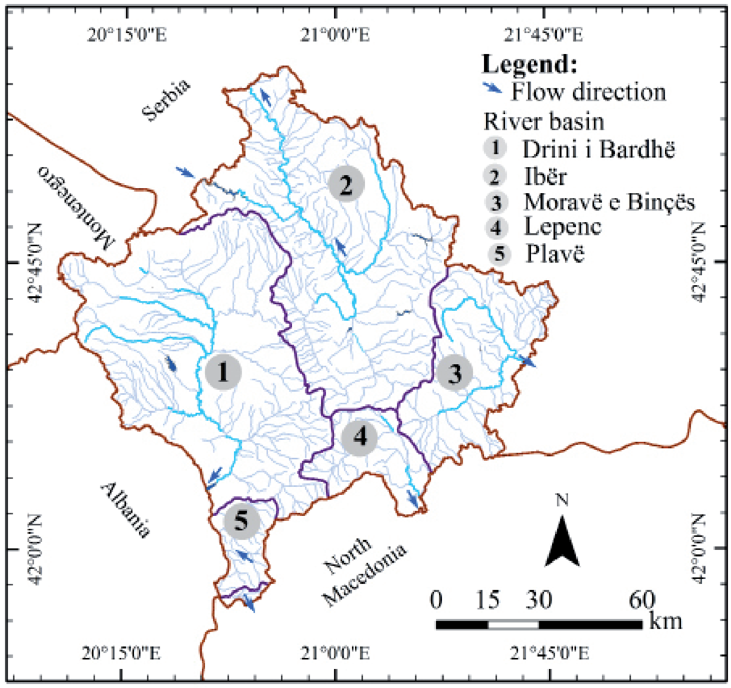

Fig. 1 - Physical-geographical position and river basins in Kosovo (Source: own elaboration)

waters are vital for aquatic flora and fauna, while they have served and are still serving to human society for several uses: drinking, irrigation, industry, energy, transportation, sports, recreation, etc. Consequently, recognizing, monitoring and controlling their quality takes on particular importance. In order to know the water quality in the hydrographic network of the Republic of Kosovo, a considerable number of scientific researchers have been conducted in recent decades, which are published in high scientific indexed journals.

The climate conditions

In the territory of the Republic of Kosovo, three types of climate dominate: Mountainous, Continental and Modified Mediterranean Climate (Pllana, 2015) interwoven with microclimates conditioned by the alternation of river valleys with high mountains, which leads to various modifications of the Mediterranean and continental climate. In the climatic conditions, the hydrographic network plays an important role by assuming a local microclimate (IH, 1983).

According to the Mazza (2025) the climate system can exhibit a degree of inertia across multiple temporal scales from short-term feedbacks to millennial scale processes.

The air temperature in the territory of Kosovo is subject to daily, monthly and annual fluctuations. The lowest temperatures are in January, February and December, while the highest temperatures are in July and August. Air temperatures (Prishtinë station) for the period 2020-2025 ranged from +30 °C (Summer) to -10 °C (Winter). So, the maximum average monthly air temperature in 2025 was in August (40.2 °C), while the average minimum temperature was in February (- 12.7 °C) (KAS, 2026). All forms of atmospheric precipitation are present in Kosovo. The most important precipitation is in the form of rain in the valleys and in the form of snow in the mountains (KAS, 2026). According to (KAS, 2025) the average rainfall for the period 2020-2025 varied from 595.2 mm (year 2025) to 809.1 mm (year 2021). The highest rainfall during this period was recorded in the western part of Kosovo Rrafshi i Dukagjinit (Dukagjini Plain with 906.9 mm in 2021), while the lowest rainfall was recorded in the central part Rrafshi i Kosovës (Kosovo Plain), with 569.8 mm in 2022.

Geology

The territory of the Republic of Kosovo is characterized by a variety of geological formations ranging from the crystalline Proterozoic to the Quaternary era, including sedimentary and igneous rocks along with subordinate metamorphic rocks (ICMM, 2006a; Lončarević, 1971). The Paleozoic formations are represented by shales, sandstone quartzites, limestones, greywackes and conglomerates. They are generally clastic rocks that contain metamorphosed parts. The schists are represented by clayey-schist, phyllites, mica-schist, albite-sericite, albite-chlorite schists, as well as metamorphosed quartz-conglomerates. They are spread in several parts of the territory of Kosovo, such as: the Sharr Mountains, the Alps (Bjeshkët e Nemuna), the (Mali i Thatë) Thatë Mountain (Menkoviq, 1995), the Blinajë Mountain, Çiçavicë, etc. The Triassic is represented mainly by limestones and dolomites which were formed under quiet sedimentation conditions (Mekshiqi *et alii*, 2009). The limestones are tectonically destroyed, with cracks and fissures. The density of the network of these fissures sometimes favours erosion and karst processes which, in turn, serve as pathways for groundwater flow. Their most visible distribution is in the western and north-western parts of Kosovo. The Jurassic formations are represented by the diabase-shale formation containing layers of soft limestone. They are spread to the south, southwest and west of the country. They are very heterogeneous and are represented by sandstones, siltstones, limestones, marls, clays, diabases and serpentinites. Ultramafic rocks, serpentinites, serpentinized peridotites, etc., are found in the Deva massif (ICMM, 2006a) (southwest of Kosovo), in the Golesh massif (central part) (Meshi *et alii*, 2012), etc. The Cretaceous is represented by limestones and flysch. The flysch formation consists of: siltstones, sandstones, limestones, marls, conglomerates and graywackes. It is spread in several areas of Kosovo, such as: in the Prizren area, Volljak (Elezaj & Kodra, 2008), etc. Limestones are spread mainly in Mount Pashtriku and Koritnik, Shkozë, in the central part of Kosovo, Mount Drenicë, Carralevë, Kosmaq (Ahmetaj, 1981) and other areas of Kosovo. They are represented by limestones, marly limestones and fragmental limestones. Thanks to the destructive tectonic effects, they have a developed system of cracks and fissures (Çadraku, 2014). The Miocene formations are represented by intercalations of sands with gravels, marls, with tuff levels, green sandstones, conglomerates and coal seams (IH, 1983). The Pliocene formations have a wide distribution and consist of gravels and clays. Quaternary sediments are widely distributed in river valleys. Pleistocene and Holocene sediments are represented by glacial and fluvioglacial deposits in the elevated parts of the terrain, while proluvial, deluvial and alluvial formations are widespread along the valleys (river valleys).

Hydrogeology

Based on the hydrogeological map (ICMM, 2006b), it results that the rocks with good hydrogeological characteristics spread out in the territory of Kosovo and are represented by alluvial deposits, rocks with cracks and fissures, and carbonate rocks (mainly karst limestone). Groundwater along river valleys forms aquifers with free water table (phreatic aquifers) and subartesian aquifers characterized by intergranular porosity. The fracture-type aquifers are hosted by faulted and fissured hard rocks. Carbonate rocks (limestone, dolomite, etc.) are of greatest interest from the aspect of groundwater storage, forming the type of karst aquifer from which a considerable number of water spring emerge. So, based on geological formations and their lithological, structural and tectonic features, the following types of aquifers have been distinguished in the territory of the Republic of Kosovo: a) aquifer with intergranular porosity with medium to high hydraulic conductivity (K_f>10^{-5} m/s) (aquifer medium: sand, sand and gravel, sand, gravel and silt); b) the Karst aquifer (K_f=10^{-3}-10^{-6} m/s) of the White Drini (Drini i Bardhë) watershed from which the largest springs in Kosovo discharge: the Radavc spring, Istog, Vrellë, Vërmicë, Poslisht, Opterushë, Zaqisht, Studençan, Bajë, etc; c) fractured porosity aquifer with medium to low filtration coefficient (limestone, limestone, marl, marble, metamorphic rocks, sandstone, conglomerate, limestone, marl, plutonic rocks). Filtration coefficient (K_f=10^{-5}-10^{-9} m/s); d) aquifer with intergranular porosity with low to very low filtration coefficient is related to clay, sand, silt, having hydraulic conductivity values of 10^{-5}-10^{-9} m/s; e) aquiclude formations, without intergranular and fracture porosity (sandstone, claystone, conglomerate, metamorphic, volcanic, plutonic and pyroclastic rocks), with filtration coefficient (K_f <10^{-9} m/s). The carbonate rocks (limestone, dolomite, marbled limestone) represent a favourable environment for the storage of groundwater in their depths. These rocks are rich in cracks, fissures, breaks, channels, caverns, pits, caves, etc., which favour the rapid infiltration of a large amount of precipitations and water that comes as a result of snowmelt. Based on literature data, it is shown that the precipitation infiltration coefficient in carbonate rocks (limestone, dolomite) is generally high, often ranging from 0.5 to 0.8 (50% to 80%) of annual precipitation.

Literature review

Numerous written and electronic literature are currently available in which surface and groundwater quality is addressed using WQI methods (for example: Zheng *et alii*, 2024; Jing Xu *et alii*, 2024; Aldrees *et alii*, 2024; Marselina, 2024; Sakke *et alii*, 2023; Patel *et alii*, 2023; Ariza-Restrepo *et alii*, 2022; Ramadani *et alii*, 2017; Bouslah *et alii*, 2017; Effendi, 2016; Tyagi *et alii*, 2013; Lumb *et alii*, 2011; Patel, 2011; etc.). Uddin *et alii* (2021) in their paper provide the historical development of the WQI model showing that the first model for

Number of parameters selected for WQI calculation	Number of WQI Models	Percentage
4	2	10
5	1	5
6	1	5
7	1	5
8	4	20
9	2	10
10	3	15
11	2	10
13	2	10
26	2	10

Tab. 1 - Number of parameters considered for WQI calculation (Uddin et alii, 2021, modified by the authors)

WQI was created by Horton in (1960) and then modified and developed by different authors until now when the 2nd modified version (West Java Index, 2017) is in use, which represents the modified version of NSF Indonesia. According to Uddin *et alii* (2021), since 1960 are used about 20 WQI models available,

Rating scale (number of classes)	Number of WQI Models	Percentage
Five	10	50
Four	3	15
Three	1	5
Seven	1	5
Not specified	4	20
Parameter based individual rating scale used	1	5

Tab. 2 - Rating scale of WQI models

which differ from each other by the number of water quality parameters selected for calculating the WQI index. Thus, the minimum and maximum number of water quality parameters considered in the WQI models was 4 and 26, respectively, while 4 of 20 models (20% of them) consider 8 parameters for calculating the WQI (Table 1).

WQI model	No. of Applications	Type of Study Area			Type of Study Area in Republic of Kosovo
		River	Lake	Marine /coastal/sea	River
CCME	36	28	5	3	3
NSF-WQI	18	17	1	-	3
FIS	12	10	1	1	-
MWQI	8	6	1	1	1
Horton	7	6	-	1	-
SRDD	6	6	-	-	-
Bascaron	4	3	-	1	-
EQI	2	1	1	-	-
Oregon	2	2	-	-	-
Smith	2	2	-	-	-
Almeida	1	1	-	-	-
BCWQI	1	1	-	-	-
Dalmatian	1	-	-	1	-
Dojildo	1	1	-	-	-
Dinius	1	1	-	-	-
Hanh index	1	1	-	-	-
House index	1	1	-	-	-
Liou index	1	1	-	-	-
Said	1	-	-	1	-
WJWQI	1	-	-	1	-

Tab. 3 - List of applied WQI methods

All WQI assessment models have a rating scale which indicates the water quality and is derived by the WQI model calculations. Most of WQI models (10 of 20) have a rating scale that includes 5 categories or classes (Table 2). The calculated WQI number ranges from 0 to 100.

Uddin *et alii*, (2021) provide in their study a summary of scientific publications that applied the WQI models during the period between 1960 and 2019 (Table 3), while this study complements the Table 3, provided by Uddin *et alii*, (2021), with publications by Kosovar authors (1999-2024) who used the WQI models to assess water quality.

Chidiac *et alii* (2023) provides data on the trend of publications from 1975 to 2022 in which the authors used the WQI model for water quality assessment (Fig. 2a), while in the (Fig. 2b), recent (2013-2023) Kosovar publications that used WQI model are shown.

Also (Chidiac *et alii*, 2023) in their paper show a trend of publications by country based on the use of the WQI model used for water quality assessment (Fig. 3a).

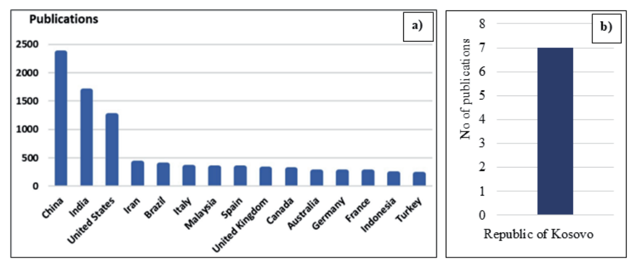

Fig. 3 - a) Acoording to (Chidiac et alii, 2023) and b) Source: own elaboration

Çadraku *et alii* (2013), applied the NSF-WQI model for the assessment of the River Drini i Bardhë water (Table 4). Based on the qualitative data for the monitoring period between the year 2005 and 2011 at five measuring stations on the River Drini i Bardhë, they found that the WQI of the River Drini i Bardhë water ranges from 50 to 70. A reassessment of the WQI of the river waters, at the same monitoring stations, would show the trend of the water quality changes over about 15 years during which significant demographic, industrial and agricultural progress has occurred along the valley of the River Drini i Bardhë.

Bytyqi *et alii* (2018) applied the NSF-WQI model for the

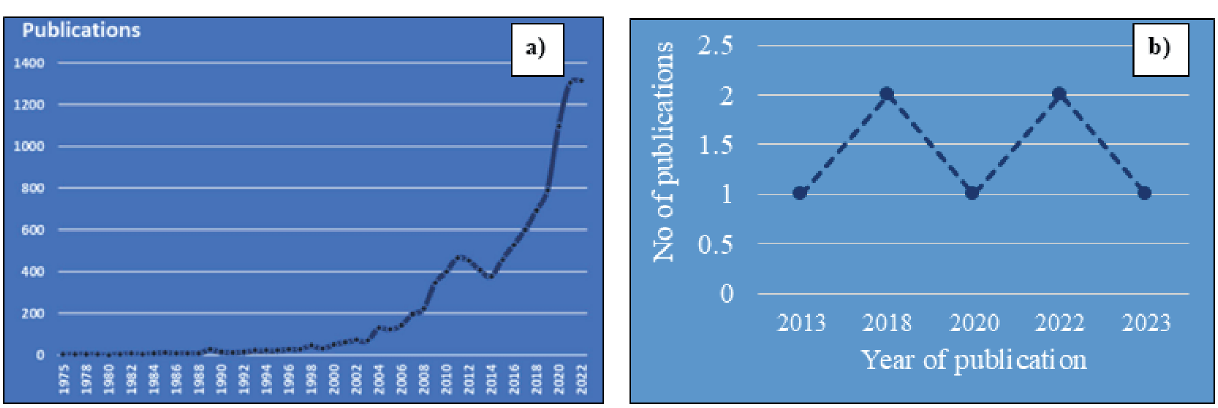

Fig. 2 - Trend in time of WQI publications a) Acoording to Chidiac et al., 2023 and b) in Kosovo

water quality assessment of the Lepenc River (Table 4) by using nine quality parameters. For this, they sampled waters in eight locations over three seasons (Spring, Summer and Autumn) and found the following WQI values: 54, 51 and 50 for the Spring, Summer and Autumn, respectively. Such values of the WQI classify the Lepenc water to the lower limit of the average (WQIrange=50-70) water quality range. While considering the variation of the WQI values across the eight sampled stations, an apparent trend of water quality deterioration is evidenced passing from the middle to the lower reaches of the Lepenc River.

Nura *et alii* (2023) applied the NSF-WQI model to evaluate water quality in the Drini i Bardhë River basin (Table 4). Water samples were taken in Lumbardhi of Pejë, in the water supply channel of the Radoniqi artificial accumulation and in the Radoniqi water accumulation during the year 2019, 2020 and 2021, respectively. This study revealed that the average water quality index for the three locations was 51.3 (Lumbardhi of Pejë), 52 (Radoniqi supply channel) and 55.3 (Radoniqi accumulation). These average WQI values of the water quality are within the range 50-70, ranking the water quality from these three locations as average (medium).

Note: Even the average WQI values in the Lepenc River and in three above locations of the Drini i Bardhë River (Lumbardhi of Pejë, Radoniq accumulation water supply channel and Radoniq accumulation) are similar, these values are not the result of the same physical-geographical, human activities or hydrological factors. In fact, the rivers of Drini i Bardhë and Lepenc differ significantly by the water flow quantity, the physical-geographical elements, geological structure, and civil, industrial, agricultural activities which are the main sources of water pollution.

Musliu *et alii* (2018) applied the CCME-WQI model to assess water quality in the Moravë e Binçës River (Table 4). They report an average water quality index WQIavg=77.60 for the Moravë e Binçës River water assessed at five different locations: Korbliq (WQI=88), Viti (WQI=86), Uglare (WQI= 67), Pogragjë (WQI=65) and Dheu i Bardhë (WQI=82).

Shala Abazi *et alii* (2020) used the CCME-WQI model to assess water quality of the Sitnicë River (Table 4). They reported an average water quality index (WQIavg) of 63.5 derived by WQI index values calculated at ten stations: WQI-S1 =95, WQI-S2=68, WQI-S3=60, WQI-S4=59, WQI-S5=71, WQI-S6=46, WQI-S7=53, WQI-S8=63, WQI-S9=64 and WQI-S10=56.

Rizani *et alii* (2022) used the CCME-WQI model to calculate the water quality index in the Lepenc River (Table 4) based on the qualitative data from three different locations: Hani i Elezit, Kaçanik and Brezovicë. The WQI calculation refers to data collected in 2009, 2010 and 2014 at the above-mentioned locations. They calculated an average value of WQIavg.=70.4 derived by the values provided for each location: WQIBrezovicë=81, WQIHani i Elezit=62.3 and WQIKaçanik=68.3. The results, as expected, reflect the sampling locations and the impacts of different human activities on the water quality of the Lepenc River.

Aliu *et alii*, (2022) used the Weighted Arithmetic Index method (WA-WQI) to calculate the WQI, for the assessment of water quality

No	Authors' names	Article title	Year of publication	Journal/Reference	WQI Methods
Surface Waters					
1	Çadraku H, Dobruna B, Beqiraj A	Assessment of the Surface Water Quality of the Drini i Bardhe Basin Using The Water Quality Index (WQI) Method	2013	International Journal of Ecosystems and Ecology Sciences (IJEES) Volume 3, issue III, 2013	NSF-WQI
2	Bytyçi, P.S., Çadraku, H.S., Zhushi Etemi F. N., M.A. Ismaili, O.B. Fetoshi and A.M. ShalaAbazi	The Assessment of Surface Water Quality in the Lepenc River Basin Using Water Quality Index (WQI) Methodology	2018	Rasayan J. Chem., 11(2), 653-660(2018) http://dx.doi.org/10.31788/RJC.2018.1123015	NSF-WQI
3	Arianeta Nura, Rozeta Hasalliu, Pajtim Bytyçi, Berat Durmishi, Shkëndije Sefa Haziri, Flutura Ajazi, Veton Haziri	Application of water quality index for assessment of surface water, Dukagjini Region, Kosovo	2023	Ecologia Balkanica, 2023, Vol. 15, Issue 2	NSF-WQI
4	Milaim Musliu, Astrit Bilalli, Bujar Durmishi, Murtezan Ismaili, Halil Ibrahimi	Water Quality Assessment of the Morava e Binçës River Based on the Physicochemical Parameters and Water Quality Index	2018	Journal of Ecological Engineering. Volume 19, Issue 6, November 2018, pages 104–112	CCME-WQI
5	A. M. Shala Abazi, B. H. Durmishi, F. S. Sallaku, H. S. Çadraku, O. B. Fetoshi, P. H. Ymeri and P. S. Bytyçi	Assessment of Water Quality of Sitnica River by Using Water Quality Index (WQI)	2020	Rasayan J. Chem., 13(1), 146-159(2020) http://dx.doi.org/10.31788/RJC.2020.1315344	CCME-WQI
6	Smajl Rizani, Fidan Feka, Osman Fetoshi, Bujar Durmishi, Shkumbin Shala, Hazir Çadraku, Pajtim Bytyçi	Application of Water Quality Index for the Assessment the Water Quality in River Lepenci	2022	Ecological Engineering & Environmental Technology 2022, 23(4), 189–201 https://doi.org/10.12912/27197050/150297 ISSN 2719-7050, License CC-BY 4.0 & ENVIRONMENTAL TECHNOLOGY	CCME-WQI
7	Mehush Aliu, Sabri Hajdini, Faruk Hajrizi	Assessment of Water Quality Index in the River Ibër	2022	Journal of Chemical Technology and Metallurgy, 57, 4, 2022, 780-786	WAWQI
Groundwater					
1	Hazir Çadraku	Quantitative and Qualitative Characterization of the Curreli Spring Groundwater, Golesh Massif, Kosovo	2022	IFAC Papers OnLine 55-39 (2022) 36-41	CCME-WQI
2	Cadraku H.S., Beqiraj A.	Assessment of water quality in Blinaja River Basin (Kosovo) using the Canadian Water Quality Index (WQI)	2023	Journal of Survey in Fisheries Sciences 10(1) 29-47 2023	NSF-WQI+CCME-WQI
3	Çadraku HS, Laha F, Gashi F and Fetoshi O	Groundwater quality assessment using the water quality index: case study in the north-western part of Drini i Bardhë River basin, Kosovo	2023	Journal of Environmental Engineering and Science 18(2):81-93,	WA-WQI

Tab. 4 - List of publications that applied WQI methods for water quality assessment in Kosovo (Source: own elaboration)

in the Ibri River. They calculated water quality indexes at four different locations in the Ibër River watershed: WQI-S1=69.479, WQI=S2=65.509, WQI-S3=127 and WQI=S2=170.13.

Summarizing the above publication data, it results that the assessment of water quality in Kosovo's rivers was conducted by applying the NSF-WQI, CCME-WQI and WA-WQI (or M-WQI) index methods, of which, seven works applied WQI methods for the assessment of surface waters quality and three others for assessing groundwater quality (Table 4). The publications are available on the electronic platforms Web of Science, Scopus, etc. (Table 4).

METHODS AND MATERIALS

The evaluation of water quality applying different WQI methods consists in two main stages: the first includes water sampling and laboratory analysis of the required water quality parameters, while is focused on data processing and WQI calculation, water quality classification, drawing results and conclusions. This paper aims to bring a systematic review of the written and electronic literature which was collected from a wide range of reliable scientific databases such as: Web of Science, Scopus, JSTOR, Google Scholar, PubMed, ResearchGate. Some of the previously published or recent scientific research papers that were relevant to this research were referenced (cited) within this paper. The methods differ from each other in water quality classifying ranges, that is, on the value of the WQI index (Table 5), but the differences between the intervals and the description of the water quality status in the NSF-WQI and CCME-WQI methods are not significant, while in the WA-WQI method a difference is also shown in the class's description. In addition, here we have Water Type (Class) and the last range (above 100) which is unlimited.

NSF-WQI		CCME-WQI		WA-WQI	
Index	Quality status	Index	Quality status	WQI	Water Types (Class)
91-100	Very Good	95-100	Very Good	0-25	Excellent water
71-90	Good	80-94	Good	26-50	Good water
51-70	Fair	60-79	Fair	51-75	Poor water
26-50	Bad	45-59	Marginal	76-100	Very poor water
0-25	Very Bad	0-44	Bad	Above 100	Water unsuitable for drinking purposes

Tab. 5 - *Classification of water quality status according to WQI methods (Source: own elaboration)*

RESULTS AND DISCUSSIONS

This review paper evidenced that Kosovar researchers applied NSF-WQI, CCME-WQI and WA-WQI methods to calculate the WQI for assessing the quality of Kosovo waters. The map of water quality index calculation points in the rivers of the Republic of Kosovo is shown in (Fig. 4a).

NSF-WQI method

The lowest (41) WQI value, calculated using the NSF-WQI method, were found in the Lepenc River basin in 2018, while the highest (170.13) ones, calculated using Weighted Arithmetic Index method (WA-WQI), were found in the Ibër River basin in 2022.

The water quality index (WQI) in the surface waters of the Drini i Bardhë River basin, for the period 2005-2011, varied from a minimum value of 63 (year 2010) to a maximum of 80 (year 2007), with an average value of 71.8±4.61, classifying its water quality as Fair to Good. The lowest water quality index, ranging from 63 (2010) to 70 (2011), with an average value of 67±2.19, was reported at the Piranë monitoring station, classifying its water quality as Fair. Such water quality at this station could be expected considering its physical-geographical position where this station is located, the discharge of polluted waters derived by different contamination sources but mostly by an wide intensive agricultural area and, finally, the decrease of the river water flow, followed by a pollution charge in the water and respective of the natural self-purification of the river water. In fact, from the upper to the middle course of the Drini i Bardhë River where the Piranë station is located, the quality index shows a slight decrease (Fig. 4b), while at the two stations in the middle river course both good and fair quality waters are present without showing and prevalence. So, as it could be expected, the waters of the Drini i Bardhë River are more polluted in the middle and lower reaches, which in many situations. Addressing the evaluated water quality to monitoring stations, the good quality (WQI=71-90) waters belong to two upstream (Deçan and Klinë) stations decreasing downstream to fair quality (WQI=51-70) waters in Piranë station. The alternation of fair and good quality waters is characteristic for the two stations (Gjonaj and Vllashje) located in the lower part of the river course.

The water quality index (WQI) classified the Lepnec River basin waters for the year 2018 as Bad (WQImin=41) with a tendency to Fair-Good (WQImax=73) with an average value of WQIavg=51±12.51. Bytyqi *et alii*, (2018) evidenced a decrease of WQI values that is a deterioration of water quality from upstream locations (Nerodime) to downstream ones (Lepenc), which is similar to that reported for the Drini i Bardhë River Basin water.

The water quality monitoring over three years (2019, 2020, 2021), at three locations (Lumbardhi Pejë, Derivative Channel and Radoniq accumulation) in the Drini i Bardhë River Basin showed that values of WQI ranging from a minimum of 51 to a maximum of 55 with an average value 53±2.14 falling in Fair water quality class.

For the same above years, Nura *et alii*, (2023) noted that the water quality distinguishes the Lumbardhi Pejë station (WQIavg.=51.3) from other monitoring station of Drini i Bardhë River basin and also from two other stations in the upper reaches of Drini i Bardhë River (Derivative Channel which leads water to the artificial surface water accumulation Radoniq) and Radoniq accumulation.

This WQI value at the two upstream stations of Drin i Bardhë River basin (Derivative Channel and Radoniq accumulation), opposites the above-mentioned water quality deterioration from upper to lower reaches, reported for both Drin i Bardhë and Lepenc rivers. On the other hand, the higher average value of WQIavg. index=55.3 in the water of the Radoniq accumulation against that in the Derivative Channel may be consequence of the higher amount of water and of assimilation processes of the pollutants that are more probable within the Radoniqi accumulation ecosystem.

CCME-WQI method

The method was applied for calculating the water quality index (WQI) in the Lepenc, Sitnicë and Moravë e Binçës river catchment. The WQI values calculated using the CCME-WQI classified the water of the Lepenc River as good and fair. The best water quality in this case is found in the upper reaches, that is similar to that of the Drini i Bardhë and Lepenc rivers according to NSF-WQI method, The water quality in the Moravë e Binçës River, being Good and Fair, shows a similarity with the Gjonaj and Vllashje stations of the Drini i Bardhë River, apart from the method used in the classification of water quality.

The application of the CCME-WQI method for calculating the WQI index, showed that Sitnicë River water quality belongs to Very good, Fair and Marginal classes. The highest values of WQI (95) are found at the Devetak station (Fig. 4c) which is in the upper part of the Sitnicë River watershed, where there is no human (industrial, agricultural, infrastructure, etc.) activities or they are scarce. A low effect could be expected road traffic aside the left river bank to the water sampling point (Devetak). Shala-Abazi *et alii* (2020) reported a water quality deterioration (Fair to Marginal) in the middle and lower reaches of the river watershed (Fig. 4c). This deterioration of water quality from the Vojnoc to the Mitrovica station (where the Sitnicë River discharges into the Ibër River) was caused by urban, industrial and agricultural activities concentrated in the Rrafshi i Kosovës (Kosovo Plain), whose water discharges are generally not treated before being entering the river water. So, apart from the WQI method conducted for the water quality characterization, in all the above mentioned research studies on the Drini i Bardhë, Lepenc and Moravë e Binçës watersheds, the deterioration of water quality in the river occurs mainly in the middle course, thus showing that this segment is more loaded with pollutants of various types.

Finally, Aliu *et alii* (2022) used the Weighted Arithmetic Index method (WAWQI) to assess water quality in the Ibër River classifying river water as poor water (location S3, WQI-S3=127) and water unsuitable for drinking purposes (location S2, WQI= 170.13) (Table 4; Fig. 4d).

Currently, 7 scientific publications have been found on the electronic platforms Web of Science, Scopus, etc., where authors from the Republic of Kosovo have published their works on the assessment of surface waters in Kosovo Rivers by applying the water quality index or WQI. In three publications, the authors used the NSF-WQI method (model), respectively the CCME-WQI method, while only in one paper was the WA-WQI method (model) used. All scientific publications issue a quality index for water in Kosovo's rivers which ranks these waters mainly in the middle class (with average quality). An excess of values is shown

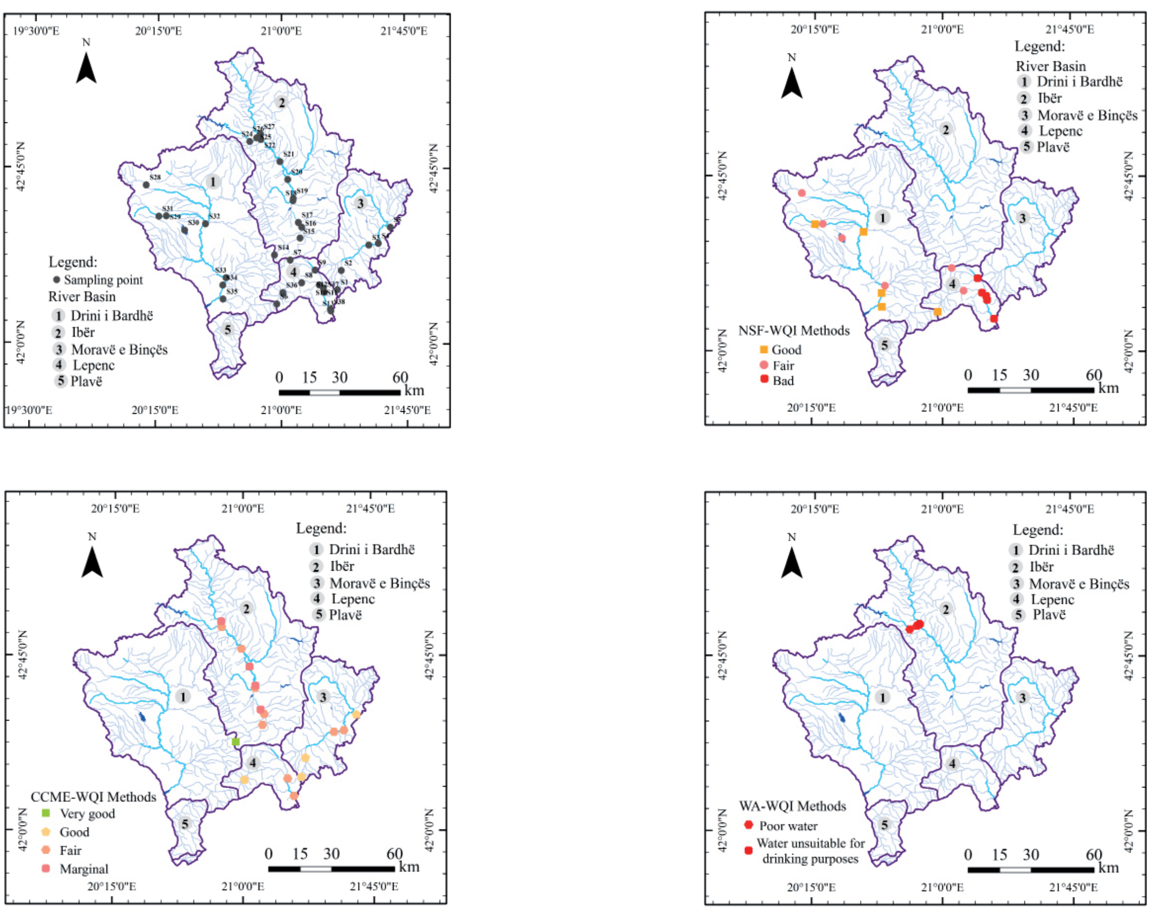

Fig. 4 - a) Sampling point and WQI according to the method: b) NSF-WQI; c) CCME-WQI and d) WA-WQI (Source: own elaboration)

River Basin Name	Number of water sampling stations	Sampling time / year	WQI values	Water Quality Status
NSF- WQI Method				
Drini i Bardhë	5	2005	79	Good
		2006	75	Good
		2007	80	Good
		2008	76	Good
		2009	76	Good
		2010	79	Good
		2011	77	Good
		2005	77	Good
		2006	74	Good
		2007	78	Good
		2008	74	Good
		2009	77	Good
		2010	74	Good
		2011	66	Fair
		2005	68	Fair
		2006	66	Fair
		2007	68	Fair
		2008	67	Fair
		2009	66	Fair
		2010	63	Fair
		2011	70	Fair
		2005	73	Good
		2006	68	Fair
		2007	69	Fair
		2008	72	Good
		2009	72	Good
		2010	66	Fair
		2011	73	Good
		2005	74	Good
		2006	66	Fair
		2007	68	Fair
		2008	70	Fair
		2009	67	Fair
		2010	72	Good
		2011	73	Good

River Basin Name	Number of water sampling stations	Sampling time / year	WQI values	Water Quality Status
NSF- WQI Method				
Lepenc	8	2018	73	Good
		2018	53	Fair
		2018	68	Fair
		2018	43	Bad
		2018	46	Bad
		2018	42	Bad
		2018	44	Bad
		2018	41	Bad
Drini i Bardhë	3	2019	51.3	Fair
		2020	52	Fair
		2021	55.3	Fair
CCME-WQI Method				
Lepenc	3	2009, 2010, 2014	81	Good
		2009, 2010, 2014	62.3	Fair
		2009, 2010, 2014	68.3	Fair
Moravë e Binçës	5	2018	88	Good
		2018	86	Good
		2018	67	Fair
		2018	65	Fair
		2018	82	Good
Ibër	10	2020	95	Very Good
		2020	68	Fair
		2020	60	Fair
		2020	59	Marginal
		2020	71	Fair
		2020	46	Marginal
		2020	53	Marginal
		2020	63	Fair
		2020	64	Fair
		2020	56	Marginal

River Basin Name	Number of water sampling stations	Sampling time / year	WQI values	Water Quality Status
Weighted Arithmetic Index method (WA-WQI)				
Ibër	4	2022	69.479	Poor Water
		2022	65.509	Poor Water
		2022	127	Water Unsuitable for Drinking Purposes

Tab. 6 - Water quality index in the hydrographic network of the Republic of Kosovo (Source: own elaboration)

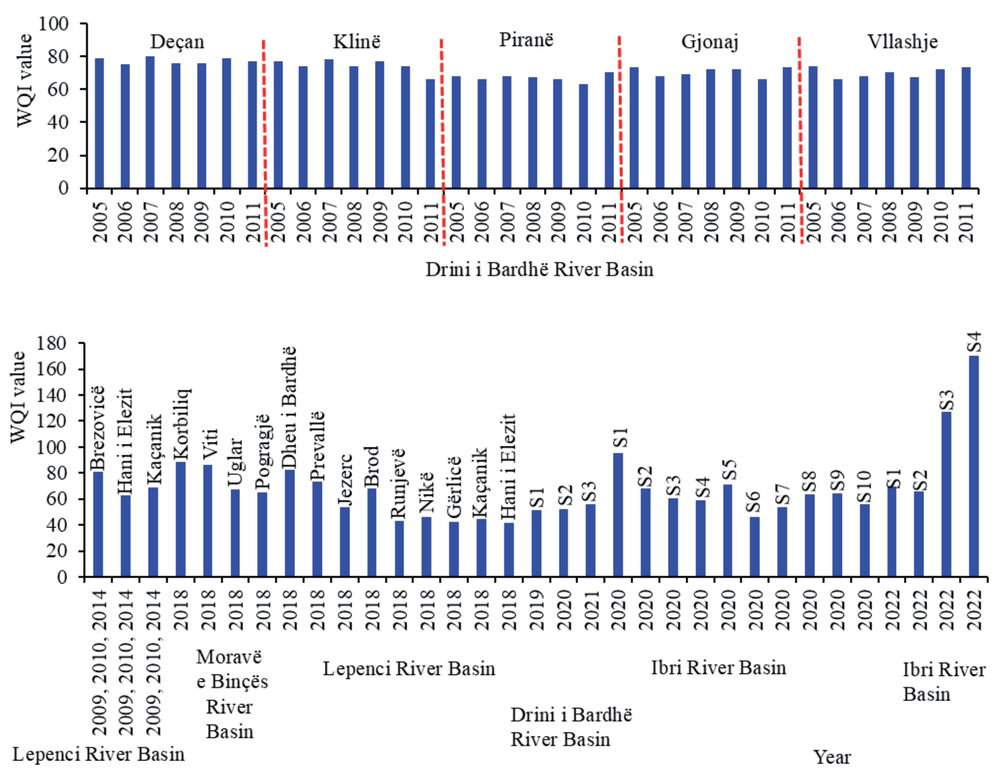

Fig. 5 - Variation of the water quality index in the hydrographic network of the Republic of Kosovo (Source: own elaboration) (Note: S1, S2,…,S10, are the symbols of the stations where water samples were taken)

in two locations (Table 4). A sampling point (Figure 4a) and the WQI performance in the Rivers of the Republic of Kosovo based on these data (scientific publications) from 2013, 2018, 2020, 2020 and 2023 is shown in (Fig. 4b, c, d). The spatial distribution of WQI values in the rivers of Kosovo is shown according to the method: a) NSF-WQI; b) CCME-WQI and c) WA-WQI (Fig. 4b, c, d).

In the Table 6 and Fig. 5 are summarized the findings from all researches to date regarding the assessment of water quality in the rivers of the Republic of Kosovo through the use of water quality index (WQI) calculation methods.

CONCLUSIONS

The physical and geographical context, climate, geology, pedology, land use, distribution of residential areas, pollution from urban, industrial and agriculture activities, mining of riverbed alluviums, disposal of various liquid and solid waste into rivers, lack of the polluted waters treatment, altogether have contributed to the deterioration of the river water quality in Kosovo. This review paper of the recent studies that applied different WQI methods for assessing water quality concludes that the calculated WQI values give a real view on the quality of water in the rivers of the Republic of Kosovo. We can also conclude that methods such as: NSF-WQI, CCME-WQI and WA-WQI represent a very suitable, fast and productive tool to highlight the water quality in the hydrographic network (surface waters) through the WQI index which is a number and then easily communicable and understandable for the wide audience. On the other hand, the quality parameters that these methods take in consideration for the WQI calculation, are analytically available. Finally, a water quality assessment through the Water Quality Index (WQI) is visible in the National List of Environmental Indicators.

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