Transboundary Water Resources “a Comparative Study”: the Learnt Lessons to Help in Solving Nile Basin Water Conflict

Mohamed A. Ashour, Tawab E. Aly, El-Said M. S. Ahmed, Haitham M. Abueleyon

Abstract— Nowadays, in such problematic water situation in Egypt, as one of the River Nile basin countries, on the light of what is being said about the harmful effect of Ethiopian Renaissance Dam, on Egypt's share of Nile water. The attention in Egypt was directed to study the problems of sharing the transboundary water all over the world, to assist in understanding the most proper methods for dealing successfully with such situations to solve the water shortage in some sharing countries. The study here focuses on the successful experiences carried out in some international river basins (one basin from each continent) for highlighting the most applicable successful experiences and analyzing them, for studying the possibility of applying these experiences in other basins especially in the River Nile basin. The study proved that; overcoming the problems of water shortage in Egypt, can be solved, first of all, through cooperation seriously between all the basin countries for minimizing the river huge water losses (more than 1480 Billion cubic meters per year which represents 90% of its whole water income, were documented and identified in this paper), in addition to make use of the successful experiences applied in other international river basins, mentioned in the present study, for the proper sharing of transboundary water according to fair and reasonable practical criteria.

Index Terms— Inter-basin water transfer; Nile water losses, Transboundary water; Water shortage overcoming.

1 INTRODUCTION

THE complex historical, physical, political, economic, institutional, and human interactions within transboundary river basins make the management of these shared water resources more difficult. So studying and analyzing of different experiences carried out successfully in sharing the water of international rivers must be highlighted, and be under focus of other several water sharing problems, to make use of it. Issues of increasing water scarcity, degrading water quality, rapid population growth, and uneven levels of economic development all over the world, are commonly cited as potentially conflicting factors among the river sharing countries. Water agreements and institutions, scientific creative solutions and modern engineering treatments and approaches such as the non-conventional water resources and others, are different ways of managing transboundary water. Therefore; management of transboundary water can be one of the efficient tools for solving such problems, instead of handling them only through political or conflicted solutions.

The prime goal of this paper is to study, analyze, and highlight the successful experiences applied in the most important transboundary river basins, all over the world including the most applicable succeeded solutions to be a good guide for solving other international water sharing problems in other places that still hot areas and waiting for a solutions, like in the Nile River basin.

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Hence, the methodology will be processed in this paper by dividing it into four phases. The first phase, is to briefly review the main properties and nature of only one of the international rivers in the different continents of the world. The second phase, is to identify the problems faced the sharing management of the transboundary water of such rivers. The third phase, is studying the different solutions that successfully applied for solving the problems of water scarcity in some countries of that basin. The fourth and last phase is to make the needed comparison between the condition of the studied rivers, and the condition of the river Nile, studying and selecting the most properly succeeded solutions used in the studied rivers that can be applied in the case of the river Nile.

2 LITERATURE REVIEW

Transboundary river basins which cover almost 50% of the land surface, serve nearly 40% of the world's population, and provide about 60% of the global water discharge [1] can be a source of conflict or cooperation among the sharing countries. Conflicts for water in transboundary river basins resulted from several issues such as natural flooding, natural droughts, political tension, or mistrust. [2] analyzed 1831 water events covering 122 transboundary river basins during the period from 1948 to 1999 from the total 286 transboundary river basins worldwide, and identified three categories of basins at risk of conflicts due

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to freshwater resources. The first category was basins have negotiations due to current conflicts, including the Aral Sea, Jordan, Nile, and Tigris-Euphrates river basins, these basins are well known as "Hot spots", where the potential for future disputes is considered high. This category represents about 3% of the studied transboundary river basins, according to [3]. The second category was basins with indicators for future conflicts and protests among the basin countries due to development projects in the basin, including Lake Chad, Mekong, Okavango, Salween, Senegal, Kune, Indus, Han, Ganges, Orontes This category represents about 7% of the studied transboundary river basins, according to [4]. The third category was basins with indicators for future conflicts without any protest among the basin countries, including Ca, Chiloango, Cross, Drin, Irrawaddy, Kura-Araks, La Plata, Lempa, Limpopo, Ob, Red, Saigon, Song Vam Co Done, Yalu, Zambezi. This category represents about 11% of the studied transboundary river basins, according to [5]. The rest of the analyzed transboundary river basins were not included in the previous categories as the cooperative events in these basins were more than the conflictive events.

From the literature review it can be noticed that; the negotiations for reaching such political solutions take a long time while the problem still existing. So technical and un-ordinary engineering solutions become very important to overcome the present and expected near future problems of water shortage in some of the river basin countries, until reaching a good political solution or a good agreement which may take a long time.

2.1 Technical Solutions to Overcome the Problems of Water Scarcity

Water shortage in transboundary river basin countries is being recognized as a present and future threat to human activities in 43% of the river basins all over the world [6], this problem cannot be handled only with political solutions. So, the scientific solutions and engineering approaches, such as desalination, reuse of treated wastewater, inter basin water transfers (IBWTs), and virtual water trade (VWT), can develop alternative "non-conventional" water resources to be handled side by side with the political solutions.

2.1.1 Desalination

Desalination technologies can be classified by their separation mechanism into thermal and membrane desalination. [7] reported that about 22500 desalination plants are operating all over the world; from which around 60% are reverse osmosis membrane plants. Energy consumption by the reverse osmosis plant is the lowest among all desalination options, making it more economically efficient in regions with high energy costs due to some technological innovations, such as the use of energy recovery equipment or variable frequency pumps in reverse osmosis plants [8].

For seawater reverse osmosis desalination “plants, the power costs can account for up to 50% of the total plant operating and maintenance costs” [9]. The following examples are for the largest reverse osmosis desalination plants:

1) The world's largest seawater reverse osmosis membrane desalination plant lies in Ashkelon, Israel, which produces about 140 million m3/year [7].

2) The world's largest brackish water reverses osmosis membrane desalination plant lies in Jordan with a maximum capacity of 185,000 m3/day [10].

3) The African's largest reverse osmosis membrane desalination plant lies in Algeria with a maximum capacity of 230,000 m3/day [11].

2.1.2 Reuse of Treated Wastewater

Wastewater treatment and reuse play a significant role in water resources management in many countries. As an example, according to [12], about 70% of the wastewater in Israel is treated for agricultural reuses. A new standard for unlimited reuse of the treated wastewater has been formulated taking into account public health, soil, and hydrological conditions. This standard will enable the relocation of nearly 50% of the freshwater (about 500 million m3/year) from agriculture to the municipal and industrial sectors. In 1999, treated wastewater in Israel constituted about 22% of the consumption by agriculture, and 40% in 2005. It is estimated that, treated wastewater will constitute 50% of the consumption of agricultural in 2020.

2.1.3 Inter-Basin Water Transfers (IBWTs)

Inter-Basin Water Transfer (IBWT) has been defined as transferring of surplus water from a basin to another in the same country or to another country, which has a shortage of water, or from one river reach to another [13]. [14] conducted a research on IBWTs worldwide and estimated that about 1100×109 m3 of water per year are currently diverted out of basins through IBWTs, which represent around 20% of the global water withdrawals. Diversion of water through IBWTs is multidisciplinary problems, such as political and legal situation, environmental impact, cultural, and economic feasibility as a result of the high cost of the installations accompanying IBWTs, such as diversion channel, tunnels through mountain, dams, pump stations, siphon structures, and relocation of some residents.

China and India have huge IBWTs projects. China's IBWTs are connecting its national rivers, while India's IBWTs have two types; the first is, to connect its national rivers and the second is to connect rivers that India is sharing with other countries as shown and presented in constructed Table 1.

It worth mentioning that IBWTs in the south of Africa are good examples of benefits sharing as follows:

1) The Gauteng province in South Africa relies on five inter basin water transfers to secure its water and energy requirements; which are water from Umbeluzi River basin (350×106 m3/year), Orange River basin (690×106 m3/year), Maputo River basin (85×106 m3/year), Limpopo River basin (550×106 m3/year), and Incomati River basin (110×106 m3/year) [17].

2) The Lesotho Highlands Water Project, which began in 1986 and completed in 2009, aimed to supply water to South Africa and electricity to Lesotho through transferring about 950×106 m3 of water per year from the Senqu River in Lesotho to the upper Vaal River in South Africa [18]. Both rivers form the headwaters of the Orange River basin, which is shared by Lesotho, South Africa, Botswana, and Namibia. This project is considered as one of the few successful inter-basin water

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transfer schemes in the world.
Also, there have been attempts to transfer water in the Zambezi River, Okavango River and Mekong River. However, none of them has achieved the same level of success as the Southern African case [19]. In addition to the inter-basin water transfer from the Volga River basin in Western Asia to the Rhine River basin in Europe [20].

TABLE 1
IBWTS PROJECTS IN CHINA AND INDIA

	China [15]	**India** [16]
IBWTs Projects	The south-to-north water transfer project through east, middle, and west routes. The middle route alone will cross about 200 river channels including the Yellow River, on its way to Beijing	The Peninsular river development "the western areas" which only link national rivers, and the Himalayan river development "The North-East Part" which link rivers that India is sharing with China, Bhutan, Nepal, Pakistan, and Bangladesh
Costs	The cost of the first phase of the east and middle route construction is estimated at US $ 18.7 billion. The total cost of all the three routes is estimated at US $ 60 billion "based on the year 2000 prices"	The total costs are currently projected to be US $ 120 billion "based on the year 2006 prices"
Benefits	Transfer about 44.8×10^9 m^3 of water per year by year 2050 through the three routes	Divert about 178×10^9 m^3 of water per year, link 37 rivers, construct 3000 reservoirs, generate 34000 MW of hydropower, and irrigate 35 million hectares

2.1.4 Virtual Water Trade (VWT)

The amount of water consumed in the production process of the agricultural or industrial product is called the "Virtual water" embedded in the product. [21] estimated the virtual water content of the crops in the exporting countries "the producing countries" to be about 683×109 m3/year, while if these crops had been produced in the importing countries, these would require about 1138×109 m3/year, which means that; about 455×109 m3/year (represents 8% of the global water) was saved. This situation reflected that, the real virtual water content of a product, which depends on the production conditions at the production sites, is often lower than the hypothetical virtual water content of the product if the product would have been produced at the consumption sites.
According to [22], the virtual water content of the French maize is about 0.6 m3/kg, while the virtual water content of the Egyptian maize is about 1.12 m3/kg. Therefore; transporting 1 kg of maize from France to Egypt saves globally about 0.52 m3 of water. In the year 2000, Egypt imported about 5.2 million tons of maize from France; this represents a saving of 5.8 billion m3 of water "about 10%" from the Egyptian annual water allocation. Therefore; water-scarce country can import products that require a huge quantity of water for their production rather than producing them domestically. By doing so, real water savings can be achieved through relieving the pressure on the water resources worldwide and improving the global water use efficiency.

2.2 Political Solutions to Overcome Conflicts in Transboundary River Basins

The political solutions which can be applied to get over any conflict between the basin countries refer to international water agreements and creation of river basin institutions to implement certain issues concerning the river basin. International water agreements have been proposed to facilitate cooperation over the shared water. According to [23], there are 14 issues which characterized all water agreements as introduced in a simple chart shown in [Figure-1]. Some agreements based on one issue, while others based on more than one issue. The importance of contribution of each issue in such water agreements was studied by [24]. He stated that; the hydropower projects have the maximum contribution in water agreements during the 20th century, and then the water allocation comes in the second order, while the other issues have minimum percentages. [Figure-2] was introduced to illustrate these percentages.

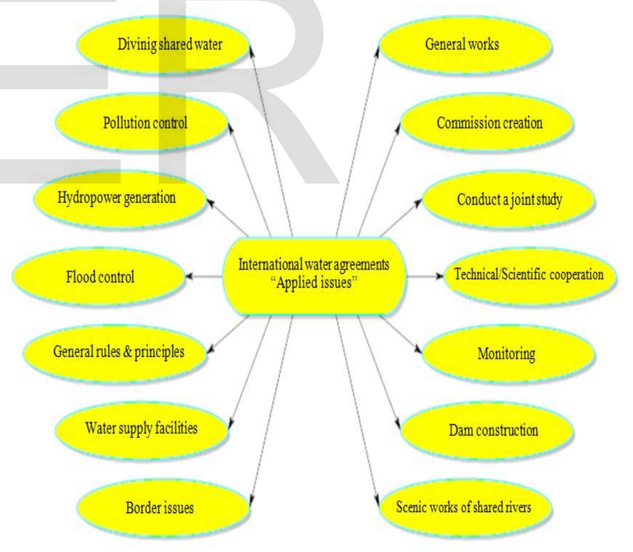

Fig. 1. Issues applied to international water agreements

[24] illustrated that; the hydropower projects have the maximum contribution in water agreements during the 20th century, then the water allocation comes in the second order, while the other issues have minimum percentages, as introduced in [Figure-2].

In the present study, a comparison between five international river basins representing the world continents is introduced, for knowing to what extent each of conflict or/and cooperation can be used successfully in solving some of the problems of sharing and management the transboundary water. The

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introduced comparison covers the conflict and cooperation in the international freshwater management in terms of international water laws, water agreements, and river basins institutions in the under study river basins. Before getting through the international management of the selected river basins; [Table-2] indicates the characteristics of these basins based on data from [25] and [26] while, [Table-3] illustrates the description of each basin.

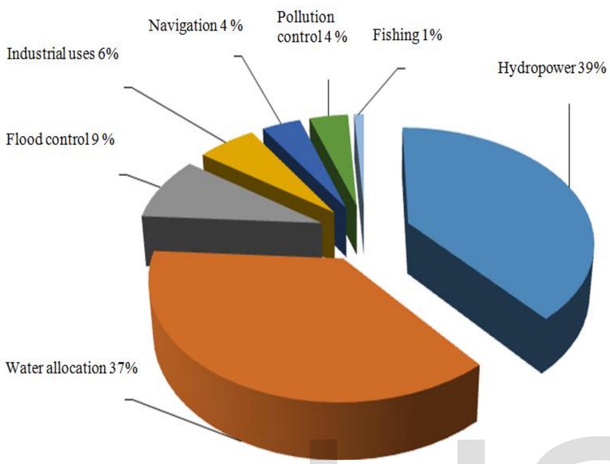

Fig. 2. The contribution of different issues adopted in water agreements during the 20th century

TABLE 3
DESCRIPTION OF THE SELECTED RIVER BASINS

River basin	Continent	Description
Orange-Senqu	**Africa**	The Orange Senqu River Basin is the most developed of all the basins in Southern Africa. It is a recipient basin for three inter basin transfers and a donor basin for three inter basin transfers, with four intra-basin transfers [27].
Aral Sea	**Asia**	The environmental problems of the Aral Sea River Basin are among the worst in the world water diversions, agricultural practices, and industrial waste, resulted in disappearing part of the sea, salinization, and organic and inorganic pollution [28].
Rhine	**Europe**	The Rhine River basin has the most important industrial areas in the world and about 30 % of the world production of chemical substances [29].
Columbia	**North America**	Columbia River Basin represents the transboundary water along the United States – Canada boundaries
La Plata	**South America**	The La-Plata River Basin includes the most important industrialized areas of Latin America, with high rates of population growth [30].

3 Analysis and Discutions

3.1 Technical Solutions

The carried out comparison between some of the selected alternative water resources was made to identify the advantages, disadvantages, and most applicable solutions for overcoming such disadvantages as introduced in the constructed [Table-4].

TABLE 4
COMPARISON BETWEEN THE GIVEN ALTERNATIVE WATER RESOURCES

Alternative water resources	Advantages	Disadvantages	Solutions for disadvantages
Desalination	Desalination plants can provide fresh drinking water with safe, quality in areas which have no potable water supplies	The energy required for desalination is high	Applying energy recovery devices; and the use of alternative or renewable energy sources such as solar, wind, and nuclear energies.
Reuse of Treated Wastewater	Reuse of treated wastewater can be a better solution compared to desalination at least for restricted agricultural use	It has some hazards to the public health	Using treated wastewater should be under the regulations and guidelines for health protection
Inter-Basin Water Transfers	These projects are good examples of benefit sharing as in southern Africa, China, and India	High costs of construction and operation Environmental and political effects	The fund can be borrowed from the World Bank as in the case of the Lesotho Highlands Water Project in Southern Africa, and the basin countries should share in the costs and benefits as well.
Virtual Water Trade	Relieving pressure on scarce water recourses by adopting a policy to grow and export products with relatively low water requirements and import products need higher water requirements	Increasing the global food prices	Land acquisition for the agriculture purposes in countries which have excess water and less development

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TABLE 2
CHARACTERISTICS OF THE SELECTED RIVER BASINS

River basin	Area of basin (km^2)	Sharing countries	Area in basin		Population ($\times 10^3$) (Year 2011) [26]	Water / Capita (m^3/year)	Water resources		
			(km^2)	(%)			Internal (km^3/year)	Total (km^3/year)	Dependency ratio (%)
Orange-Senqu	945500	South Africa	563900	59.65	50460	1019	44.8	51.4	13
		Namibia	240200	25.40	2324	7625	6.16	17.72	65
		Botswana	121400	12.85	2031	6027	2.4	12.24	80
		Lesotho	19900	2.10	2194	1377	5.2	3	0
Aral Sea	1231400	Kazakhstan	424400	34.46	16207	6633	64.4	107.5	40
		Uzbekistan	382600	31.07	27760	1760	16.34	48.87	80
		Tajikistan	135700	11.02	6977	3140	63.5	21.9	0
		Kyrgyzstan	111700	9.07	5393	4380	48.9	23.6	0
		Afghanistan	104900	8.52	32358	2019	47.2	65.3	29
		Turkmenistan	70000	5.68	5105	4852	1.4	24.8	97
		China	1900	0.15	1378506	2060	2813	2840	1
		Pakistan	200	0.01	176745	1396	55	246.8	78
Rhine	172900	Germany	97700	56.49	82163	1874	107	154	31
		Switzerland	24300	14.05	7702	6946	40.4	53.5	24
		France	23100	13.34	63126	3343	200	211	5
		Belgium	13900	8.03	10754	1702	12	18.3	34
		Netherlands	9900	5.75	16665	5461	11	91	88
		Luxembourg	2500	1.46	516	6008	1	3.1	68
		Austria	1300	0.76	8413	9236	55	77.7	29
		Liechtenstein	200	0.09	36	-----	-----	-----	-----
		Italy	70	0.04	60789	3147	182.5	191.3	5
Columbia	668400	USA	566500	84.75	313085	9802	2818	3069	8
		Canada	101900	15.24	34350	84483	2850	2902	2
La-Plata	2954500	Brazil	1379300	46.69	196655	41865	5418	8233	34
		Argentina	817900	27.68	40765	19968	276	814	66
		Paraguay	400100	13.54	6568	51157	94	336	72
		Bolivia	245100	8.30	10088	61707	303.5	622.5	51
		Uruguay	111600	3.78	3380	41124	59	139	58

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From the above table, it is clear that, desalination and inter-basin water transfers need huge investments "loans or grants" that can't be sustained by many countries. While; the most common and the least expensive of non-conventional water resources are the reuse of treated wastewater and virtual water trade, where treated wastewater "domestic or drainage agriculture wastewater" is reused with standards in some agricultural purposes taking into account public health, soil, and hydrological conditions. For virtual water trade, which happened between countries through exchanging of products in return of money or services should be under some kind of protocols to avoid the increasing of the global product prices.

3.2 Political Solutions

In many places, conflicts for water in transboundary river basins can be solved through reaching a good water agreements to outline rules/regulations that govern the behavior of basin countries concerning with the shared river, or setting out detailed solutions for common conflicts. [31] illustrated that the strained relations among the basin countries could hinder reaching water agreements as in the Tigris-Euphrates River and the Ganges-Brahmaputra-Mechna River basins, while in some cases water agreements can be reached despite the strained relations as in the Indus and the Senegal River Basin. On the other hand, conflicts can be arisen with the existing water treaties due to water flow variability in the rivers such as the 1997 droughts in the Ganges River Basin, which threatened the 1996 water treaty between India and Bangladesh [32].

[Table-5] is constructed and introduced, to illustrate the international management of the selected basins through conflict causes, mechanisms of dispute settlement, and comments are given for the management of each basin.

The table prove that, studying the political solutions implemented for conflict resolution in the previous selected studied basins, that establishment of a permanent legal and institutional frameworks enabled the sharing countries to address water-related issues in an organized manner which can be achieved through: i) flexibility of water agreements for introducing some needed modifications with time, ii) mechanism of water allocation based on reasonable use of water should be identified in the water agreements, and iii) water institutions established based on the water agreements should have specific tasks in the river basin.

[Table-6] was constructed to conclude the percentage of using the political and other technical solutions in solving the water scarcity in all transboundary river basins all over the world; the percentage was calculated as the number of transboundary river basin using the intended solution to the total number of the transboundary river basins in the continent.
From the table it can be noticed that, international inter-basin water transfer projects are rarely used in solving the problems of water scarcity that may be due to the huge cost and desire of each country to save its water inside its borders. Also the percentage of using other technical solutions such as water recycling and desalination is very low in Africa, which can be attributed to the high cost of such projects compared to the income of African countries, however they are used with a reasonable percentage in Asia, and with a high percentage in other continents, finally, using the political solutions in solving the conflicts through water agreements and establishment of water institutions can be considered as the most effective approach that proved success in solving the most problems of international transboundary water, by equitable and reasonable share of water associated with prevention of harm to other basin countries. It was used in 25 % of 63 River basins in Africa continent, 23 % of 73 River basins in Asia continent, and 30 % of 67 River basins in Europe continent, 41 % of 46 River basins in North America continent and 30 % of 37 River basins in South America continent.

4 River Nile basin characteristics and situation

The River Nile, the longest river in the world, starts from Lake Victoria in Uganda and goes to the north by the Mediterranean Sea on the northern borders of Egypt having more than 6800 km long [43]. Through such a very long distance, the River passes through eleven countries, occupied more than 3.1 million km2 [44], and serves a population of around 426 million. Egypt is the only country completely depends on the river water with a dependency ratio of about 97%, while some countries, like Ethiopia and Rwanda, didn't depend at all on the river water where their dependency ratio equals 0% [26]. The given [Table-7] was constructed for giving an overview situation about the River Nile Basin Countries.
Studying the table, strongly clarifying that, the huge incompatibility and unfairness between the actual situation of the basin countries and its share of the river water..!!, and there have been, for a long time, a clear inequity in the distribution, and sharing of the Nile water among the upstream and downstream countries. Egypt "the major downstream country" that is totally dependent on the Nile water, has the minimum water per capita compared with the upstream countries. This disparity between the upstream and downstream countries is the source of conflict within the River Nile Basin [45].

The rainfall on the River Nile basin is about 1661 Billion m3/year, at the same time the losses of the river water through its long travel, is very high, where the losses by evaporation are about 544 Billion m3/year from the Sudd swamps [47], about 120 Billion m3/year from the Equatorial lakes plateau, about 6 Billion m3/year from Bahr el Jebel into the Bahr el Ghazal swamps [48], about 500 Billion m3/year from Bahr el Ghazal basin [49], about 10 Billion m3/year from the Machar marshes swamps in the Sobat Basin, about 14 Billion m3/year from Bahr el Ghazal River into the Bahr el Ghazal swamps, about 14 Billion m3/year from Bahr el Jebel and Bahr el Zeraf swamps [50 & 51]. [50] indicated that evaporation from the huge man-made reservoirs is about 15-20 Billion m3/year and the conveyance losses along the Nile course are about 20-30 Billion m3/year. Also; according to [51], about 13% (216 BCM/year) of the total rainfall in the Nile basin is evaporated from agricultural systems (10% from rain-fed agriculture and 3% from irrigated agriculture).

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TABLE 5
CONFLICT CAUSES, RESOLUTIONS, AND COMMENTS FOR THE SELECTED RIVER BASINS

River basin	Conflict causes	Conflict resolution	Author`s comments
Orange-Senqu	Political boundaries between South Africa and Namibia [33]	In 2000, an agreement between Botswana, Lesotho, Namibia, and South Africa for the establishment of the Orange-Senqu river commission was made [34]	The water protocol of Southern African development community plays a role as a legal framework for the development of water cooperation in many of international river basins in Southern Africa
Aral Sea	Water scarcity, water allocation approaches from the Soviet Era, and water sharing issues such as sharing the costs of basin management [35]	In 1992, an agreement for water allocations with the establishment of the interstate commission for water coordination was determined. In 1993, establishment of the interstate council for the Aral Sea, and the international fund for saving the Aral Sea. In 1997, these two bodies were merged into one body [35].	The difficult and complex conditions that followed the collapse of the Soviet Union have harm attempts to provide regular satisfaction of water demands because of the sharing countries are not only working together in planning, but also in operating and managing of the basin
Rhine	Navigation and water pollution because of the location of the most important plants for chemical production along the Rhine River [36]	Central Commission for navigation on the Rhine has been established since 1815. International Commission for the protection of the Rhine against pollution was established in 1950. International Commission for the hydrology of the Rhine basin was established in 1970. A convention for the protection of the Rhine against chemical and chloride pollution was held in 1976 [36]	Sustainable management of the Rhine bas needs a river basin approach for the who basin, with integrated water resource ma agement as the task of one institution, avoid duplicating work between the existi institutions
Columbia	Construction of the Libby dam in the USA in the 1950s; and the McNaughton plan for hydropower through a diversion of a part of the Columbia River in Canada into the Fraser River [37]	In 1964, the Columbia River treaty was established to achieve equal sharing of benefits from hydropower and flood control with the establishment of US army corps of engineers and Bonneville power administration [37]	The Columbia River treaty focused on certain projects without taking any account of the complexities of the timing, siting, and sizing of any alternative projects
La-Plata	Control over the Guairá Falls "the land where the Itaipu dam now sits", was a source of great disagreement between Brazil and Paraguay that formed the border between the two countries [38]	In 1969, the La-Plata basin treaty was determined and followed by the establishment of the coordinating intergovernmental committee of the La-Plata basin countries in Buenos Aires in 1973 [39]. Many bilateral treaties between the sharing countries and hydroelectric projects had come out of the 1969 multilateral agreement [40].	The development of hydropower, navigation infrastructure and the introduction of intensive agricultural practices caused severe environmental degradation throughout the basin

TABLE 6
THE PERCENTAGE OF USING THE POLITICAL AND OTHER TECHNICAL SOLUTIONS IN SOLVING THE WATER SCARISTY IN ALL TRANS-BOUNDARY RIVER BASINS

Continent	No. of Transboundary River Basins [4]	River Basins Agreements [41]	Water Recycling [6]	Desalination [6]	National Water Transfer [42]	International Inter-Basin Water Transfer [19 & 20]
Africa	63	25 %	13 %	9 %	3 %	5 %
Asia	73	23 %	35 %	27 %	7 %	3 %
Europe	67	30 %	88 %	65 %	52 %	1.5 %
North America	46	41 %	81 %	35 %	22 %	0
South America	37	30 %	86 %	56 %	15 %	0

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TABLE 7
CHARACTERISTICS OF THE RIVER NILE BASIN COUNTRIES

Country	**Area in basin** [44]		**Population ($\times 10^3$)**	**Water/Capita (m^3/year)**	**Water Resources** [26]			**Irrigated land (ha)**	**Irrigable land (ha)**
	(km^2)	**(%)**	**(Year 2011)** [26]		**Internal (km³/year)**	**Total (km³/year)**	**Dependency ratio (%)**	[46]	
Burundi	13260	0.4	8575	1462	10.1	12.5	20	50	80000
D.R.Congo	22143	0.7	67758	18935	900	1283	30	80	10000
Egypt	326751	10.5	82537	[694]	1.8	57.3	[97]	2923200	4420000
Eritrea	24921	0.8	5415	1163	2.8	6.3	56	5800	150000
Ethiopia	365117	11.7	84734	1440	122	122	**0**	32100	2220000
Kenya	46229	1.5	41610	738	20.7	30.7	33	9800	180000
Uganda	231366	7.4	34509	1913	39	66	41	9100	202000
Rwanda	19876	0.7	10934	868	9.5	9.5	**0**	3300	150000
Sudan / **South Sudan**	1978506	63.6	44632	1445	30	64.5	77	1930300	2750000
Tanzania	84200	2.7	46218	2083	84	96.3	13	14100	30000
Total	**3112369**	**100**	**426922**					**4927830**	**10192000**

The above mentioned examples of losses, which were documented and identified in this paper, equal 90 % of the rainfall on the River Nile Basin and represent 1480 Billion cubic meters /year. These huge losses need true technical cooperation between all River Nile Basin countries to minimize and control them by constructing new needed projects.

Construction of channels to link unconnected river systems, or so-called Inter-basin Water Transfer (IBWT) has not occurred on a large scale in Africa except in southern Africa; however the author after studying many transboundary river basins all over the world found that; in countries which depend heavily on freshwater from rivers; such as Egypt, the most suitable non-conventional solution, which can be applied for providing the needed sustainable freshwater for the current and future generation is inter-basin water transfer from another basin that has excess of water, or huge losses. Inter-basin water transfers are international projects with multiple purposes such as development of irrigation along the linking channel between the two basins and increasing of regional hydropower generation. This kind of international projects which are based on international cooperation are the most supported from the international donors; especially the World Bank to cover the very high expenses of such international projects, while the other non-conventional water resources are national projects which depend extremely on huge national investments.

5 CONCLUTIONS

After the above mentioned reviewing and studying of the experiences implemented in the most popular transboundary river basins in different continents, the following main conclusions can be drawn down:

1) There is a great need for constructing clear criteria for making the needed absence balance between the rights of both estuaries and source countries for avoiding any expected conflicts between them.
2) The most effective approach that proved success in

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solving the most problems of international trans-boundary water sharing was the political agreement by equitable and reasonable share of the international water associated with preventing the harm to other basin countries. It was used in 25 % of 63 River basins in Africa continent, 23 % of 73 River basins in Asia continent, and 30 % of 67 River basins in Europe continent, 41 % of 46 River basins in North America continent and 30 % of 37 River basins in South America continent. So that approach is the most recommended one to be used in other conflicted River basins, such as River Nile.

3) The study highlighted that the succeeded water agreements for conflict resolution in the studied transboundary river basins were based on the principle of equitable and reasonable utilization of the river basin, and the principle of obligation not to cause harm among the basin countries.
4) Establishment of a permanent legal and institutional frameworks proved that, it enables the sharing countries to address water-related issues in an organized manner which can be achieved through: i) flexibility of water agreements to introduce some needed modifications with time; ii) mechanism of water allocation must be based on reasonable use of water which should be identified clearly in the water agreements, and iii) establishing water institutions based on the water agreements should have specific tasks in the river basin.
5) The major problem facing the management of some transboundary river basins such as the Tigris-Euphrates River (between Turkey-Syria/Iraq) and the River Nile (between Egypt and Ethiopia) is the absence of the principle of prior notification and consultation before executing projects on the river. So, the water resources scientists and experts, by the cooperation with the international law scientists, have to proceed to put a framework for a strict and mandatory international law prohibiting starting to establish any projects on transboundary river basins
6) River Nile basin has a special property, that is the huge amount of losses reaches more than 1480 BCM/year, represents 90% of the whole river basin water income. So a special technical care must be taken into consideration for minimizing such huge amount of loses in the above mentioned locations along the long distance journey of its water.

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