III

Streaming Tears of The Middle East

How to Clean The Euphrates and Tigris Basins?

Dr. Sudeh Dehnavi,
Dr. Muhammad Khalifa,
Zryab Babker, Prof. Dr. Lars Ribbe
In cooperation with ENRoot GmbH

Dr. Sudeh Dehnavi

CEO and founder of the ENRoot GmbH

Sudeh is an expert in the sustainable development of food and water systems, especially in the fields of natural resources and agricultural economics, food and water security, and sustainability entrepreneurship. Her experience is focused on strategic planning and coordination of international development projects and networks.

Dr. Muhammad Khalifa

Research Associate at TH Köln

Water-Food-Climate Nexus; Sustainable development in transboundary basins

Preface

As an international and interdisciplinary team of researchers, we aim to share good practices on how rivers can be cleaned, particularly in the Euphrates and Tigris basin.

At first readers may directly think of lessons learned on technological advancements in treating polluted water. However, having learned from less successful experiences, we are convinced that knowledge transfer from one basin to the other without considering the socio-economic, cultural, environmental, and political compatibility of both regions may result in higher risks of failure.

Technology is only one part of the solution, which should comprise other components. Therefore, we do not restrict this paper to the lessons learned from existing technologies to clean Euphrates and Tigris, but rather we focus on the necessary prerequisites and institutional arrangements for a successful technology transfer. We trust that this knowledge would support the practitioners in choosing and investing in the proper technologies that fill their demand, considering the facts that:

- The Euphrates and Tigris basin is a transboundary basin, shared among six countries.
- The source of water pollution and its effects are disentangled.
- Iraq is located in the downstream region of the Euphrates and Tigris basin.

Discussing the river's share in Iraq means dealing with pollution whose source may be in an upstream country. Therefore, it is challenging to devote efforts for a clean Euphrates and Tigris at the Iraq level without considering this basin's transboundary context. At the same time, we are interested in lessons learned practices applicable at the Iraq

level, even if the transboundary collaboration is not yet in force. Indeed, to set up a partnership at the transboundary level, each riparian country should provide the required infrastructure and legal and institutional arrangements at the country level. Therefore, the lessons learned addressed in this document are applicable to both levels, i.e., country and transboundary basin. In fact, Iraq could play a key role in forming such a partnership by presenting a showcase of the region's best practices.

Moreover, ensuring a clean Euphrates and Tigris is mostly about avoiding pollutants' sources from entering the rivers. As many sectors may be identified as sources of pollution, e.g., industries, farmers, consumers, and other stakeholders, they should be involved in the effort to clean the river, supported of course by legislation, monitoring, and financial mechanisms. Integrated Water Resources Management, to a good extent, provides the required frameworks for this purpose.

Based on the above-mentioned arguments, we have selected the example of the Rhine basin for knowledge transfer of best practices that can lead the way forward to clean the Euphrates and Tigris. The Rhine basin is a successful and inspiring case for transboundary cooperation and water resources management practices.

We are fully aware that transferring knowledge from the Rhine basin to the Euphrates and Tigris basin is ambitious. Though the pollution situation in the current Euphrates and Tigris basin is comparable to the Rhine basin in the past, the two regions experience very different social, economic, and political conditions. Those differences may influence the degree of the feasibility, applicability, and success of the lessons learned. Still, we believe that the lessons learned in this work could serve as an inspiration for stakeholders in Iraq and the Euphrates and Tigris basin. This paper presents a collection of different frameworks, infrastructures, and actions implemented to clean the Rhine basin.

Zryab Babker

Research Associate

Research Associate at TH-Köln and co-founder of RICOS-WATER, Sudan. Water resources modeling, management and engineering expert with more than 8 years of experience, working on different international development projects related to water and land resources management and their interactions.

Prof. Dr. Lars Ribbe

Dean of Faculty of Spatial Development and Infrastructure Systems at TH Köln; Professor for Integrated Land and Water Resources Management.

Summary

The Euphrates and Tigris basin consists of all the rivers, canals, and streams that drain to the Euphrates and Tigris rivers, involving tributaries that flow from neighboring countries and join in Iraq. Water in the Euphrates and Tigris basin is highly polluted, especially in Iraq - the most downstream country. Demographic pressure, hydro-engineering development, and the impacts of agriculture and industrial development in the riparian countries are counted as the main reasons.

Improving water quality in the basin is a complex challenge controlled by many factors of physical, legal, and political nature. As it is shared between Turkey, Syria, Iraq, Iran, Jordan, and Saudi Arabia, the transboundary status of this basin adds more complexity to the challenge. The riparian countries are highly dependent on the Euphrates and Tigris; however, transboundary cooperation between the countries sharing the Euphrates and Tigris basin is relatively low. Preserving good water quality is imperative to ensuring sustainable development in these countries.

During the last decades, different approaches have been developed and implemented in many transboundary basins worldwide to conserve and enhance the water quality of rivers. Examples of best practices include, but are not limited to, the Rhine and Danube river basins.

Transferring knowledge from such basins, with regards to the prerequisites and best practices for cleaning rivers and preserving good water quality under transboundary conditions, is crucial. However, to ensure the efficiency and effectiveness of the lessons learned from other transboundary basins, they should be sifted through, and their application has to be adapted according to the specific conditions in the Euphrates and Tigris basin.

In the current study, literature review and expert interview approaches are used to produce evidence-based knowledge that is understandable and applicable to a broader audience. This paper aims to support policy-makers, public authorities, environmental Non-governmental Organizations (NGOs), International NGOs (INGOs), and environmental activists to better understand the water quality status in the basin, the operational conditions, and potential pathways to enhance water quality and restore a clean Euphrates and Tigris basin.

The paper describes the status of water quality in the basin based on a detailed literature review. Moreover, a framework of the controlling factors in preserving clean rivers is created and a list of best practices is compiled. The case study results are fine-tuned by interviewing local experts concerning the socio-economic, political, and ecological conditions of the Euphrates and Tigris basin.

1. Along The Euphrates and Tigris

1.1. Geographic Setting

The Euphrates and Tigris river basin is a transboundary basin shared mainly between Iraq (45.8%), Turkey (20%), Iran (18.9%), and Syria (13.1%), with tiny portions in Jordan and Saudi Arabia (McCracken and Wolf, 2019). Both rivers originate in Turkey. While the Euphrates rises near Mount Ararat at an elevation of around 4500 m above sea level (a.s.l) near Lake Van, the Tigris river's leading source is Hazar Lake, which is located at an elevation of 1150 m in the southeastern region of Turkey. Most of their streams go through the highlands of eastern Anatolia in Turkey and the valleys of the Syrian and Iraqi plateaus before entering the arid plain of Mesopotamia and joining each other near Qarmat Ali, about 160 km above the head of the Persian Gulf (also known as Arabian Gulf), forming the Shatt al-Arab river (Issa et al. 2014). However, upstream within Iraq, both rivers are connected through several human-made canals. Figure 1 displays the geographical location of the basin with its riparian countries. This basin's water is crucial to sustaining human lives and the socio-economic development in the riparian countries, especially for Iraq, Turkey, Iran, and Syria - the countries that heavily rely on its water.

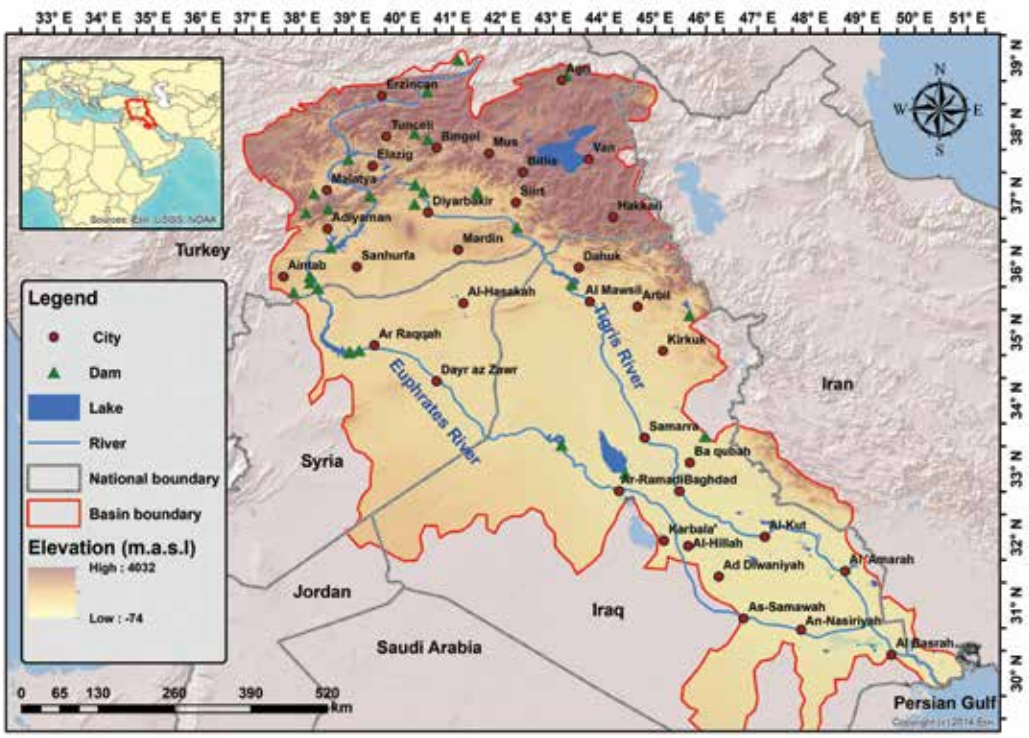

Figure 1. Location map of the Euphrates and Tigris basin with the riparian countries.

Data sources: DEM: SRTM Tile Grabber (https://dwtkns.com/srtm/); River network: WorldMap (https://worldmap.harvard.edu/maps/8246); Major cities: ArcGIS Hum (https://hub.arcgis.com/); Major dams: Global forest watch.org (https://data.globalforestwatch.org/).

1.2. Current Status of Surface Water in The Basin

The Euphrates-Tigris river basin is characterized by large temporal and spatial variations in rainfall with an average of 335 mm/year (New et al. 2002). Water resources in the basin consist of surface water mainly from the Euphrates and Tigris rivers and their tributaries, and from limited groundwater resources. The region currently faces water shortage problems due to the rapid growth and development in the region, which makes it challenging to meet the increasing demand and creates competition and tension between the riparian countries over the available water resources. Figure 2 shows the percentage of water withdrawals by each of the riparian countries. Issa et al. (2014) showed that Iraq receives 45.4 and 25.52 billion cubic meters (BCM) of water annually from Euphrates and Tigris, respectively. Those figures are expected to decrease down to 9.16 and 8.45 BCM in 2025 on average (UN Iraq, 2013), mainly due to the expected effects of climate change and the upstream countries' storage projects.

Box 1: Water - the most basic resource

Water is a vital resource to sustain life and socio-economic development on Earth. Look around you! Nothing on the planet can survive without water. Some organisms, such as certain types of bacteria, can live without oxygen, but they cannot survive without water. Every living thing, from humans and animals to plants and bacteria, needs water to flourish. Would you be surprised if you knew that the human body is composed of a large amount of water? On average, an adult's body consists of 60-65 %

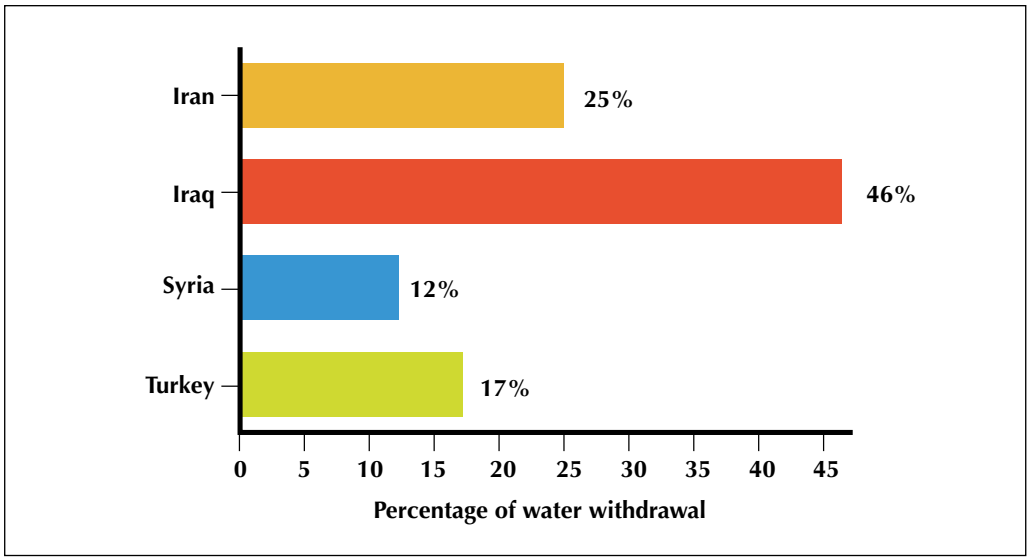

Figure 2. Total water withdrawals by the different countries in the Euphrates and Tigris basin (in percentage of the total withdrawal) based on data from TWAP (http://twap-rivers.org/#global-basins)

water by weight. Humans need water to drink, irrigate crops, grow livestock, generate energy, and produce goods in factories. Water has played an essential role in human history. A closer look at the ancient civilizations' distribution map reveals that these civilizations are centered mostly along rivers and nearby water resources. Examples of such ancient civilizations include the Akkadian, Sumerian, and Babylonia along the Euphrates and Tigris rivers, and the Pharaonic, Nubia, and Aksum civilizations along the Nile. Water has played a key role in the fall of many old civilizations, including the Akkadian Empire in Mesopotamia and the Old Kingdom in Egypt, which had collapsed due to severe drought that extended over a long period of time (Sheffield and Wood 2011).

All of the water in the Euphrates river comes from outside the Iraqi border, while its tributaries inside Iraq supply around 60% of the Tigris discharge whereas the rest comes from Turkey. Groundwater aquifers in Iraq consist of extensive alluvial deposits of Euphrates and Tigris, and have limited potential because of the low water quality that results from over-abstraction.

Artificial storage to manage the basin's surface water resources is necessary due to environmental conditions. Flow rates in the Euphrates and Tigris rivers fluctuate considerably between seasons and years, making water use for irrigation and other purposes difficult without proper planning and management. Water storage plays an important role, mostly in overcoming spatial and temporal variation of water availability. That is why around 32 major dams and several diversion canals have been built in the basin during the last decades by the riparian countries. Figure 3 shows the percentages of water withdrawals for different purposes in the main countries in the basin.

By constructing the Al Hindiya and Ramadi-Habbaniya dams on the Euphrates in 1914 and 1951, respectively, Iraq was the first country in the basin to construct engineering projects in both rivers. The primary purpose of these dams was to control floods and use the stored water for irrigation purposes. More dams and irrigation canals were then constructed to continue managing the water of the Euphrates and Tigris rivers and their main tributaries for irrigation and other uses, with a total on-river storage capacity of 115.9 BCM (FAO, 2009; Issa et al., 2014).

As demonstrated in figure 3, most of the water in the basin is allocated for irrigation purposes. However, in all riparian countries, the agriculture sector's contribution to the Gross Domestic Product (GDP) is relatively small (Table 1). Yet, it should be considered that the agriculture sector in the whole region mainly consists of small farm households and subsistence agriculture. Moreover, though the agriculture sector's GDP share is low, between 10% to 20% of the total employment in the riparian

countries is in agriculture, which is the main water-consuming sector in the basin. For instance, although around 46% of the total water withdrawals in the Euphrates and Tigris basin are taking place in Iraq and 87.3% of the water is used for irrigation purposes, the agriculture sector's contribution to the GDP of Iraq is only 2%.

Figure 3. Dependency of different sectors on water availability.

Source: TWAP (http://twap-rivers.org/#global-basins)

Country	GDP (Gross Domestic product) (Billion US$)	GDP per capita (current US$)	Agriculture, forestry, and fishing, value-added (% of GDP)	Employment in agriculture (% of total employment)
Iran	445.35 (2017)	5520.31 (2017)	9.5 (2017)	17.816 (2020)
Iraq	234.09 (2019)	5955.11 (2019)	2 (2019)	17.788 (2020)
Syria	40.41(2007)	2032.62 (2007)	19.54 (2007)	10.494 (2020)
Turkey	754.41 (2019)	9042.49 (2019)	6.43 (2019)	18.02 (2020)

Table 1. The economic status of the Euphrates and Tigris riparian countries (Saudi Arabia and Jordan are not included because of their small share of the area).

Source: (World Bank, 2020)

Box 2: Transboundary basins

There are around 310 transboundary basins (McCracken and Wolf 2019) around the world shared between two or more countries, including the Euphrates and Tigris, Nile, and Rhine basins. These basins are significant because they accommodate a large fraction of the world population. What makes these types of basins challenging for water resources management is that the political boundaries do not confine water, and a river that originates in one country might cross the border and flow to a neighboring country. Managing water resources in such transboundary basins is more challenging as each riparian country might have its own development plans and water use policies. This can cause severe disputes between these countries, especially if there is no cooperation framework or treaty to guide and govern water sharing between the riparian countries. Examples of such conflicted river basins in the Middle East region include the Euphrates and Tigris, and the Nile. For example, Iraq cannot manage the Euphrates and Tigris without communicating and cooperating with Turkey and Syria - the upstream countries. Interventions at the upstream parts of the transboundary basins would affect the downstream regions. Usually, these riparian countries have different and perhaps conflicting development plans, and any intervention in the upstream countries might have consequences on water quantity and/or quality in the downstream countries. Without cooperation between the riparian countries that share transboundary basins, proper water management in such basins might be a complex challenge.

1.3. Water Sector in Iraq

1.3.1 Main stakeholders in the Iraqi water sector

The Ministry of Water Resources in Iraq is the main responsible body for water resources management. It takes measures to overcome all challenges related to water resources in the country by having well-defined strategic water management plans, including cooperation and coordination with other riparian countries, research and development, improving agriculture and sanitation sectors, and conducting public awareness programs. Other stakeholders involved in the water sector are the water users (e.g., environment, municipalities, agriculture, and industry), the Ministry of Health and Environment, the inter-ministerial National Water Council, the private sector, and NGOs involved in water and sanitation work.

1.3.2 Main water users in Iraq

According to recent estimates by the Ministry of Water Resources in Iraq, the vast majority of water in Iraq (more than 85% of the total withdrawal) is used for agriculture (Fig. 3). Municipal and

industrial water needs, as well as those of the Mesopotamian Marshlands, come in the second place, although the actual water sent to the marshes varies from year to year. In third place (at 6%) is water sent to the Gulf via the Shatt al-Arab river as an environmental flow requirement, and then finally comes water use for fish farms and livestock. The Iraqi Energy Institute (IEI) in 2018 reported the current water supply to urban areas to be around 73% coverage. In rural areas, this falls to 40 - 45%.

Box 3: Water is not just water!

Earth is composed of several distinct but continuously interacting systems. These systems include, for instance, the hydrosphere (all water on Earth, including rivers, lakes, and oceans) and the biosphere (all living organisms, including humans, animals, and plants). Water is a connector resource that links many of the components of Earth's systems. Therefore, for the sound management of water resources, one should not overlook such crucial interlinkages. For example, humans (bio-sphere) are severely affecting water resources (hydrosphere), not only in terms of water quantity but also in quality. Currently, there is a wide agreement on the importance of holistic (integrated) approaches for water management, the so-called «Integrated Water Resources Management (IWRM).» The main objective of the IWRM concept is to manage all the available water and land resources in a coordinated and integrated way and an equitable manner, to maximize their economic return and social welfare, taking into consideration the sustainability of those resources for the future generation. It looks at water resources beyond the political borders between riparian countries and promotes managing the basin's resources as one system. Water management involves several disciplines, including, but not limited to, science, water, social sciences, economy and project management. These disciplines should be involved in water management activities to ensure the effectiveness of the proposed solutions.

2. Problem Dimensions: why is the basin's water quality so bad?

Iraq is facing many challenges in managing its water resources, partially due to external reasons, but mainly because of the mismanagement of internal water resources. This, consequently, has affected water services, which in some cities are limited to a few hours per day, and where the water is often of poor quality and, in many cases, undrinkable (Al-Ansari, 2013). These challenges are summarized in figure 4. Among them, the two overarching challenges that affect water quality in the basin are the lack of adoption and implementation of Integrated Water Resources Management (IWRM) principles, and the poor transboundary cooperation between the riparian countries.

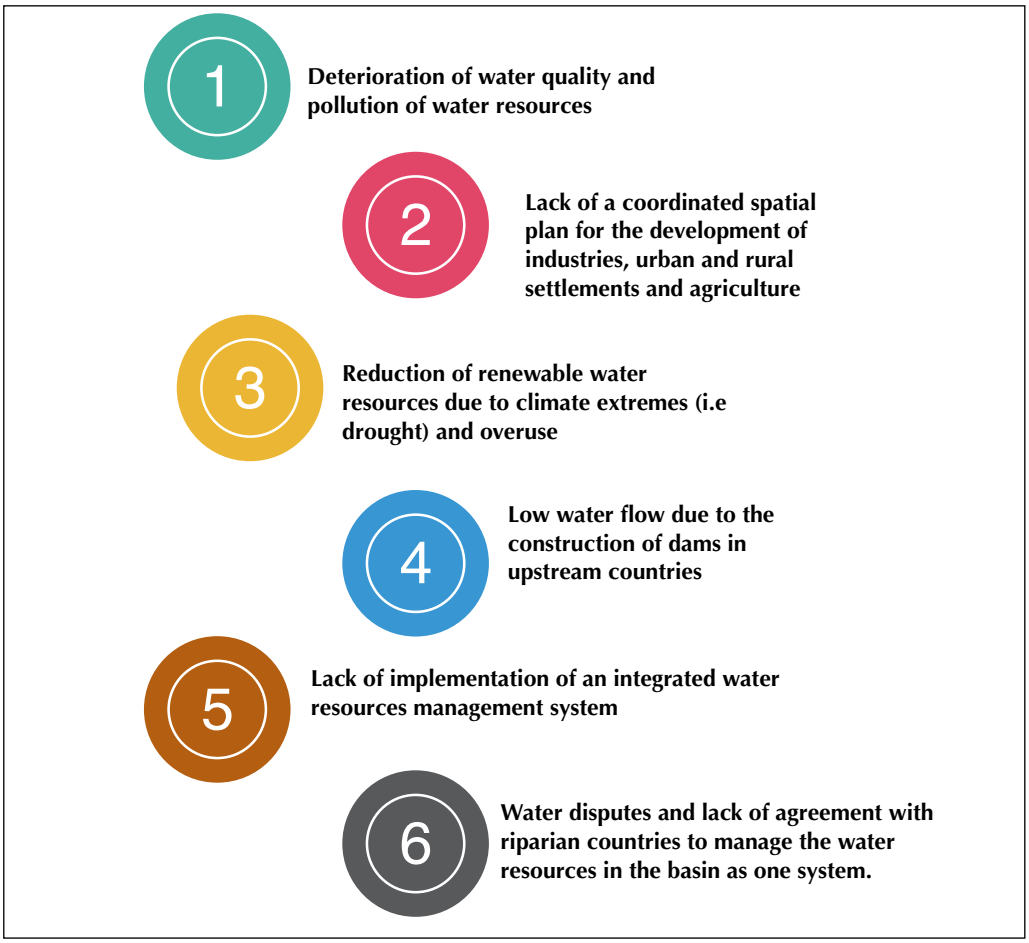

Figure 4. Main challenges in managing water resources in Iraq.

2.1. Lack of an Integrated Water Resources Management (IWRM) in The Euphrates and Tigris basin

The riparian countries of the Euphrates and Tigris basin need to establish an IWRM plan and implement the concept to maximize the benefits for the whole system and use the resources efficiently and sustainably. This includes cross-sectoral management of different economic sectors within and between the riparian countries, by involving all the relevant stakeholders in the decision-making process. This sounds easy to implement; however, the IWRM concept was not successful in the basin, despite the attempts over many years to agree on an integrated solution and management for the water resources. This could be related, in part, to some geo-political obstacles (e.g., political instability) as well as social and demographic differences that must be tackled, first by the riparian countries if they want to manage the available limited water resources in the basin according to international legal principles, and second by following proper planning grounded on science-based knowledge.

2.2. The Euphrates and Tigris Transboundary Water Management

Turkey, Syria, and Iraq rely on the Euphrates-Tigris river system to ensure their water, energy, and food securities. Syria and Iraq are severely dependent on Turkey - the upstream basin riparian country – and its willingness to share its surface water supply (Future Directions International, 2016). Construction of dams in the upstream part of the basin has decreased the flow of both rivers with an impact on the water quality, especially in Iraq followed by Syria (Al-Ansari et al. 2018).

International cooperation is crucial for agreeing on a water allocation mechanism and on water resources and water pollution management strategies that avoid the deterioration of water quality. Water treaties play an essential role in the peaceful resolution of water-related conflicts, including the water pollution from upstream and its consequences for the downstream. In total, seven treaties and agreements exist among the basin riparian countries. However, the treaties and agreements stay weak in improving the situation as long as workable monitoring provisions, enforcement mechanisms, and specific water allocation provisions addressing variations in water flow and changing needs are not in place.

Moreover, the mode of negotiation among the Euphrates and Tigris riparian countries defines the success of those agreements. One River Basin Organization and commission (ORB) exists in the basin. The ORB ensures joint decisions of its member states on the shared resource (Schmeier, 2013). However, the Joint Technical Committee on Regional Waters (JTCW) for the Euphrates and Tigris rivers failed to come to any consensus decision on the principles of water resources management between Turkey, Syria, and Iraq; it eventually ceased to exist (Islar and Ramasar, 2009).

Trust-building among riparian countries is a common good necessary to achieve a united Euphrates and Tigris. In particular, sharing data and information are of the utmost importance. Considering the spatially disentangled source of pollution and its effects, Widmer (2019) argues that interconnected and multilevel collaborative arrangements that support institutional capacity building are the best approaches for addressing such a social-ecological mismatch.

3. Water Quality in The Euphrates-Tigris

With its geo-political position as the most downstream country within the Euphrates and Tigris, Iraq is experiencing severe water pollution. According to different studies, the quality of water in these rivers and their tributaries near the border with Syria and Turkey is relatively good (FAO, 2009), including the water originating from tributaries within Iraq. Expansion of irrigation areas in upstream countries and the rivers' return flow is the main cause of the water pollution

that enters Iraq. Water quality degrades while moving downstream, especially in urban areas near rivers like Baghdad and Al Basra. This could be associated with many factors, such as the rapid increase in population growth rate, which reached 2.25 % according to the World Bank Statistics (2011), but also the degradation of water-related infrastructure and sewage systems, as well as direct pollution caused by industrial and domestic sectors - which are, in most cases, discharging their wastewater directly into the river without prior treatment.

According to a study done by Al-Ansari (2013), more than 500,000 m^3 of raw sewage are discharged into rivers in Iraq every day. The quality of water in both rivers is further degraded by return flows from irrigation activities in Iraq. Furthermore, the Euphrates and Tigris rivers' declining water flow in Iraq due to the upstream developments also contributes to the problem.

The high rate of evaporation, sharp climatic variations, repeated frequency of drought events, accumulation of salts and sediments, poor drainage, and low

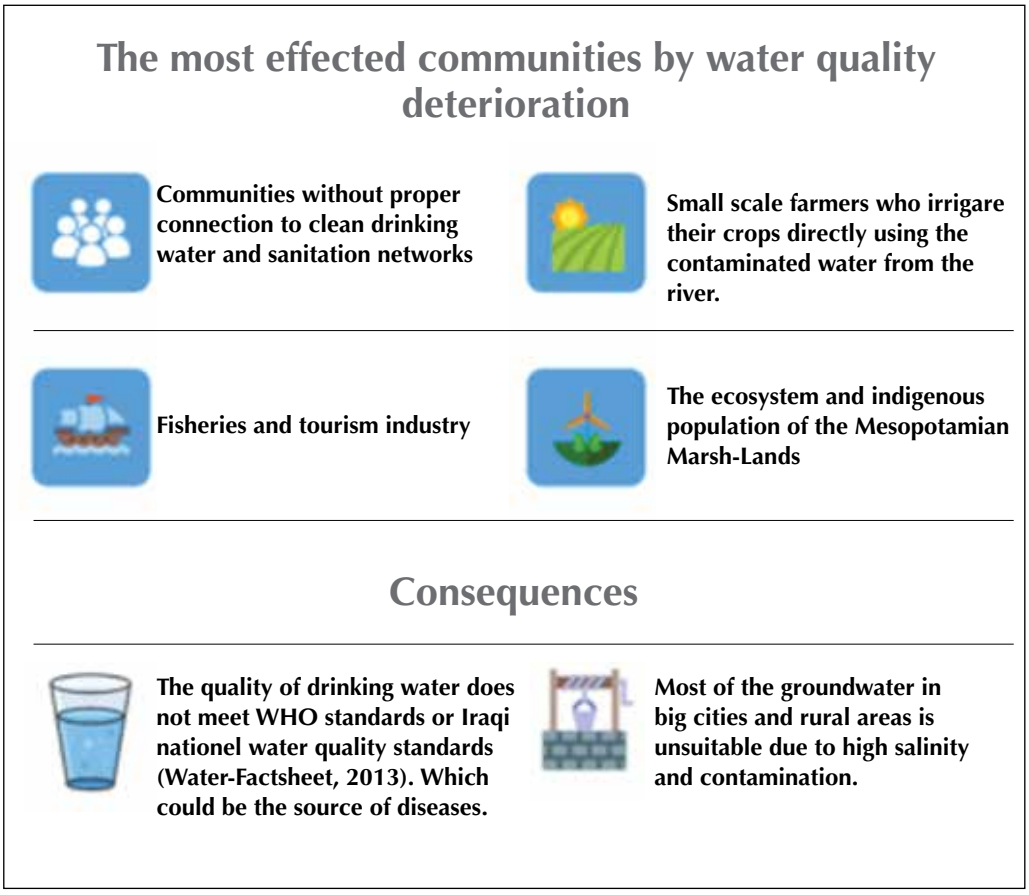

Figure 5. Consequences of water quality deterioration on the affected communities

soil quality in the lower reaches of the Euphrates and Tigris, are all natural causes that exacerbate the damaging effects of human pollution. The deterioration of water quality and the heavy pollution from many sources, in addition to the rapid increase in water salinity, are becoming serious threats to Iraq, imposing urgent challenges that need to be solved. This is amplified by the lack of adequate water monitoring networks, making it difficult to understand the extent of the problem and to subsequently take measures to address water quality and pollution. Below, figure 5 shows the communities affected by the problems mentioned above, as well as the consequences.

Box 4: Why are we currently concerned about water?

Firstly, we should know that freshwater represents a small fraction of the total amount of Earth's water, and most of this small fraction is found in glaciers, ice and groundwater, which are difficult to obtain. Therefore, the remaining surface and more accessible freshwater on Earth are quite limited and unevenly distributed worldwide. While some regions enjoy relatively abundant quantities of it, others face extreme scarcity. For instance, European countries enjoy abundant amounts of surface and groundwater resources and receive large amounts of rainfall annually. Simultaneously, regions such as the African Sahel - one of the driest areas in the world - have limited surface water sources and receive negligible rainfall quantities. The quantity of water is a problem of concern, but preserving its good quality represents a significant challenge. Worldwide, water can be found in various qualities, ranging from clean and drinkable water to highly polluted. Because of human activities and other natural phenomena (e.g. seawater intrusion into groundwater), global freshwater has become a scarce resource. Sources of water pollution can be from industry, agriculture, mining, and untreated sewage. An increase in the global population and increased demand for water for socio-economic development, such as food production, is putting this vital resource under tremendous pressure.

3.1. Assessing Sustainable Development Goal (SDG) Target 6.6.1

Indicator 6.6.1 tracks change in the extent of water-related ecosystems over time, and includes data on the spatial extent of water-related ecosystems and the quantity and quality of water within them.

Water-related ecosystems are those dominated by freshwater or brackish water, and include vegetated wetlands (swamps, swamp frosts, marshes, paddies, peatlands, and mangroves), open water (rivers and estuaries, lakes and reservoirs), and groundwater aquifers (Dickens, et al., 2017; UN-Water, 2020).

Iraq is characterized as one of the

lowest-ranked countries in the world based on the United Nations (UN) ranking when it comes to meeting the SDG indicator 6.6.1, with a 15% negative change in the extent of its water-related ecosystem compared to the historical reference. This situation is also reflected in the Euphrates and Tigris river basin, as all downstream countries have a negative change in their water-related ecosystem, while Turkey's performance in achieving target 6.6.1 is relatively good, not only compared to other countries in the basin, but also in the world (Fig. 6). Assessing this indicator here points to the fact that the water-related ecosystem in the basin and especially in Iraq is facing a big problem, and that it is being used in an unsustainable way, which will increase the deterioration of the quality of these resources and their availability for future generations.

Box 5: The United Nations Sustainable Development Goals (SDGs)

The 17 Sustainable Development Goals (SDGs) of the 2030 agenda call for action by all countries to promote prosperity and ensure a sustainable future for all, while protecting the planet (UN.org, n.d). They became effective on the 1st of January 2016 and «address the global challenges, including poverty, inequality, climate change, environmental degradation, peace, and justice» (UN.org, n.d). Due to the significance of access to safe drinking water and adequate sanitation and hygiene for everyone, this has been highlighted with a particular goal (Goal #6), which ensures sustainable management and access to water and sanitation for all. It has six main targets, which should be monitored in an integrated way.

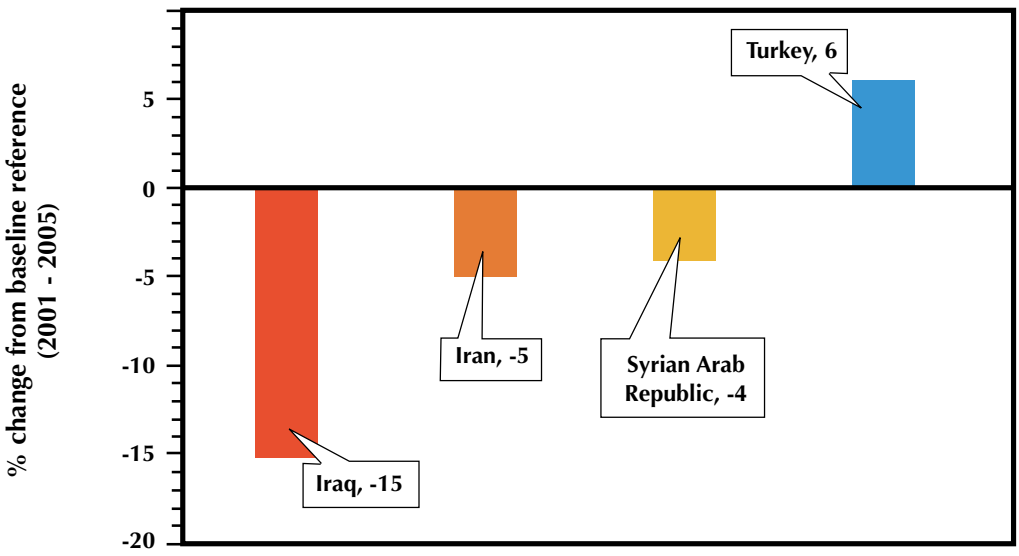

Figure 6. Status in different countries (or areas) in the basin on SDG Indicator 6.6.1 Change in the extent of water-related ecosystems over time (%) (2016) compared to the baseline reference 20012005-.

Data source: UN-Water (2020)

4. Is There Hope for a Clean Euphrates and Tigris?

4.1. Role of Knowledge Transfer

On the global level, pressure on water resources necessitates the adoption of effective policies and the development of modern technologies in order to efficiently address the great challenge that faces humanity today. Many transboundary basins have succeeded in restoring good water quality (e.g., the Rhine basin). As many countries and river basins are quite advanced in developing and adopting such modern technologies and policies, knowledge transfer is central; countries can learn from each other's experiences.

Many of the challenges related to the deterioration of water quality and pollution could be addressed through lessons learned from successful case studies. The Rhine transboundary basin, located in Europe and shared between nine countries, will be studied to facilitate knowledge transfer to the Euphrates and Tigris cases. This will help answer questions such as how

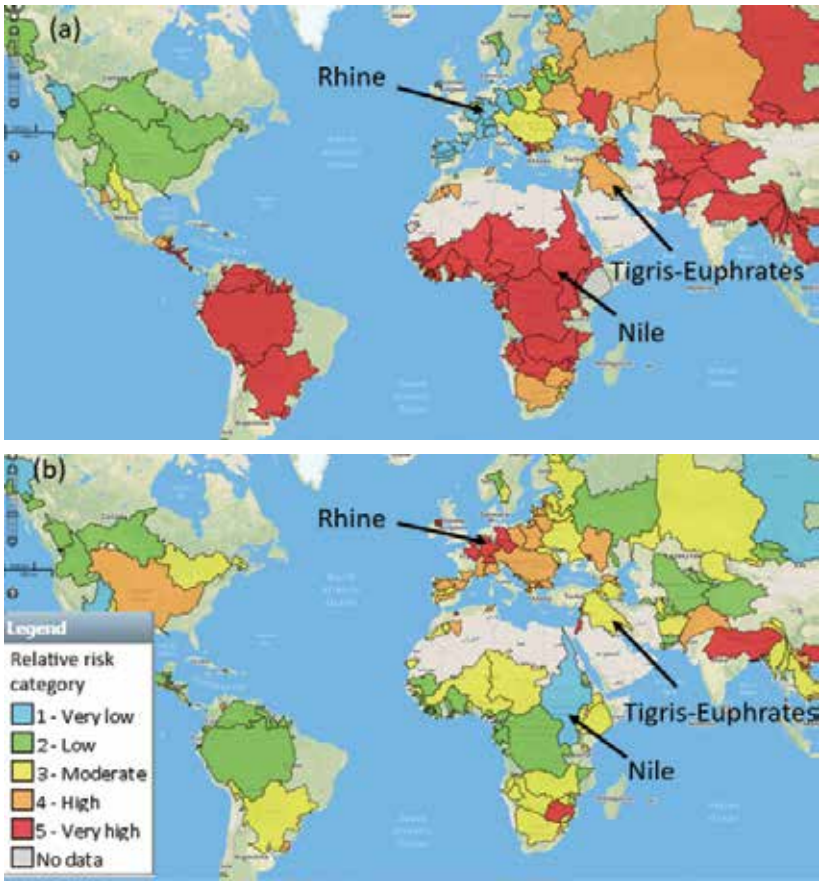

Figure 7. Comparison of Euphrates and Tigris, the Rhine and the Nile in terms of a) wastewater and b) nutrients pollution.

Source: TWAP (http://twap-rivers.org/#global-basins)

Euphrates and Tigris can be cleaned, and the prerequisites and actions that need to be taken to do so.

Knowledge transfer can facilitate the adoption of the most effective approaches without the need for trial and error (Vinke-de Kruijf et al., 2013) - an approach that can result in costly solutions in time, effort, and financial resources.

Transferring knowledge from other basins is an excellent practice to plan and implement solutions that aim to enhance and maintain water quality in rivers. However, not all basins are the same and the challenges faced in each case could differ depending on several factors, including socio-economic, political, and financial. According to the Transboundary Waters Assessment Program (UNEP-DHI and UNEP, 2016), all the transboundary basins located in the Middle East and North Africa (MENA) region, including the Nile and the Jordan basins, are displaying high-risk levels regarding water quality, especially regarding wastewater pollution (Fig. 7). Moreover, some of these transboundary basins are projected - like the Euphrates and Tigris - to be hotspots for future transboundary conflicts (Farinosi et al., 2018). Despite the local context and setting (e.g., socio-economy), other basins (e.g., the Rhine) could be a good model of how highly polluted rivers can be turned into rivers with high water quality. They represent good examples of the adoption and implementation of IWRM concepts and provide evidence-based knowledge on how effective transboundary cooperation has contributed to the success in improving water quality.

4.2. Think Global and Act Local

Management of water resources differs from region to region according to the geographic setting. Therefore, knowledge transfer between, for example, developed and developing countries, is challenging and needs to take special care, particularly with regards to the cultural and political differences. Best practices on water management, especially water quality, should consider these relative differences, and the solutions should be customized and adapted according to the local circumstances (Campbell and Barlow, 2017). The lessons learned from successful river cleaning cases could be adapted to the Euphrates and Tigris with particular attention to the parameters of «source of pollution, type of pollution, funding limitations, transboundary conflicts, water Governance, law and legislation, social and cultural concerns.» Adaptation of the knowledge from other basins to the Euphrates and Tigris basin's local specifications would facilitate proposing tailor-made solutions.

Table 2 provides the knowledge transfer framework of different factors influencing the applicability of lessons learned (limitations and potentials) from the Rhine basin to the Euphrates and Tigris. The findings lead to the lessons learned, which are presented in section 6.

Factor	Rhine (1986) *	Rhine (today)	Euphrates and Tigris (today)
Area (km2) (UNEP-DHI and UNEP, 2016)	164,000	164,000	868,000
Population (million inhabitant) (UNEP-DHI and UNEP, 2016)	-	48,831	65.437
Number of riparian countries	-	9: Austria, Belgium, France, Germany, Italy, Liechtenstein, Luxembourg, Netherlands, Switzerland	6: Iran, Iraq, Jordan, Saudi Arabia, Syria, Turkey
Economic status (Gross Domestic Product, GDP in current USD) (World Bank, 2020) (UNEP-DHI and UNEP, 2016)	Austria: 99.04 Belgium: 120.01 France: 771.47 Germany: 1046.26 Liechtenstein: 0.78 Luxembourg: 6.92	49,543.47 USD per capita	5,879.19 USD per capita
River discharge (km3/ year) (UNEP-DHI and UNEP, 2016)	-	74.97	147,67
Type of pollution	Physical, chemical (including heavy metals such as cadmium, mercury, lead, and zink), and biological pollution	Micro-plastic (Mani, et al., 2016)	Physical, chemical (heavy metals, salinity) and biological pollution (Al-Bayatti et al., 2012; Mansour and Said, 2018)
Source of pollution	Multiple sources: domestic, agriculture, and industry	Multiple sources: wastewater treatment plants, tributaries, and weir (Mani et al., 2016)	Multiple sources: domestic, agriculture, industry, construction of dams upstream, and remnants of war (Al-Layla and Al-Rawi, 1988; Thana, et. al., 2009; Varol et. al., 2010; Al-Aansari and Knutsson, 2011; Al-Ansari, et. al., 2018)
Pollution intensity	Highly polluted	Good quality in general. However, highly polluted with micro-plastic	Highly polluted
Transboundary agreements aimed exclusively at reducing river pollution	Available	Available	Not available
Information sharing	Exist, but needed to be strengthened	Transparent information sharing mechanisms	Inadequate
Basin-wide early warning system and alert plan	Available	Available	Unavailable

Table 2. A knowledge transfer framework of different factors influencing the applicability of lessons learned from the Rhine Basin for the Euphrates and Tigris

*The reference year 1986 was chosen based on the fact that the riparian countries started to take action after the fire in the pharmaceutical company Sandoz in the Swiss city of Basel, which polluted the Rhine.

**Italy, Netherlands, Saudi Arabia, and Jordan are not included because of their small areas within the respective basins.

The Euphrates and Tigris basin is 5.3 times bigger than the Rhine basin, and the river discharge is 2 times higher. This fact results in a potentially more complicated IWRM implementation process in the Euphrates and Tigris basin compared to the Rhine, especially considering that from where and in what amount pollutants enter the rivers correlate with the size of the basin and the activities that take place. The Euphrates' and Tigris' current water pollution status is comparable to the Rhine in the old days; physical-chemical and biological pollution exists. The Rhine of today exhibits huge improvements, which offers hope for Euphrates and Tigris.

The number of riparian countries involved in transboundary management for the Euphrates and Tigris (6 countries) is less than that of the Rhine (9 countries). Therefore, a less complicated water transboundary setup can be expected. However, due to the region's geo-political situation, and its past and ongoing wars, water has turned into a national security issue in the riparian countries, and has a strategic value. This results in a very specific transboundary context, limiting the applicability of the lessons learned and knowledge transfer from other basins.

The lessons learned derived from the experience of the Rhine, and that are aligned with the knowledge transfer framework, are discussed with stakeholders, including experts from academia and civil society, as well as practitioners and environmental activists.

5. Requirements to Reach a Clean Euphrates and Tigris

Preventing pollutants from entering the river system is a crucial step toward a clean river. This includes monitoring who is polluting the river, the intensity of pollution, and pollutant types. To tackle this, countries prioritize the different sources and impacts of pollution and then target actions to reduce those. Stopping pollution sources is a prerequisite for improving water quality. Generally, point source pollution is easier to reduce and manage than diffuse sources. Strategies that can be employed include:

- Treating wastewater before it is discharged to river systems.
- Managing and minimizing the use of fertilizers in the agriculture sector.
- Decentralized water treatment approaches.

For polluted rivers such as the Euphrates and Tigris, some widely implemented methods and techniques that can be used to clean a river include chemical and mineral cleaning and nature-based solutions. However, successful implementation of such methods at the basin level requires appropriate conditions and infrastructures, as well as integrated approaches, including public participation and government efforts combined. Moreover, such strategies and techniques cannot be successful without transboundary cooperation frameworks with the riparian countries.

Box 6: Bioremediation

Bioremediation is a technology for removing pollutants from the environment using living micro-organisms to degrade environmental pollutants or prevent pollution. It aims to restore the original natural surroundings and prevent further pollution (Sasikumar et al, 2003). This degradation can be optimized through practices including cultivation and the addition of nutrients. The micro-organisms, plants, microbial or plant enzymes are used in this process to detoxify contaminants in the soil and other environments (Gouma et al, 2014). The relatively low costs of this method make it especially interesting for developing countries with limited financial resources. For a successful implementation of the bioremediation techniques, effectively engaging multiple stakeholders is a precondition (O'Brien et al, 2020).

Box 7: Examples of decentralized technological solutions for clean water

There are many decentralized technological solutions to purify water in the household and to clean water bodies. Below are a few examples. Many of these solutions are low-cost, low-tech, and can be produced domestically. Click on the links to learn more about these solutions.

Household systems:

Solar water sterilization: https://en.wikipedia.org/wiki/Solar_water_disinfection

Ceramic and clay filters: https://en.wikipedia.org/wiki/Ceramic_water_filter#:~:text=Ceramic%20water%20filters%20(CWF)%20are,and%20bacteria%20out%20of%20water.

Slow sand filtration: https://en.wikipedia.org/wiki/Slow_sand_filter

River systems:

Trash traps: https://stormwatersystems.com/trash-traps/

River cleaning system: Cleaning System: https://rivercleaning.com/river-cleaning-system/

Sunlight-powered purifier: https://www.sciencemag.org/news/2017/02/sunlight-powered-purifier-could-clean-water-impoverished

The Great Bubble Barrier: https://thegreatbubblebarrier.com/en/

5.1. Inspiration from The Rhine - IWRM in a Transboundary Context

In 1986, there was a catastrophic fire at the Sandoz chemical factory near Basel, Switzerland, which resulted in the release of toxic chemicals that were discharged into the Rhine River. The river flows through four countries - Switzerland, Germany, France, and the Netherlands - before flowing into the North Sea. The massive water pollution from the Sandoz catastrophe and the heavy industrial presence along the riverbanks led to the disappearance of all fish and other living organisms in the river, and made the Rhine river too dangerous to swim in and its water unsuitable to use for any purpose. A public outcry, in addition to politicians from all the Rhine countries, agreed that action had to be taken. The result was the Rhine Action Program of 1987 (BBC, 2014). Accordingly, there have been many measures taken and efforts made to clean the river by the riparian countries, including building new effluent treatment plants along the river course and increasing the chemical companies' safety precautions around the river. There have also been improvements in legislation, international cooperation, monitoring network, and emergency procedures to prevent pollution or minimize its effects. These efforts have been very successful and resulted in a high reduction in nitrate and phosphorus pollution, as well as other types of pollution.

Box 8: Rhine Action Program (ICPR, 2003)

Commitment: Thoroughly rehabilitate the Rhine by the year 2000.

Objectives: Reduce the discharge of noxious substances, increase safety norms in industrial plants, and reduce the pollution contents of river sediments.

The estimated expenses for implementing the Rhine Action Program (RAP) (1989 to 1995) are 13 billion Euro.

The estimated expenses for improvement of wastewater treatment plants are 9 billion Euro.

Involved actors: The Rhine bordering countries, the Länder, the municipalities, and industry all joined forces and implemented the rehabilitation measures.

The process to define targets, conclude agreements, and achieve control is accompanied by more than 150 experts.

The RAP targets are set in the field of chemistry, techniques, and biology.

The extremely successful Rhine Action Program is under the auspices of clearly defined strategy and milestones implemented by all Rhine bordering countries.

RAP has been successful in increasing the political willingness of the countries to engage. Required public means were predisposed to implement the program. RAP has submitted strict instructions to the industry.

Box 9: International Commission for the Protection of the Rhine (ICPR, 2003)

ICPR was founded in 1950.

Contracting parties: France, Germany, Luxembourg, Netherlands, Switzerland, EU Delegates.

Leading civil servants and experts from all contracting parties.

President: Mathias Krafft (2002 - 2004)

Headquarters: Koblenz

The representatives of the different ICPR member states established a highly committed and trusting cooperation. The ICPR secretariat coordinated their meetings, informed the public, and established contacts with non-governmental organizations in the economic sector, municipalities, and nature protection. Thus, a river commission turned into the nucleus of modern water protection.

Different river commissions have used the ICPR model, including the River Elbe (1990), the Rivers Danube, Meuse, and Scheldt (1994), and the River Odra (1996).

5.1.1 Factors that can influence the success of IWRM

Referring to the Rhine river experience, several mediating factors that can influence the success of IWRM in a transboundary context (Medema and Jeffrey 2008) are as follows:

- **IWRM (Integrated Water Resources Management) is about changing perspectives**

The openness of the different actors involved in the water management process would increase the chances of collaboration towards the integrity of stakeholder processes, and of adjustment of the institutional structures required to design and implement IWRM.

- **Level of the integrity of different interests**

A success factor of the IWRM implementation in the Rhine is the involvement of a wide range of stakeholders with different interests throughout the planning processes: those with the power to influence the process and those who are affected by the process. Acceptance and support of these stakeholders for actions and interventions could assure their successful implementation. Moreover, their involvement can create a sense of ownership and responsibility. However, as the number of stakeholders with different interests increases, the negotiation process might become more complicated. Simultaneously, the strong support of diverse stakeholders with different interests is required to assure an agreement and its implementation. In particular, excluding powerful stakeholders from the decision-making process could hinder the achievement of effective solutions.

Box 10: The Integrated Water Resources Management Joint Exchange MSc Program with a focus on the Middle East and North Africa (IWRM MENA)

Programs for raising awareness and educating young water professionals on the principles of IWRM - social equity, economic efficiency, and environmental sustainability - are quite needed to effectively address water challenges such as water pollution problems. An example of such programs is the IWRM master's program run jointly between TH Köln (Germany) and the German Jordanian University (Jordan). Interdisciplinary and multicultural educational programs play a key role in educating agents of change and young water professionals who can understand complex water resources management systems.

Collaboration partners: TH Köln (University of Applied Sciences) and German Jordanian University

Aim: educate experts in Integrated Water Resources Management who can understand, analyze, and find solutions for complex water problems considering the interdisciplinary and trans-disciplinary aspects of water resources management.

Duration: four semesters (first and second semesters in Germany; third semester in Jordan; fourth semester in the MENA region)

Profile of the participants: Mostly from the MENA region and Germany and from different academic backgrounds (social sciences, politics, economics, engineering, environmental sciences… etc.)

The program provides the participants with an interdisciplinary and intercultural atmosphere, with the chance to experience life, education, and systems that work in both regions. For further information: https://www.iwrm-master.info/iwrm-mena/

- **Willingness to collaborate**

The stakeholders' willingness to collaborate depends on many different factors, such as their level of trust in the process. Regular interaction between the different parties through formal and informal networks can create an atmosphere of trust and mutual understanding. Trust between the Rhine basin's riparian countries has been built through long-lasting cooperation (Raadgever et al., 2008).

A sense of urgency and awareness of the environmental crisis could increase the willingness to collaborate. In the case of the Rhine River, the Sandoz disaster was an environmental crisis that provided a significant boost to the work of the ICPR. Climate change is another common threat that has successfully brought different actors together. Another factor that can affect the willingness to collaborate is the social and economic interests of the involved stakeholders and countries. The

economic power of involved stakeholders and countries would affect their priorities, including funding for environmental measures. The Rhine River experience indicates that a similarity of economic development between countries involved is an enabling factor for the integration process.

Box 11: Rhine Clean-up Day

Eight billion kilos of plastic waste are dumped in the oceans every year, 80% through rivers. The Rhine river alone is responsible for disposing of 1000 tons of trash in the ocean. The Rhine River Cleanup is a Europe-wide program of volunteers cleaning up the river. In total, 58 cities contribute to the program. Cleaning, awareness-raising, and promoting collaboration among the stakeholders to reduce the number of disposable products at source are among the main purposes of the Rhine Cleanup Day actions.

For further information: https://www.rhinecleanup.org/de

- **Guaranteeing access to data and information**

The Rhine experience indicates the importance of available, accessible, and understandable data and information for all stakeholders, for decision-making and monitoring purposes. Rhine water management information is publicly available through websites and publications. The availability of information and data is increasing as more sophisticated techniques and methods for data collection and information sharing are being developed. Moreover, at the transboundary level, international inspection capability between riparian countries is needed to monitor the implementation of agreements.

- **Legal arrangements and setting at country level versus transboundary**

The riparian countries have set up the International Commission for the Protection of the Rhine (ICPR) to ensure the implementation of agreed decisions for action. However, as each member state has its own legal arrangements, ICPR has limited legal power, which can cause difficulties; this could be the case in many transboundary settings. In the case of the Rhine, The Water Framework Directive (WFD) and European Commission (EC) are in place to counterbalance the limited power of the ICPR. The Water Framework Directive (WFD) is more specific on how to deal with and involve stakeholders, as well as how to develop formal agreements on problems to be solved. At both country and transboundary levels, clarity of roles and mandates increases simplicity, efficiency, and effectiveness through the implementation process and collaboration.

- **The complexity of the governance systems**

According to the Rhine river experience, an important factor that may impact the duration and complexity of designing and implementing IWRM is the complexity of

the governance systems and institutional structures, as well as unclear roles and responsibilities. A high number of involved stakeholders with very different interests and needs may increase frustration.

At the transboundary level, the complications may increase as the degree of compatibility between riparian countries decreases. Different national policies, interests, institutional structures, legal arrangements, and bureaucracy levels may lead to a time-consuming and frustrating process.

6. Lessons Learned for The Euphrates and Tigris and The Ways Forward in Discussion With The Stakeholders

This section presents the lessons learned from the Rhine experience, adopted for the Euphrates and Tigris in three parts considering the knowledge transfer framework and expert interviews. The first part refers to the integrated and transboundary requirements of water resources management in the basin. It introduces a regional network to increase willingness to collaborate at the regional level. The second part demonstrates different approaches to reduce pollution, from technical solutions to legal frameworks and laws, as well as to raise awareness of the matter. The third part focuses on the financial resources, which have been identified as an obstacle for realizing any of the suggested lessons learned.

The main text presents the lessons learned from the Rhine experience, considering the knowledge transfer framework introduced in previous chapters.

The text in the framed boxes represents the viewpoints of the interviewed experts, their concerns, and the prerequisites needed to realize those lessons learned.

6.1. Changing Perspectives, Creating an Enabling Environment, and Fostering Cooperation: Integrated Water Resources Management (Iwrm)

Holistic approaches are key to solving water quality through multiple lenses (e.g., socio-economic, political, technical, and ecological). Adopting the principles of Integrated Water Resources Management (IWRM) is one of the most successful concepts for the implementation of a holistic approach. This would offer opportunities to discover potential synergies to be promoted and for trade-offs to be minimized. For example, IWRM promotes the management of the whole water cycle. Treating wastewater could protect natural water sources and would provide a new unconventional water source that can be reused. The decision-making process should be based on a good understanding of IWRM.

To implement IWRM in the region, according to the experts, the following obstacles (social, political, technical, ecological …) are to be overcome:

- Lack of a regional strategic plan for the whole basin and for each of its riparian countries.
- Lack of a clear vision for the water sector and strategies at the national level. Decisions are rather political considerations.
- Lack of political will, as well as political instability and corruption.
- Absence of water treaties and cooperation among the riparian countries at the transboundary level, including treaties and laws that would regulate water pollution.
- Lack of enforcement of existing policies.
- A high number of stakeholders involved in water issues, which challenges the implementation of public policies.
- Low awareness and lack of targeted education regarding the IWRM.
- Lack of environmental awareness at different levels from schools and community to the private sector.
- Lack of experts who could implement IWRM at different scales and levels.
- Old technologies and infrastructure.
- Lack of local and national studies about IWRM and automated monitoring for water resources.
- Outdated research and lack of investment for research and application of the research recommendations.
- Limited financial resources available, mainly due to the economic crisis in Iraq.

Implementation of IWRM by all the riparian countries is crucial; political, technical, and economic teams should be present in the negotiation.

- **Transboundary water management**

Under transboundary conditions, improving water quality cannot be guaranteed without all riparian countries' involvement, through, for instance, a water quality treaty. From the Rhine basin experience, the signed water quality treaties were an essential part of the success of this case (Bernauer and Moser, 1996).

The riparian countries need to join forces and prioritize the well-being and security of the Euphrates and Tigris rivers to address the water quality deterioration threats to the Euphrates and Tigris river basin caused by the heavy pollution from different sources. Only through intense collaboration between different stakeholders within Iraq and among the riparian countries can an effective water-monitoring network be initiated, which would provide the members with the required data and information on the water quality and pollution throughout both rivers, the

bottlenecks, potential pollution sources, and workable solutions.

To reduce river pollution in the Euphrates and Tigris, there is a need for a transboundary agreement that focuses exclusively on water quality.

According to the interviewed experts, the agreements signed by the riparian countries for over a century have ended with no solid cooperation. This is mainly due to a fragile political system, lack of incentives to gather the riparian countries at one negotiation table, and not legally binding limitations of the international law for watercourses to enforce (instead of urge) the riparian countries' cooperation.
Therefore, the above factors should be considered in the design of a comprehensive plan of water cooperation at the regional level. Specifically, the riparian countries should agree on the definition and standards of "acceptable water quality". At the transboundary level, however, the legal frameworks and agreements with riparian countries are not enforced. For example, clear laws to prevent the unfair distribution of the water resources, as well as revised operation rules for dams, could reduce the pollution and salinity problem. Moreover, political restrictions from the riparian countries, especially Iran and Turkey, play a key role to avoid dumping waste and agricultural return flows to the rivers before even entering Iraq.

- **Willingness to collaborate at the regional level**

Creating a mutual sense of belonging to the basin and introducing collaboration incentives could increase the willingness of the riparian countries to cooperate.

Creating a sense of common identity and belonging to Euphrates and Tigris among and within the riparian countries could increase their willingness to collaborate and their commitment to a clean Euphrates and Tigris. Despite all the complex geo-political conditions, a sense of shared ownership can be encouraged through different interregional activities and actions that strengthen a shared value and a sense of belonging.

Introducing collaboration incentives to the riparian countries that foster their willingness to cooperate is essential, including the promotion of shared benefits and win-win solutions. It is important to understand the standpoint of different riparian countries regarding the basin in order to identify their potential incentives for collaboration. Referring to the interviewed experts, potential incentives that would promote collaboration among riparian countries include incentives for trading exchange, free trade zones, developing a regional strategy for food production, joint projects and research centers, and security agreements.

- **Establishing regional and national networks**

Establishing a network of riparian countries at the Euphrates and Tigris basin level would facilitate the interactions among the riparian countries. A network is an excellent opportunity to foster dialogue among the members. It provides a solid base for the riparian countries to communicate and collaborate. Depending on the expected outcomes and impacts, the network could be designed at different levels, including different stakeholders from academics, politicians, civil society, and business.

The main concern in establishing regional centers and networks is ensuring their sustainability. According to the expert interviews, specific challenges of such a network in the context of Euphrates and Tigris include:

- The fragile political situation in the region.
- Financial challenges.
- The complexity of communication among the riparian countries and stakeholders.
- Leadership, management, and network structure.
- Logistic and management challenges due to the instability caused by ISIS.

- **Establishing a regional IWRM**

Establishing a regional IWRM higher education program with an interdisciplinary and intercultural focus among the riparian countries would increase their mutual understanding of the problems and the perspectives. It would educate water professionals and agents of change who could transform the water sector at the regional level.

Moreover, according to the experts, the establishment of a higher education program with a focus on IWRM could play a key role to create awareness about IWRM and internalize system thinking and a holistic understanding of water-related issues among the stakeholders at different levels.

To implement IWRM, according to the interviewed experts, the shortage of water professionals in the areas of technology, management, governance, and public policy, as well as a lack of system and nexus thinking, should be overcome. In addition, specific skills needed in order to resolve the water pollution issue include wastewater management experts, experts for laboratory work, and academics; the continuous feeding of information is a necessity. There are plenty of opportunities to do research. The IWRM Master Program could contribute to filling those gaps.

- **Establishing a basin-wide independent research center**

A basin-wide independent research center and joint development projects among the riparian countries could promote interaction and an exchange of knowledge, experience, and perspectives, and could accelerate openness and willingness to collaborate. It is quite important to facilitate data transfer to researchers and to civil society.

- **The establishment of a basin-wide monitoring network**

A basin-wide monitoring network along watercourses, with an early warning system and an alert plan, would help track pollution sources and could amount to responding quickly to potential risks.

However, the successful implementation of a monitoring network requires commitments of all the riparian countries. Only through intense collaboration between different stakeholders within Iraq and among the riparian countries can an effective water monitoring network be initiated, which would provide the members with the required data and information on the water quality and pollution throughout both rivers, the bottlenecks, and on potential pollution sources and workable solutions. According to the interviewed experts, in Iraq, monitoring stations are few and old. Technical expertise needs to be updated, while the collected data has not been used for action. Moreover, although Iraq has installed a modern system for the two rivers, the project has been suffering from logistics and poor communication between several local authorities. An independent institute that collects reliable data from different locations along the rivers in Iraq would be a great step that can be implemented without the riparian countries.

Availability and accessibility of data and information at the local level play an important role in the success of such networks. An important aspect of transboundary cooperation is facilitating the flow of information; this improves our understanding of the water quality risk and builds trust among the riparian countries, which is an important part of any solution effort.

An efficient way to enhance the monitoring network is to establish a community-based monitoring program, by creating local living labs within each city/village, where every citizen would have a role, reporting the situation near his/her place and playing a part of the cleaning process.

- Training programs are required in order to educate local people about the reporting system and dealing with certain technology and devices, such as the Remote Sensing technologies used to collect data and monitor water quantity and quality in the rivers and tributaries.

- **Establishing a Regional Awareness Raising Center**

The goal of establishing a Regional Awareness Raising Center is to initiate a common identity among the riparian countries for the Euphrates and Tigris rivers. Among many different potential activities of such a center would be the organizing of:

- Regional campaigns highlighting the importance of realizing that water is a valuable element for the entire region.
- Regional festivals, art, and cultural awareness-raising to foster the mutual sense of belonging to the basin among riparian countries.

6.2. How Can Water Pollution in The Euphrates and Tigris Basin Be Reduced?

- **Technological solutions to treat the polluted water**

During the last few decades, water-cleaning technologies have advanced. Using advanced and up-to-date technologies can deliver better results provided they are adopted for the Iraqi environment, i.e., taking into consideration the local weather conditions and hydrogeological system. Also, knowledge transfer should be integrated with the technology transfer to ensure its maintenance and long-term performance.

The interviewed experts emphasize the need to address the below points in a prestudy to decide on a technology:

- Is it possible to adapt the technology to the Iraqi environment?
- Which policies are needed to implement a technology that deals with the treatment plants, and which local entity has to be responsible for them?
- How can the sustainability of that technology, especially its maintenance, be ensured?
- What expertise and capacity building for the operating staff are needed to operate that technology?
- What are the expected costs and available financial resources?

Deciding on a proper technology would depend on the type and source of pollution as well as the required cleaning techniques:

- For domestic water uses, the promotion of low-cost water-cleaning and filtering systems, like in-house water filters and small-scale decentralized water treatment plants, could be feasible, considering the current economic situation in Iraq and some other riparian countries.

- Regarding the river's streams and tributaries, a segregation approach for water usage could be implemented: i.e., green water (from rainfall), blue water (used for irrigation), and gray water (polluted). Each has a different treatment phase and technology.
- While the few existing wastewater treatment plants are old, their rehabilitation and maintenance has not been a priority. Some countries in the region (e.g., Jordan) have good experience in treating and reusing treated wastewater, from which inspiration can be drawn for the case of Iraq, where it can be implemented on a large scale.
- Drainage systems should be adjusted to avoid polluted agricultural wastewater (pesticides and fertilizers) in the rivers.
- Technologies to treat waste from oil production are urgently required.

Legal frameworks and the enforcement of laws between polluters and the affected communities

The interviewed experts emphasized the need for new laws and the revision of outdated laws, and clear roles and responsibilities. The process is characterized as time-consuming. It requires full commitment and willingness from the different stakeholders to revise the existing environmental laws, data, and information as well as complementary capacity building programs for the involved stakeholders and decision-makers. The stakeholders include the ministries responsible for environmental and water resources, agriculture, and industry, as well as local committees and local associations and marginalized local stakeholders (i.e., farmers, fisheries, etc.). These should be involved in the decision process and implementation.

The interviewed experts confirmed the need for a stakeholder network in Iraq that connects decision-makers, academics, and private sectors to discuss and understand the shortages and reveal the opportunities.

Successful enforcement of the legal frameworks and laws in Iraq requires the promotion of the stakeholder's incentives to cooperate on the one hand, and to ensure the support of the authorities, i.e., Ministry of Water Resources, on the other hand, which would increase the chances of long-term cooperation with impact on the ground. A good example is the need to enforce the use of biopesticides by law and promote organic agriculture that would reduce water pollution resulting from agriculture practices.

Moreover, communication with stakeholders would increase their wide support and acceptance of the proposed solutions. It is highly important to define suitable knowledge transfer and communication strategies and media to effectively reach the targeted stakeholders.

- **Awareness-raising to avoid polluting the rivers**

Environmental education and awareness-raising would increase the understanding of the stakeholders, including the local people, regarding the multi-dimensional complexities of water problems. It has the potential to increase the willingness of a wide range of stakeholders to gather individual efforts and cooperate toward clean rivers.

Awareness-raising campaigns and educational actions would increase the inhabitants' sensibility regarding the well-being of the Euphrates and Tigris basin, while promoting the best examples of individual and communal activities concerning a clean Euphrates and Tigris.

Evidence-based knowledge transfer to understand water pollution and its causes and consequences:

- Increase the sense of responsibility of individuals regarding their indirect and direct actions and decisions
- Increase understanding of one's role in empowering a clean Tigris.
- Adopting decent educational material and a decent system starting in primary school.
- Awareness-raising for governmental employees to better understand the complexity of water resources challenges.
- Awareness-raising and capacity building for farmers to reduce pollution and the use of pesticides and fertilizers.
- Environmental awareness-raising campaigns focusing on the importance of cleaning the rivers to promote a sense of belonging to the rivers.

Role of Iraqi communities in contributing to a clean basin

Communities play an important role to promote bottom-up approaches that foster dialogue among the stakeholders and commit policy-makers to bring their decisions to action.

Communities could play a key role in environmental awareness-raising. Evidence-based awareness-raising activities and projects that initiate interaction and communication among the stakeholders like the "clean Tigris" project should be promoted.

NGOs could allocate funds and co-design projects to promote practical initiatives for cleaning Euphrates and Tigris. The long-term systematic support of international NGOs for capacity building and empowering local NGOs could sustain this work. In addition, awareness-raising about the importance of civil society and support from the government would increase the effectiveness of their efforts.

Community involvement in the monitoring and data collection process is required. Civil societies and associations could play an important role in the monitoring process and in managing the procedures for water distribution and data collection. However, their role would be rather complementary, with only general overviews, rather than in-depth analyses of the problems.

6.3. Financial Resources

Improving the water quality of the Euphrates and Tigris needs many financial resources. The experts have mentioned the lack of financial resources as a restriction to all the lessons learned.

The current economic crisis in Iraq reduces the ability of the Iraqi Government to finance the implementation of the lessons learned activities in this section. Specifically, **the local government is interested in technology-based solutions to clean the basin, which are cost-intensive.** In the coming year, dropping oil prices, in addition to the pandemic, will surely influence the funding availability and priority.

- **International funding organizations**

International funding organizations such as the World Bank (https://www.worldbank.org/), the Green Climate Fund (https://www.greenclimate.fund/), and other actors could play a great role in helping countries like Iraq to clean the Euphrates and Tigris rivers by facilitating grants, loans, and funds.

The international funds could promote projects and activities that foster peace and stability in the region. However, even if the necessary funds are acquired, the political instability in the region may create insecurity, as well as logistic and management issues, which will hinder the implementation of those projects. Moreover, the sustainability of the development project after the funding phase is a challenge. Therefore, new models of external funding that ensure the sustainability and impact of the project are required. To ensure success and sustainability, the projects should involve NGOs, local people, the government, and academics. Civil society is highly needed to participate in designing and jointly implementing and monitoring the projects.

The capacity gaps to generate funds from international organizations include:

- Defining the clear goals and objectives of the intended project with detailed cost estimations.
- Identifying existing funding potentials.
- Increasing the eligibility of local organizations and institutions that work in the water resources and environmental field for funding, through workshops and training.
- Developing solid financial models from the local government, private sector, and NGOs for getting funds and spending them effectively.
- Proposal writing and understanding common terminologies.
- Implementing the project, in the case that the proposal is accepted.
- Improving transparency to reduce corruption.

- **Commitments from the riparian countries**

Commitments from the riparian countries to provide the needed financial resources and mobilizing funds from the public and private sector is crucial. However, convincing arguments for joint financing of the projects are lacking at the moment.

Finally, enhancing water quality from its current deteriorated status might take quite a long time. For example, improving the quality of water in the Rhine basin has taken several decades. Hence, patience and strong commitment, not only from local stakeholders in Iraq but also in the other riparian countries of the basin, are essential.

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