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Review article

Fresh water resource, scarcity, water salinity challenges and possible remedies: A review

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ABSTRACT

Water is one of the natural resource due balance if our planet and the life on it have to sustain and economic development to be expected in the future. The increase in population of the world and level of wealth of humans is expected to withdraw more freshwater. However, since water is already one of the limited resources, global per capital water available surely drops and water shortage happens. Pollution of ground and surface water by dissolved salts are increasing and exacerbating this water shortage situation. The sources of these dissolved salts (such as primary and secondary salinity-causing agents) are known to change the chemical constituent of water. Once contributing factors for water scarcity are identified, future man should work on it to overcome the challenge. This paper therefore began with global water resource information and indicated different levels of scarcity to give overall clues on the situation. Salinity description, its global status, causative factors and challenges were revised before possible recommendations were indicated as indispensable solution.

1. Introduction

Earth is a planet with 71% of its surface covered by water, of which, 97% of this is sea water [1]. Since seawater is rarely available for human consumption, the world population depends on only the 3% available fresh water as indicated on the global water distribution in Fig. 1. Out of the available freshwater, only 0.06% can be easily accessed as the rest comprises the frozen polar ice cap or glaciers, groundwater, and swam [1,2]. Lakes and rivers play a significant role in the global environment serving as irrigation water sources, fish farming, shipping transport, industrial and drinking water sources [3,4]. And 0.3% of the world's freshwater is contained by lakes and rivers [5,6]. Lakes contain 87% of all the liquid freshwater on the surface of earth while the river is only 2% [6,7]. In addition to these two available main freshwater sources, groundwater is another huge potential freshwater source for human survival even though not easily accessible [8]. Therefore, in areas where rivers and lakes are not available, finding the groundwater which is about 99% of the world's readily available liquid freshwater resource is a must for survival [5]. About 2.5 billion people depend on this water source only to satisfy the requirement of their fresh water [9]. The larges use of groundwater is for agricaultural sector [10]. According to Misstear, D et al. [10], irrigation sector only uses above 70% of the groundwater and India, China and USA are the major leading countries in use of this water source.

Change in living standard, living culture and increasing population made increase in demand for freshwater and its withdrawals

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[11–13]. For example, 3.5 billion people living in urban area in 2010 is expected to rise to 6.3 billion in 2050 and this brings huge living culture change [14]. World population on the other hand is expected to boost from 7.7 billion of 2017 to 9.4–10.2 billion in 2050 [15]. Therefore, huge change of water withdrawal is expected to come due to the stated changes of living style and population. The number of people living under limited water supply has reached 1.1 billion according to different sources [16,17]. This value get raised to 2 billion in 2010 [15,18] and the expected face of water shortage in 2025 is 2.7 billion people according to UN [1]. According to Ref. [15], the number of people to live under sever water scarcity was also projected to be 2.7–3.2 billion in 2050.

It is not only the water quantity or withdrawal level that matters, the quality of water we use is also equally important. Researchers have been warning saturation of the limited water resource with dissolved salt as another threat to the world's water scarcity [19,20]. This paper is therefore aimed at reviewing the quantitative and qualitative aspect of water resource and put remedy and future perspective to halt the increasing freshwater scarcity. Particularly, issues focusing on freshwater resource, withdrawal, scarcity and the roles of withdrawal and salinity in freshwater scarcity is pinpointed.

2. Fresh water resource and its distribution

The world's regional potential renewable resource accounts to 52,580 km^3/year [21]. According to FAO [21] the share of the water resource was indicated for America, Europe, Africa, Asia and Oceania as 24,362, 7418, 5530, 14,451 and 819 km^3/year, respectively as shown in Fig. 2(a).

In addition to the distribution at the continental level, regional status is also indicated in Fig. 2(b) putting South America and South and East Asia with good water resource potential. There was also an estimate of the resource including per inhabitant in different regions of the world as shown in Fig. 3 [22,23]. For example, out of the total water resource estimate of 43,750 km^3/year, percent share of America, Asia, Europe, and Africa is 45, 28, 15.5, and 9, respectively. And the water resources share per inhabitant between America, Europe, Africa, and Asia according to this report was observed to be 24,000, 9300, 5000, and 3400 m^3/year, respectively.

The potential water resource of regions can only keep its status if the factors known to influence water usage mainly population, type of living style of a community (e.g. agricultural or industrial), wealth and level of development of the economy and local climate and cultural values [12] are managed properly. However, the population of the world is expected to grow from 6.8 in 2009 to 8.5 billion in 2025 [24,25]. UNEP also has forecasted different regions' population growth indicating major change in Asia, Africa, and South America as shown in Fig. 4 [5]. The continent of Asia, Africa and South America are highly increasing in populations as shown in the figure. This surely decreases the available per capital freshwater resource. Therefore, the potential water available for the world population was observed to decrease from 12,900 m^3 in 1970 to less than 7000 m^3 in 2000 and is also projected to drop to 5100 m^3 per capita per year by 2025 [5] as shown in Fig. 5.

The increase in population and decrease in available water potential has a significant impact not only on water usage or withdrawal level, but also on security of the world [27]. The reduction in the level of withdrawal means an increase in water scarcity, and this on

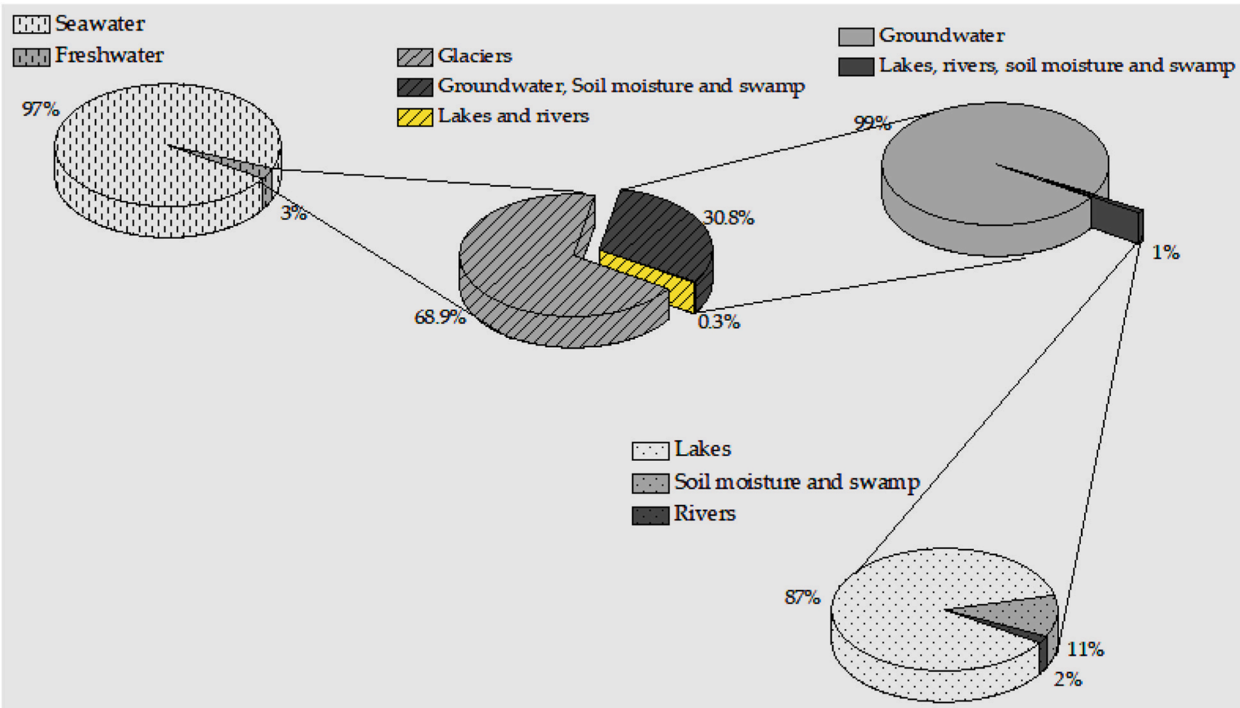

Fig. 1. Global water resource distribution [1,6,7].

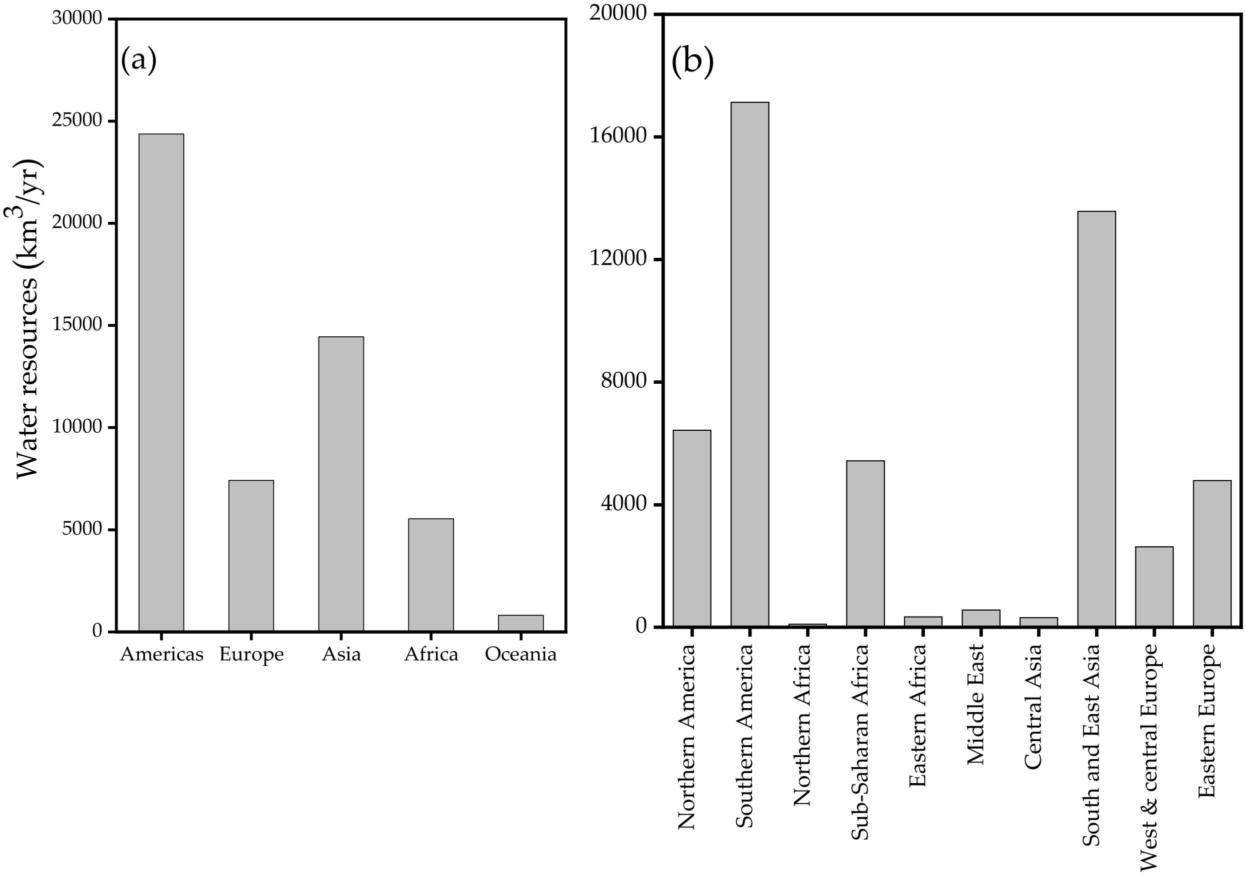

Fig. 2. Water resources at (a) continental; (b) regional levels [21].

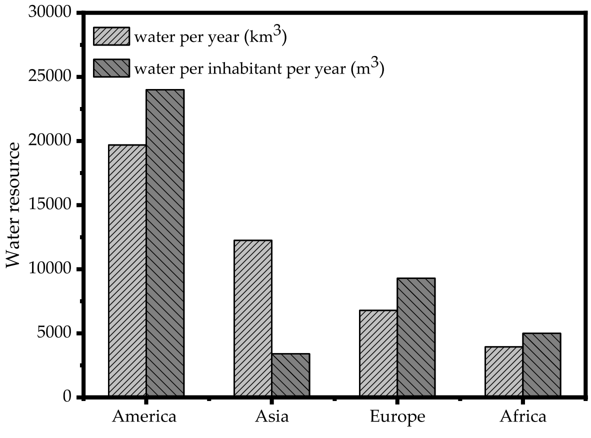

Fig. 3. Water resources and per inhabitants' status at different regions [22,23].

the other round mean a rise in security tension. The other very related issue is deterioration of water in chemical quality after use [28]. Countries such as Pakistan, China, India, Argentina, Sudan and also those in the central Asia are known to have high populations have been affected by wastewater generated after use. Therefore, if the wastewater generated after withdrawal cannot be reused by implementing treatment techniques, it will go to the remaining water body through running ways and affect the chemical constituent of freshwater which again affect usage security. The next sections of this paper therefore give an overview of the withdrawal, scarcity and salinity with its challenges.

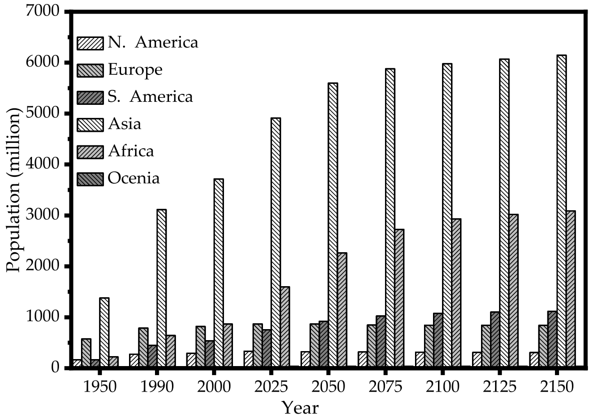

Fig. 4. Population increment and its forecast in different regions [26].

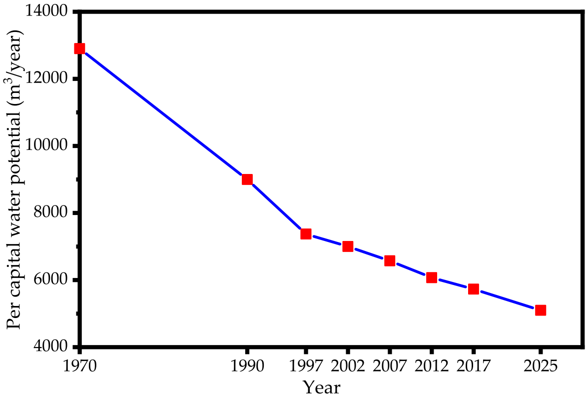

Fig. 5. World available water up to 2017 and forecast to 2025 [5].

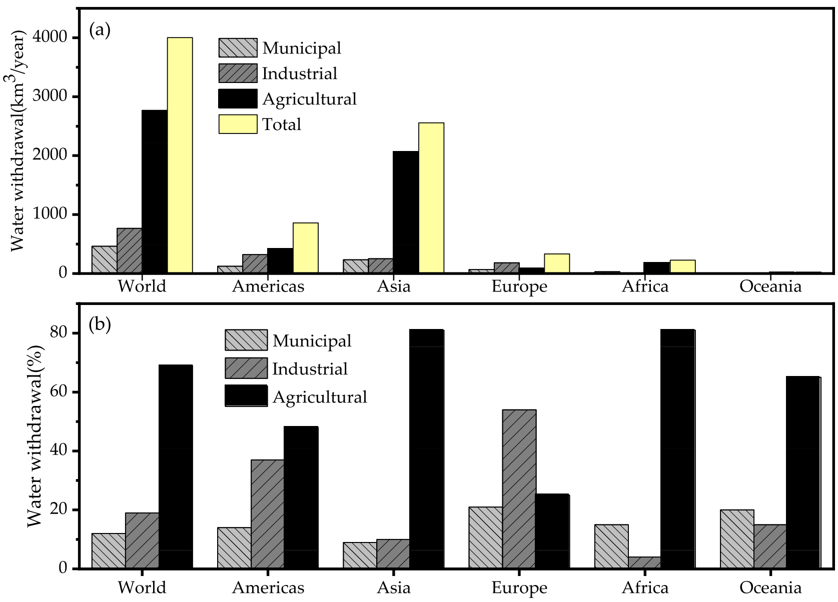

Fig. 6. Global and continental water withdrawal in (a) amount; (b) percent by sectors in 2010 [31].

3. Global water withdrawal status and contributing sectors

The annual withdrawal of freshwater in the world has been found increasing [29–31]. This withdrawal of freshwater in the world has increased from 3790 (in 1995) to 4430 (in 2000) and is expected to reach 5240 (in 2025) in kilometer cube [29]. The factors known to influence the level of water usage are the living style of a community (e.g. agricultural, residential, or industrial), wealth and level of development of the economy, local climate, and cultural values [12,32]. For example, in 2010 the total withdrawal of water was shown as 4000 km^3 with a share of 2750 (68.75%), 750 (18.75%) and 500 (12.5%) for agriculture, industry and municipal, respectively as indicated in Fig. 6 (a) and (b) [31].

The water withdrawals assessment to the year 2000 and its forecast up to 2025 at different regions (on 'a'), and by different sectors (on 'b') are also shown in the report of Shiklomanov in Fig. 7 [30]. The volume of annual water consumption by manufacturing industry was estimated to increase by 50% above the level in 1995 to meet 2025 [33] and the demand for water by this sector is expected to increase by 400% globally from 2000 to 2050 [15].

However, in all of the reports made on sectorial water withdrawal assessments, agriculture sector was found to extract water resource the most. Agricultural products such as cereals, meat and milk are the largest freshwater volume users per product or service called footprint accounting for 27%, 22% and 7%, respectively [34,35]. For example, to produce a kilogram of tomatoes, rice, cheese, and beef, the amount of water needed is 214, 2500, 3180 and 15,400 l, respectively [14]. Thus, countries producing these products for export North America, South Asia, South America and Australia are virtual water exporters while those importing Japan, North Africa, Mexico, the Middle East, South Korea and Europe are virtual water importers [28].

Increase in withdrawal of water not only raise its consumtion, but also its loss. This can be observed on the trend of withdrawal and consumption of fresh water shown in Figs. 8 and 9 [30] and also found to support UNESCO's report [29]. The increasing loss of water can be observed by the increament of the gap between the withdrawal and consumption trend shown in Fig. 8 and at different continents in Fig. 9(a–g).

Even in developed regions such as Europe and North America, the gap between withdrawal and consumption is very huge as seen in Fig. 9 (b) and (f) indicating the loss is in the worst manner in the region. Specifically, when water withdrawals for irrigation are observed, about double volume of the demand was withdrawn as shown in Fig. 10 (a) and (b) [21]. This withdrawal for irrigation was also suggested by FAO to grow by 11% up to 2050 to cope with the increasing food demands [36]. Thus, excess water has been lost and also expected to get lost from the total water bank without putting it to use.

4. Water scarcity level and its distribution

The world is facing enormous challenges in meeting rising demands for clean water as the available supplies of freshwater are decreasing due to rapid population growth, urbanization, rapid industrialization, global climate change, and more stringent health-based water quality standards [11]. When the water withdrawn are no longer adequate to satisfy human need and competition, we call water scarcity occurs [2,5]. In 2009, the United Nations estimated that 1.2 billion people in over 80 countries suffered water shortage in the world and this figure will be expected to get raise to 2.7 b y 2025 [1,2]. It is clear that, there will be less water available per capital when the population number grows since the water resource is limited. Therefore, per capital potential available water on

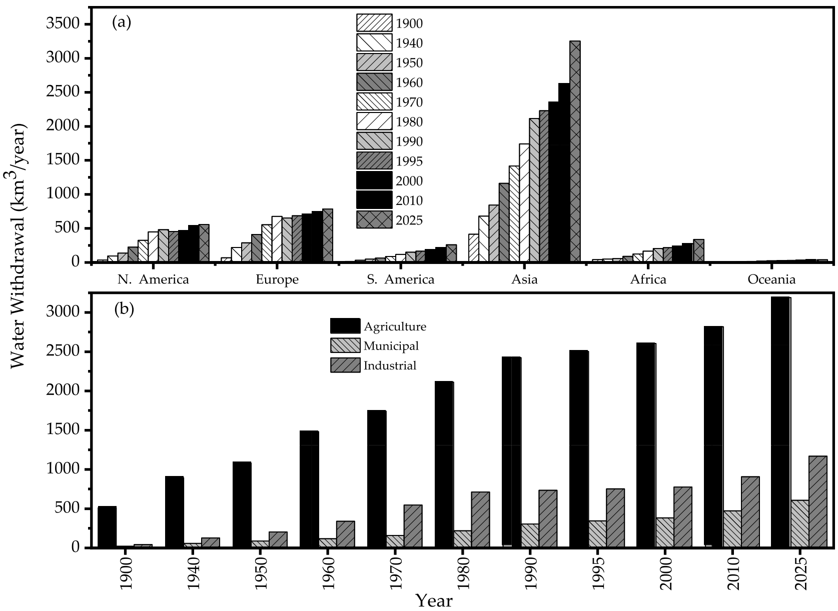

Fig. 7. Water withdrawal and its forecasted trend of (a) continents; (b) sectors [30].

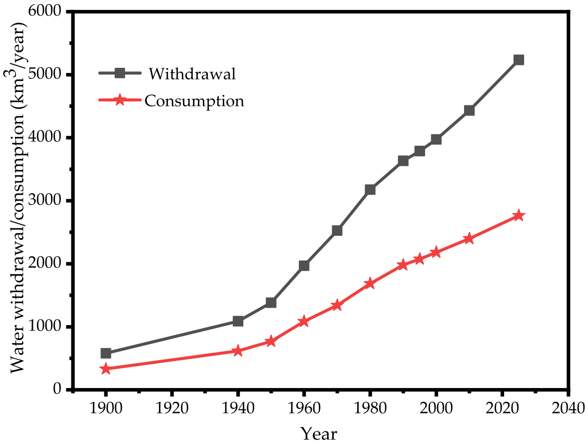

Fig. 8. World water withdrawal and consumption trends [30].

earth decreased from 12,900 m^3/year in 1970 to less than 7000 m^3/year in 2000 and this value is also projected to drop to 5100 m^3 by 2025 [5].

Different methods of water scarcity measurement exist, out of which international water management institute and Falkenmark methods are commonly in use [2]. The first method uses goal 6 of the sustainable development goal which is specifically known as SDG 6.4.2 [37,38]. It measures the stress level of water based on the classification shown in Table 1 [37]. This uses a ratio of withdrawn freshwater for all economic sectors (agriculture, industry and municipality) to total freshwater resource after excluding environmental requirements. According to this method, countries can be considered as economically water-stressed, approached physical water scarcity and said to face severe physical water scarcity if they withdraw more than 25%, more than 60% and more than 75% of their renewable freshwater resources, respectively [25]. An explanations behind these terms are so important and have also support from different research works [12,39]. Physically water-scarce countries do not have sufficient water resources even with the highest efficiency usage feasibility. And economic water scarcity countries have sufficient water resources, but they have to increase water supplies through additional storage, conveyance and regulation systems by 25% or more over the 1995 levels to meet their 2025 needs.

The stress of water can also be analyzed using the Falkenmark classification summarized by Refs. [2,40] based on per capital freshwater available which put 1700 m^3/person/year water requirement as threshold limit. According to this classification, countries with above 10,000 m^3/person/year (such as Canada, Panama and Bangladesh) are identified as having no water problem and those with less than 500 (such as Tunisia, Israel, Barbados, UAE, Jordan, Saudi Arabiya, Libya, Malta, Qatar, Egypt and Quit) are beyond chronic water scarcity or absolute scarcity. In between this gap, we find general water problems, water scarce and chronic water scarcity in the ranges of 1700–10000, 1000–1700 and 500–1000, respectively.

Arid region (such as Central, West Asia and also North Africa) countries are in physical water scarce group, and they are getting close to or below 1000 m^3/person/year [2]. In the year 2000, the North-Africa belt region (Morocco to Egypt) and Sudan had per capital of less than 1000 m^3/person/year while Middle East and Southern Africa had 1000-2000 [41]. It was also forecasted that Eastern and Southern part of Africa and the Middle East region as well will drop to below 1000 m^3/capita/year, while West Africa and large parts of South and Southeast Asia would be in the 1000–2000 m^3/person/year before 2050 [5,41]. According to various literature, there are also countries already in or expected to shift from economic water scarcity to physical water scarcity in 2025 [5,12,40]. Fig. 11 indicate the total renewable and per capital of water resource for the countries.

5. The consequence of water scarcity

The growing demand and withdrawal for water require more serious regional and international attention. This is not only for its consequence of starvation and death if not satisfied, but also because conflicts can arise due to its scarcity inside or across the border of a country. There are many conflicts already observed across or within the border of countries [42–45]. Just to mention some of the regions where the conflicts have been on water within or across the border of countries at different river basins like the Ganges river between India and Bangladesh [45] and the Indus river between India and Pakistan; Mekong river basin [46] between China, Myanmar, Thailand, Lao, Cambodia and Viet Nam; Huleh basin and the Jordan River [27] between Israel and Syria and also across the Euphrates river [27] between Syria and Iraq.

The conflict also occurred between Afghanistan and Iran due to the Helmand River [47]. Similar reports were also observed between Mexico and USA; Somalia and Ethiopia and also between Turkey and Armenia [27]. The conflict could also be in the same state due to unequal distribution as it has been on the Cauvery river between Karnataka and Tamil Nadu of Indian states [48]. Similar state reports also shown in Peru, Mexico, Ecuador, Bolivia, Somalia and Yemen [49]. There has also been a dispute between territory countries at some rivers, for example Euphrates, Nile and Okavango Rivers even though not resulted in conflict. The population status and water per capital available for the countries sharing these rivers are shown in Fig. 12 [50]. Therefore, these countries and those having similar statuses have to work on options of freshwater supply to supply the increasing population.

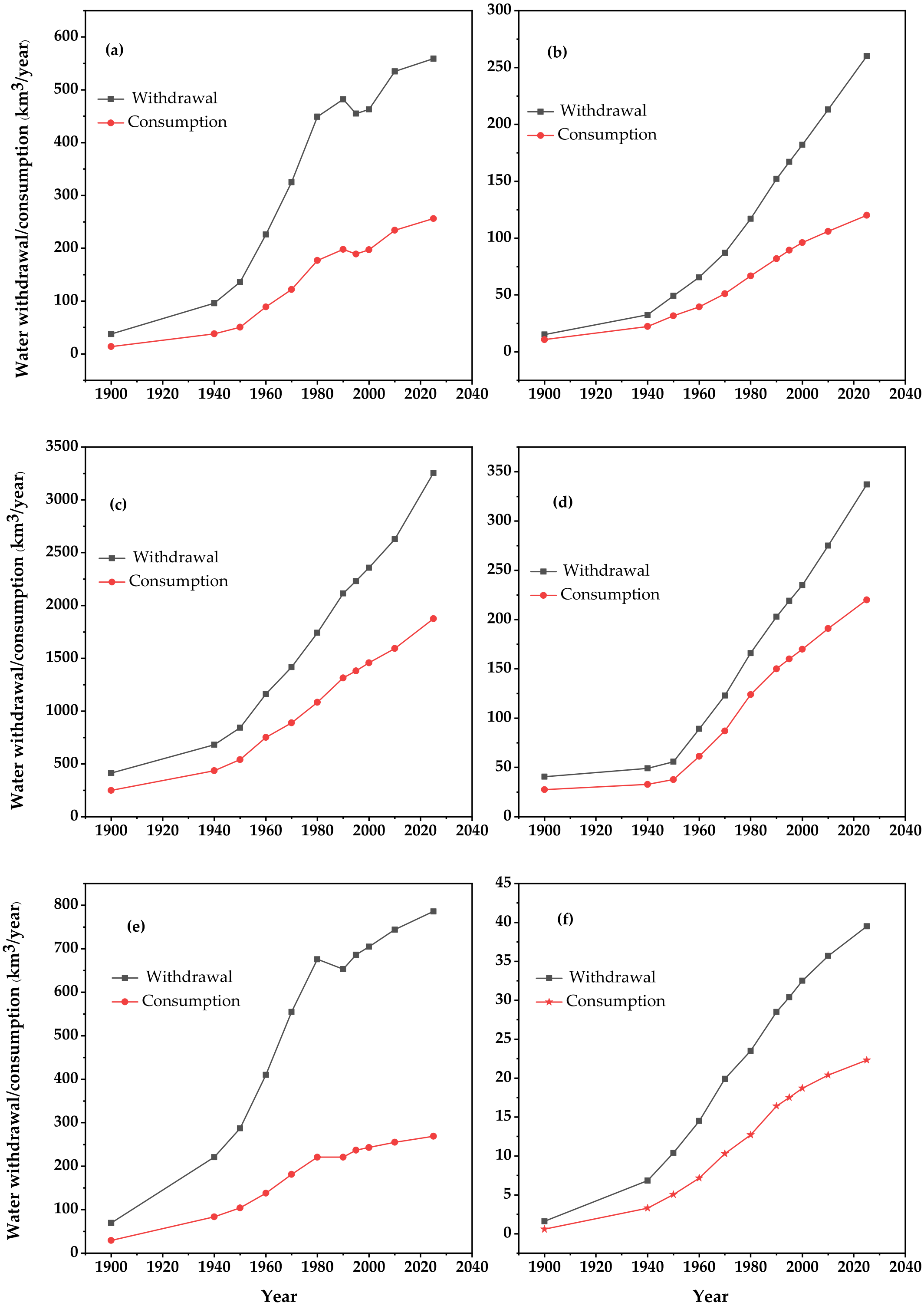

Fig. 9. Water withdrawal and consumption trends in (a) Europe; (b) S. America; (c) Asia; (d) Africa; (e) N. America; (f) Oceania [30].

6. Salinity as water stressing factor

In addition to increase in water withdrawal due to population increment and living style change, salinity or change in the chemical property of water has been identified as a scarcity-creating factor [23]. In this section, description of salinity and available standards

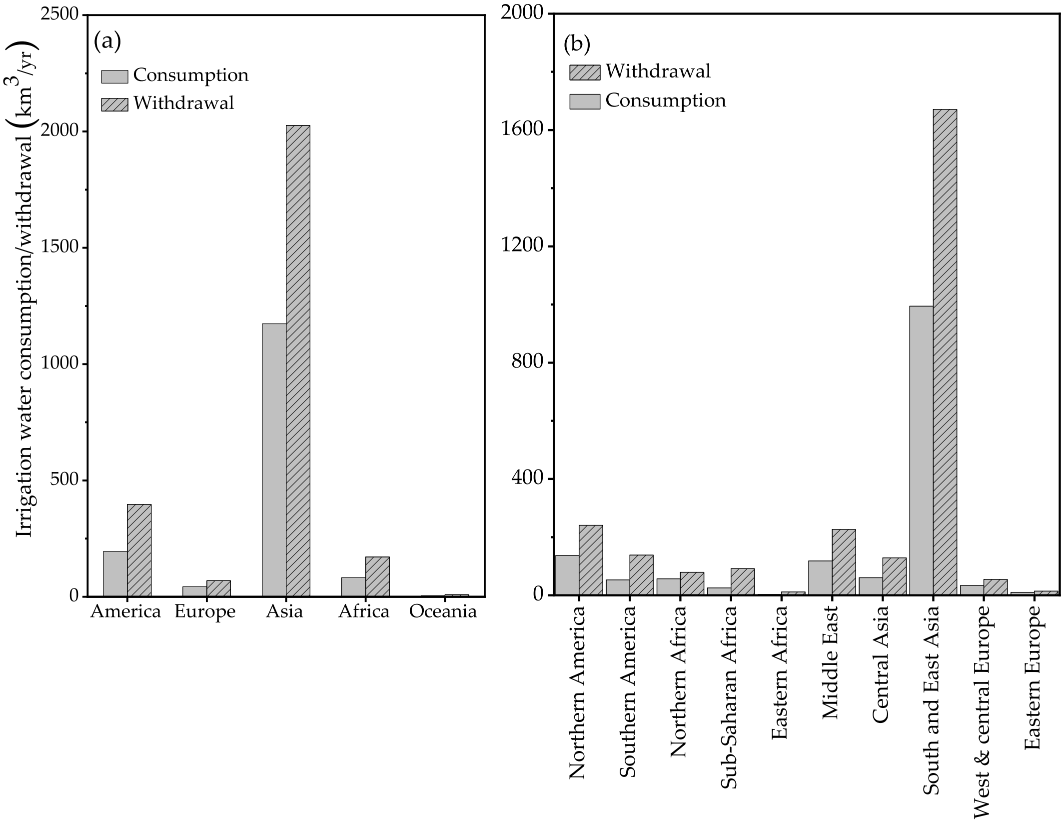

Fig. 10. Irrigation water consumption and withdrawal (a) continents; (b) regions [21].

Table 1
SDG 6.4.2 criteria for water stress classification [37].

Percent of water stress (%) = $\frac{\text{Withdrawal}}{(\text{total fresh water} - \text{environmental flow requirement})}$ *100	Meaning or stress level
0–25	No stress
25–50	Low stress
50–75	Medium stress
75–100	High stress
>100	Critical stress

(decision criteria) to judge water as saline or not from use point of view, global status of salinity, its cause and challenges are investigated to show the vast nature of the problem.

6.1. Salinity description and standards of decision

In addition to high water withdrawal, saturation of water with dissolved salts increase water stress and scarcity [19,23,51]. The increase of water with dissolved salt is known as water salinity [52]. This level of salinity can be measured by total dissolved solids, percent composition, or electric conductivity of water. A salinity of more than 0.8 ds/m in electrical conductivity shows that this water is at risk and needs care in using it [53].

Different guideline sources classified salinity levels based on their impact classes using EC values [23,54] as shown in Table 2. For example, according to the United States Geological Survey standard for Sodium chloride, different names were also given to water based on concentrations of salt as shown in Table 2 [55,56] or based on salinity measured from electrical conductivity [57].

Therefore, ionic parameters in drinking water and irrigation parameters must be guided by WHO and FAO shown in Tables 3 and 4, respectively to sustain demographic change, urbanization, industrialization and energy production [58,59].

6.2. Salinity status over the world

Globally, above 100 countries have faced problems with salinity and the extent of distribution is expected to expand [63]. Countries

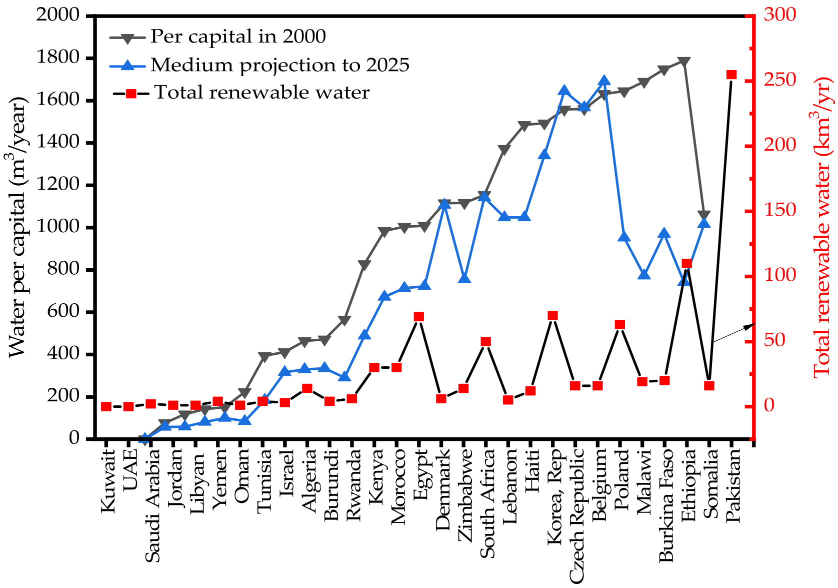

Fig. 11. Some countries experiencing water scarcity and projections [12].

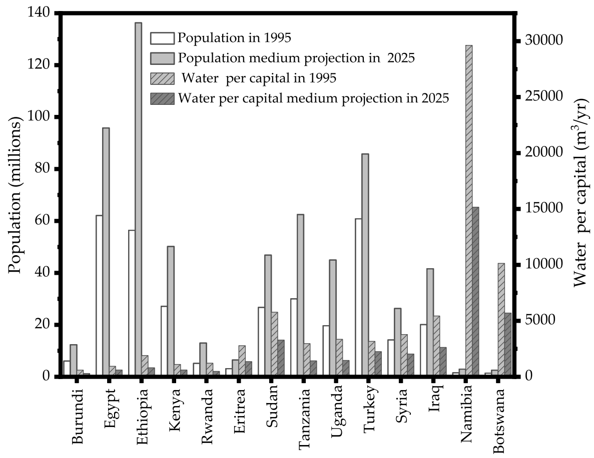

Fig. 12. Population and per capital water status around Euphrates, Nile and Okavango [50].

Table 2
Water classification based on salinity [55].

Water type	NaCl (%)	NaCl (mg/L)	Salinity (dS/m)
Fresh	<0.1	<1000	<0.7
Slightly saline	0.1–0.3	1000–3000	0.7-2-4
Moderately saline	0.3–1	3000–10000	2–10
Highly saline	1–3.5	10,000–35000	10–25
Very highly saline (Ocean/seawater)	>3.5	~35,000	>25

generally called as Persian Gulf (such as Kingdom of Saudi Arabia, Kuwait, United Arab Emirates and Bahrain) are known for having little or no fresh water available to support their population [51]. Both surface and groundwater salinization is a growing freshwater challenge [64,65]. For example, about 1.1 billion people were estimated to live in an area that had saline groundwater in 2009, [66].

South Asia region is known with about 352 varies size saline lakes [67]. Lakes and rivers in Western area, East Africa, USA, South America and Australia are the most common saline water body [68]. Particularly, countries such as Argentina, USA, Australia, Sudan, China, India, Pakistan, Iran, Russia, Afganistan, Ehiopia, Kenya and Tanzania are some of the many countries known with Lakes or river salinity [28,68]. East African (such as Ethiopia, Kenya and Tanzania) lakes were also shown salinity and alkalinity parameter

Table 3
Drinking water Chemical Qualities [60,61].

Inorganic parameter	Value	Inorganic Parameter	Value
Antimony	0.005	Sodium	200
Manganese	0.1	Chloride	250
Selenium	0.01	TDS	1000
Cyanide	0.07	Zinc	3
Manganese	0.5	Aluminum	0.2
Molybdenum	0.07	Toluene	24–170
Cadmium	0.3	Copper	1
Copper	2	1,2 Dichlorobenzene	1–10
Nitrate	50	Ammonia	1.5
Arsenic	0.01	Color	15
Fluoride	1.5	Turbidity	5
Lead	0.01	Dichlorobenzene	5–50
Chromium	0.003	Sulfate	250
Nitrite	3	Ethyl-Benzene	2.4–200
Nickel	0.02	Hydrogen Sulfide	0.05
Mercury	0.001	1,2 Dichlorobenzene	0.3–30
Barium	0.7	Iron	0.3

All values are in mg/L except for color, TCU and turbidity, NTU.

Table 4
Irrigation water quality standards US/FAO [62].

Water quality	Salinity Hazard		SAR(meq/L)	RSC(meq/L)
	EC at 25 °C (Micromhols/cm)	TDS (mg/L)	Up to 10	
Excellent	<250	<160	10–18	<1.25
Good	250–750	160–500	18–26	1.25–2.5
Medium	750–2250	500–1500	>26	>2.5
Bad	2250–4000	1500–2500	>26	–
Very Bad	>4000	>2500		–

[69]. Globally known saline water bodies are shown in Table 5 to indicate the salinity level in percent and the contributing salt components (Perez 2017). Ionic compositions of some saline lakes and rivers are shown in Tables 6 and 7, respectively.

6.3. *Causes of water salinity*

Salinity causes are so complex in variety that includes air born salts, salts from weathering of rocks and soils, underground salt contaminated groundwater, mining and construction related activities such as road and railway [23,67,68,80]. In general, salinity causing factors can be categorized as primary and secondary salinization. The primary cause of salinity is natural processes such as weathering of saline parent rocks and soil in which wind and rain transport salt and deposit over thousands of years [23,80]. Ancient marine salt beds or tidal swamps (natural salt scalds) are also in the primary salinity causing category [68]. However, the origin of the saline lakes are tectonic, volcanic, glacial and their combinations [68]. Some of the saline water body formed due to the presence of seawater or ocean intrusion in the area before tectonic or continental crust compression origin are Dead Sea, Great Salt Lake and Lake Urmia [70]. Evaporation of marine originated water environments can also cause saline lakes, and lake Assal of Djibout's and Kara-Bogaz-Gol are out of the saline water bodies created by evaporation due to geothermal heat [70]. An earthquake can also cause saline, particularly when thermal springs exist in the area like Ga'etel of Ethiopia [70]. Volcano-tectonic existence such as Basaka Lake in Ethiopia can also be the reason for saline lakes formation [81].

The causes of secondary salinization are so vast and mainly arise by human activity due to improper land use practices (such as

Table 5
Salinity of some most saline water bodies on earth [70].

Name	Location	Salinity (%)	Components (>10%)	Reference
Gaet'ale Pond	Ethiopia	43.3	CaCl2 and MgCl2	[70]
Don Juan Pond	Antarctica	24–40	CaCl2	[71]
Kara-Bogaz-Gol	Turkmenistan	27–35	NaCl	[72]
Lake Assal	Djibouti	30.4	NaCl	[73]
Dead Sea	Israel/Jordan	29.8	MgCl2, NaCl, CaCl2	
Great Salt Lake	USA	28.5	NaCl	
Lake Urmia	Iran	24	NaCl	[74]
Lake Vanda	Antarctica	12	CaCl2, MgCl2, NaCl	[71]

Table 6
Composition of some world rivers.

Country	River	Ionic composition (mg/l)							
		Na	K	Mg	Ca	Cl	SO4	HCO3	CO3
Algeria	Chelif[a]		1208	236	354	2098	1382		59
Argentina	Rio de los[a]	2432	45	33	748	2997	2922		5.5
	Rio saladillo[a]	39,403	2.0	4.8	94.1	5.9	–	–	
Australia	McKinnon[a]		726	116	180	1390	134	490	–
Iran	Niriszufilus[a]	1220	38	114	137	2261	128		138
	Salzflus[a]	7925	57	1476	616	10,898	5213		2466
USA	Kansas[a]		1150	67	136	1580	670	322	0
	Pecos[a]		1614	1301	737	4135	3060	153	0
Russia	Charisacha[a]	15,993		1899	364	28,529	3130	–	–
	Gorkoi-jerik[a]	6623		420	742	12,758	–	–	
	kalaus[a]		1769	379	303	1518	3527	378	0
Ethiopia	Hora Kelo[b]	724.2	724.2	6.0	31.3	2.4			
	Bulbulla[b]	213.8	19.5	8.5	18.0	85.1			

[a] [68].
[b] [75].

Table 7
Composition of some world lakes.

Country	Lakes	Ionic composition (mg/l)							
		Na	K	Mg	Ca	Cl	SO4	HCO3	CO3
Djibouti	Assal[d]	101,100	5160	12,500	2676	198,800	4400	134.2	
Israel	Dead Sea[e]	34,300	8000	47,100	18,300	228,600	400	300	
Iran	Urmia[e]	88,000	1100	6600	1210	153,000	14,200	284,000	
Kenya	Nakuru[a]	38,000	1312	30	10	13,000	1800		
Madagaskar	Ihotry[a]	12,900	380	1272	400	21,000	790	140	0
Australia	Beeac[a]	18,699	143	620	200	34,790	778		461
	Corangamite[a]	42,054	2640	3394	48	74,438	2821	680	358
	Red Rock[a]	11,192	1216	139	15	11,574	–	4118	4890
Canada	Goodenough[a]	12,650	511	30	14	5003	0	3312	14,208
	Big Quill[a]	8050	575	4482	382	3510	30,200	793	133
	Little Manitou[a]	12,300	890	9518	497	18,000	39,600	776	209
China	Nyer Co[f]	28,000	20,440	76,080	920	272,970	16,900	0	
	Qinghai[f]	46,800	16,540	15,320	610	88,110	56,550	4760	
USA	Great Salt[e]	101,000	6900	8500	280	175,000	22,000	50	
	South Panamint[a]	63,394	4311	1426	4233	112,971	3535	442	0
	Big Soda[a]	8000	310	145	5	6500	5600		4000
	Pyramid[a]	1720	118	114	9.3	2080	280	860	300
Ethiopia	Gaet'ale[b]	1300	2400	34,900	109,000	281,000	3900		
	Abijata[b]	7384	293	0.0	4.0	2957			
	Chitu[b]	19,863	1220	1.2	4.0	3510			
	Shalla[b]	6646	215	0.0	2.0	3010			
	Beseka[c]	2587	62	4.2	1.2	937	990	1180	320

[a] [68].
[b] [75].
[c] [76].
[d] [77].
[e] [78].
[f] [79].

deforestation, poor irrigation, overgrazing or intensive cropping) and pollution related to industrialization such as mining, use of de-icing road salt and industrial outlets [23,80,82]. Over-irrigation infilters more water and brings salt accumulated in the water table to the surface of soil to dissolve salt back to surface water and cause salinity. Under-irrigation makes water to evaporate which accumulates salt in the soil and become a causes of water salinity when flood or heavy rain comes. Another act of humans that causes water salinity are inappropriate choice of crop for different soil types [53]. For high waterlogged regions, deep root trees need to be used to increase evapotranspiration and to avoid salt coming from the lower water table, whereas low water using crops need to be used on sand (highly permeable) soil type to avoid salt accumulation.

Reduction of the river's flow and the development of agricultural and industrial projects are fuels that aggravate the level of salinity in the remaining waters [50]. Salinity is mainly related to pollution by chemicals and sediment from different sector outlets [12]. There are contaminated groundwater and surface waters in nearly every country where farmers use agricultural fertilizers and pesticides. This is because the water that trickles back into rivers and streams after irrigation or heavy rain is often severely degraded by excess nutrients, higher salinity and sediment [51]. Industrial pollutants such as salts are often dumped directly into waterways, while others such as heavy metals and organ chlorines are leached from municipal and dumpsites [51]. The dumpsites can be ocean/seawater, sewage or land application, evaporation pond, or deep-well injections. The most common industries known to discharge salinity-causing dissolved solid in various plants such as desalination plants (7.5-82 g/l), flue gas desulfurization (5-50 g/l), oil and gas (5-400 g/l), landfill leachates (1-10 g/l), textile (1.6-50 g/l), dairy (8-120 g/l), aquaculture (12-47 g/l), municipal wastewater (0.6-4 g/l), pharmaceutical (20-50 g/l) and petrochemical (20-85 g/l) as reviewed on [83]. According to Hinrichsen [51], for instance, three-quarters of the country's river water in Poland is too polluted even for industrial use. The report also indicated that more than four million hectares of high-quality land in India have been abandoned because of salinization.

6.4. Challenges of water salinity

When the withdrawn water applied to crops pass the root zone and mix with groundwater, it raises the water table and salt to the surface of the earth. When the water get evaporated from the mixture, it leaves the salt in the soil, and this creates soil salinity which reduces agricultural productivity and creates food insecurity [84,85]. This also decreases the availability of arable land supported by global climate changes [84]. Salinity in Central Asia and Africa has affected up to 50% of Irrigated land areas [84]. In Pacific region countries of Asia, 3 ha of land used for irrigation are lost per minute due to unsuitable method used and 10–20 million hectares deteriorate to zero productivity each year [85].

On the other hand, dissolved salts and ions challenge the life of human beings by affecting chemical properties of the water [58]. For example, chromium and arsenic ions are known by their toxic nature to humans, animals, and life balance of the aquatic environment. And carbonates and salfates of calcium, magnesium and sodium are known for creating hard water or scale forming. Others chemical compounds like sodium chloride are known for their aesthetic aspects (change of taste and odor) to water. Therefore, salt affected water cannot be used for normal domestic purposes.

Agriculture and crop productivity is a controlling factor for the growing demands of population [36]. And salinity is known to affect the agriculture by limiting plant growth and crop productivity through its osmotic impact [53,84–86]. On different reports, the effect of salinity in the plant has been identified to be so diverse and can be generalized to reduction in productivity and photosynthesis disturbance [80,87,88]. Reduction of chlorophyll 'a' and increase of carotenoid in leaf and reduction in size of leaf due to salinity in water is directely related to disturbance of photosynthesis [87]. High salinity in soil create water potential reduction and plant get forced to lose water rather than uptake. By this time, plants try to cope up the water stress hardship by closing stomata and this affects transpiration [80]. Higher accumulation of some ions, for example, chlorine cause leaf burn type of injury which again prohibit photosynthesis and transpiration. The over all effect then enhahce protein break down for cell to survive and result in poor shoot and root growth of plant [80,88]. Salinity effects therefore manifest due to either by water up take reduction, ion accumulation to toxic level and by nutrient availability reduction [80].

7. Remedies of water scarcity and future outlook

7.1. Use of nature-based control and efficiency improvement

Problems that can be raised on the water are mainly uneven distribution and salinity. Uneven distribution or physical scarcity is related to a mismatch in population growth. In other words, it is an increase in water withdrawal for increasing demand of water by increasing population of the world. In addition to increase in water use, salinity of water has a potential to limit the sustainability of life on earth. Therefore, preserving natural water resources, use of it in a balanced way, and searching for solutions to pay back would be the only means of sustainability. That is water usage productivity, management of water demand and diversification of water supply [89]. For water supply diversification, we may put various solutions like building dams, water channels, recycling waste, or re-use of existing wastewater to get fresh water back and feed the massive population coming in the future. Above all, there has to be public awareness on water withdrawal and consumption, so that less water can be withdrawn and used efficiently until the gap shown in Figs. 5 and 6 get close to each other.

It is also possible to work on import of high water demanding products such as cereals, meat, dairy and export of low water demanding ones like olives, and oranges [90,91]. That means countries are importing products produced in some else countries using the freshwater of the producing country. For example, countries such as Malta, Kuwait, Jordan, Israel, UAE, Yemen, Mauritius, Lebanon and Cyprus are highly external water-dependent with a dependency level of 92 to 71% [34]. It was also pointed out in Mekonnen and Hoekstra [34] that countries such as Italy, German, England and Netherlands are using external water footprint. Similarly, there are industrial products that need to implement special care in using freshwater to save water resource. A summary of these industries using high amounts of water and generating waste is shown in various papers [35,92]. Chemical industries, petroleum refining, pulp and paper, primary metals and food processing are the leading industries in water use [92]. The global water footprint share of agriculture, industry and domestic supply is 92%, 4.4% and 3.6%, respectively [35]. According to Ref. [35], China and America are the leading countries to own the water footprint industrial productions in their territory with 22% and 18% share of the total water footprint, respectively.

If salinity is already present and the level of electrical conductivity is tolerable, use of the water to avoid high evaporation rate is essential [53]. To effect this, irrigating at night, avoid of leaf contact (use drip), keeping the soil moist (to flush salts from the root zone easily), ensuring good subsurface drainage, and diluting saline water with less salty supplies or implementing saline water tolerable practices are some of the strategies. Therefore, rearing sheep, beef and dairy cattle [40] and producing salt-tolerant staple crops varieties like barley, cotton, sugar beet, canola, wheat and forage grasses like alfalfa for grazing animals are some of the important schemes [57,93]. Since extensive water uses for different purposes have deterioration potential on water quality and increases the salinity level to an intolerable level, due care should be given to industrial effluent, urban pollution, and return flows from irrigation.

7.2. Desalination using membrane and thermal method

Salinity has been a big challenge and it require feasible solution before it become water stress and public health issues. If the level of salinity is more than tolerable (TDS>1000 ppm), feasible solution for the challenge is very difficult without desalination [94–97]. Desalination has been in use in more than 150 countries of the world [98]. Prominent desalination using countries are Algeria, Egypt, Morocco, Libya and Tunisia from Africa, and Saudi Arabia, Kuwait, United Arab Emirates, Qatar, Bahrain, Oman, Israel, Japan and china from Asia [12,99,100]. Countries like Kuwait, Malta and Qatar fulfill more than 50% of their water use by desalination [28]. And

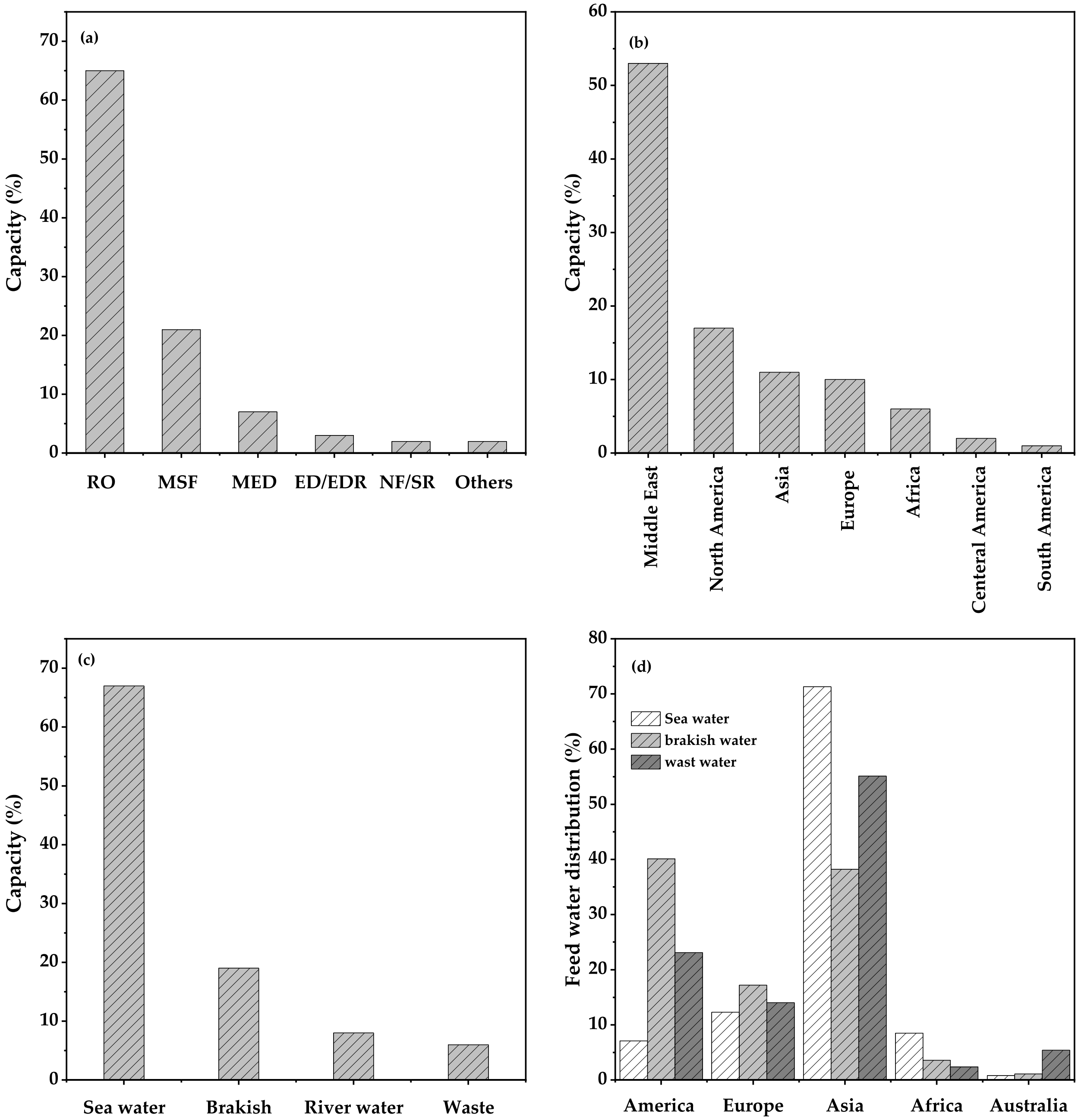

Fig. 13. Water desalination (a) technology; (b) capacity at different regions (c) feed capacity and (d) feed distribution at different regions.

the top per capital desalinated water users for irrigation and coverage percent are Kuwait (82.3%), United Arab Emirate (71.1%), Qatar (51.7%), Israel (46.4%), and Cyprus (31.9%). Despite the reduced costs of desalination, the highly energy-intensive nature made it beyond the economic capacity of most poor water-shortage countries [50]. Finding a more cost-effective, technically feasible method of desalination that can be used at different economic levels has been and also will have to be the center of research to cope with the increasing water problem.

Different technologies used and regions known in using desalination are shown in Fig. 13 (a) and (b), respectively [94,96]. The feed water type used for desalination is mainly sourced from either seawater, brackish, or wastewater and its global distribution is also indicated in Fig. 13 (c) and (d) [97]. The selection of the feed water type mainly focuses on its availability and feasibility of the plant. Therefore, it is based on the designer's preference and plant operation efficiency. Europe and America are known to use brackish water as a feed source for their desalination plant. Majorly USA from America and Spain, Italy, Cyprus, Greece and Malta from Europe are known in using this feed type for desalination [28,100]. On the other hand, Asia and Africa use seawater while wastewater is used in Australia for desalination. The use of technologies in various regions of the world depends on the facility of the using country. That is, it could be easy for some to use multi-stage flash (MSF) or multi-effect distillation (MED) because they have abundant fuel as a source of energy. These desalination technologies are limited predominantly to countries that have high oil resource such as Saudi Arabia, UAE, Kuwait, and USA etc. Others use the technological capacity to apply membrane technology like reverse osmosis (RO), Electrodialysis (ED) or Nanofiltration. Reverse osmosis (RO) technology is observed to be widely applied worldwide. RO using countries are those with high economy and technologically developed groups such as United States, Japan and Spain etc as shown for some countries in Fig. 14 [12]. As a third preference, the two (energy-resourced and membrane technologically strong countries) can also interchange the desalination techniques as a bargaining tool.

Understanding the drawback (high energy requirement) of the comercial desalination methods (RO, MSF MED and ED), use of renewable energies (such as solar, wind, wave and geothermal) has been developed. Out of 131 renewable energy based desalination plants commissioned in years between (1974–2009), 70% were based on solar and 20% on wind [89]. It was also pointed that photovoltaic configured RO takes one-third of this renewable energy based desalination [89]. Though different researchers agree on use of renewable energy integrated desalination, there are different perspectives in selection of the methods. Some sugest solar (photovoltaic) integrated RO than wind powered as it is more predictable [89,101,102]. Others suggested wind-powered RO as low cost desalination followed by photovoltaic-powered RO [103]. Hybrid renewable energy driven desalination such as Solar/Wind-RO/thermal are also recentely suggested for potential cost reduction and smooth productivity option [102].

7.3. Desalination using adsorbent materials

Water desalination by use of adsorbent materials is considered recently as eco-desalination technology for its low operational cost (minimum energy) and more friendly to the environment (low carbon dioxide release) [104–107]. If desalination efficiency and capacities of the adsorbent materials are improved, a wide range of materials showed a potential capacity for various dissolved salt removal [108,109]. Out of this range of materials, the application of aluminosilicate materials such as Zeolite [110–112] and bentonite [113–116] has been widely investigated by researchers. In addition, lignocellulose materials like rice husk [117–119], sugarcane bagasse and sugar beet pulp [120], maize cobs [121], fique fibers [122], bagasse and coffee husk [123] were investigated as potential options of desalination.

Phase change assisted adsorption desalination are recentely getting common to get frechwater. This is evaporation of the saline water and passing on adsorbents to collect the freshwater after condensation. The method uses high surface area adsorbents such as metal-organic frameworks, silica gels, hydrogels graphene and its derivates (such as CaCl2/silica gel, NaBr, CaCl2/activated carbon, LiCl/activated carbon etc.) [124], nanoparticle embedded silica gel composite with CaCl2 [125]. Renewable energy driven

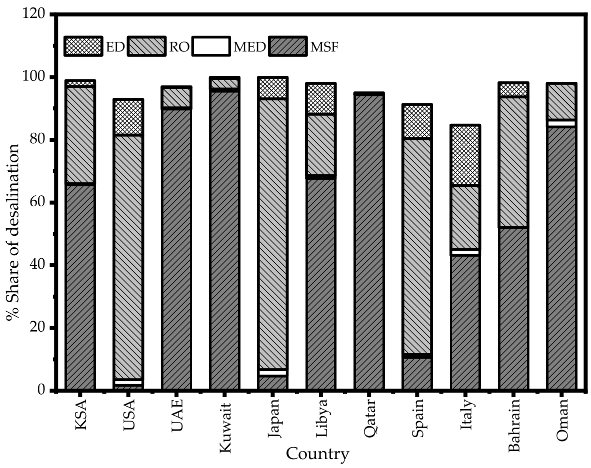

Fig. 14. Water desalination share in some countries [12].

desalinations are also recentely used in this phase change adsorption methods. For example, solar driven desalination by using silica gel and hydrogel adsorbents [126], different thermal heat source (such as solar, geothermal, waste heat and biomass) driven using porous activated carbon [127]. A hybride of phase change assisted adsorption desalination and RO desalination also used to enhance the efficiency and sugested for further research [128].

8. Conclusion

The earth was already created with its pros and cons, and that is the natural being. Finding a means to use the resource it can provide by keeping its status is humanity and that is also a natural being. However, adding a problem to the natural ecosystem in a way that can hurt the existence of others is an illegal act that human beings should put in mind in day-to-day life. It suffices well if we put this logic into the natural water resource. There is huge potential of saline water as shown in the introduction, and use of this water potential by any means is so important. However, the usage should be in a way it cannot aggravate the water problem situation. One of the safe use methods could be by desalination and use of the concentrated brine for some else product production. This is how desalination of natural seawater or brackish water should be seen or accepted.

On the other hand, salt waters generated by human beings in day-to-day life should not be allowed to leave the area it gets generated. Or direction has to be given to collect this type of waste into one place and work on the means of recycling. But when the source of salinity is the agricultural sector, substituting with nature-based fertilizers like compost, nature-based de-weeding, and making or supporting research in this area has to work well. In addition to this, use of products that cost less water resource and the use of land in a way it can regenerate itself is also very essential.

In general, to avoid future water scarcity consequences across or within the border of countries, there has to be public awareness on water use and work for its sustainability is essential.

Author contribution statement

All authors listed have significantly contributed to the development and the writing of this article.

Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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