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Review

The Future of Water: Technology, Challenges, and Islamic Perspective

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ABSTRACT

In all parts of the world, water is rapidly becoming an emerging issue. Mature technologies had been established in the water treatment process to overcome the issue. However, the water treatment technology advance does not mean it is not faced with its issues. It still leaves many problems for humans due to both technical issues and management problems. Understanding the water treatment process, current technology, and proper perspective is required to achieve sustainable and equitable development for world society. On the other hand, Islam endeavors comprehensive guidelines on human life and manages water resources. This mini-review article will briefly explain some excellent water treatment technologies and challenges associated with the advancing control over their beneficiation. In addition, an Islamic perspective will be addressed to emphasize how Islamic-based policy and management can take a leading solution to overcome the fundamental problem for the future of water for the benefit of human life. According to an Islamic perspective, natural resource management stipulates that water is a natural resource in the territory of public ownership, so privatization in this sector is not allowed according to Islam.

1. Introduction

Water in Islamic teachings is part of nature so that the talk of water is related to the talk of nature. Nature has an ontological relationship with God. Nature in its relationship with God is a manifestation (tajalli) of God and in the context of its relationship with humans is the strongest argument for God's existence (Nursi, 1998). The nature of nature is the mighty book, while the Qur'an is the expounds. Nature is not an ordinary book, but a wonderful work of art full of meaning. Nature that reflects the beauty of God's name becomes a mirror of God so that it becomes sacred so that it cannot be damaged. Anyone who opposes this view is against God (D. Ayduz, 2000).

The Islamic view of water can be seen in the holy book of the Qur'an. The terms used to designate water vary. Term that is often used, for example *ma'* (Qs. al-Baqarah/2:22, 74, 164; an-Nisa'/4:43; al-*Ma'*idah;6, and so on), in addition to the term mathar, rain (Qs. al-A'raf/7:84, 84, Hud/11:82, al-Hijr/15:84, an-Naml/16:58, 58, 58, and so on); '*ayn*, the spring (Qs. Saba'/34:12, al-Ghashiyah/88:5, 12, al-Baqarah/98:60, al-A'raf/7:160; and so on); *anhar*, river (Qs. Al-Baqarah/2:25, 74, 266, Ali 'Imran/3:15, 136, 195, 198, an-Nisa'/4:13, 57, 122, al-Maidah 12, 85, 119, and so on)

The term *ma'* (water) in the Qur'an does not entirely connote water which consists of oxygen and hydrogen elements. There are a number of meanings of *ma'* in the Qur'an. First, *ma'* relates to the process of the creation of the universe or one of the conditions in which the universe manifests (Qs. Hud/11:11). Before the universe was formed as it is today, it experienced the form or nature of "cosmic soup or liquid". At that time, the age of the universe was approaching one-hundredth of a second and the temperature was about 100 billion degrees, so the extremely high mixture of particles and radiation was called the 'cosmic soup'. Water, which is known today, consists of elements of oxygen and elements of hydrogen in the phase of the creation of the universe, and the contents of nature at that time were radiation and matter which at very high temperatures, its form was different from the water today. Second, *ma'* relates to information about the creation of man (Qs. al-Furqan/25:54, as-Sajadah/75:8, al-Mursalat/33:20, and ath-Tariq/36:6. Based on the verses of According to this, humans were created from sperm, semen which is expressed in various editorials, such as *mai'n mahin,* and *mai'n dafiq*. Third, *ma'* means water provided for the inhabitants of heaven and hell (Qs. Ibrahim/107:16, and al. -Kahf/18:29, Muhammad/95:15, and al-Waqi'ah/46:31) The meaning of *ma'* in the third part is not properly understood as water found in the present life, but water or a suitable liquid substance as well. with nature, the afterlife whose nature and shape are different from that of the world.

Islam teaches that water is a vital substance in the life of living things, including for the mechanism of the cosmos. Several verses describe water as a source of stabilizing the earth's temperature. Water is also the source of human life and the context of the element that causes it to be alive, not the source as the principle of life, because the essence of the source of life is God. Reality

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also shows that life can only run with water, such as for animals, plants, micro-organisms, and humans (Qs. Al-Anbiya/21:30). Water for living things functions to maintain the balance of body temperature, the formation of body cells, and helps the digestion of food. The Qur'an describes water as the main factor in the process of enriching everything on earth, especially soil (Fushilat/61:39). Fertile soil conditions cause plants and all life in that place to be fertile. The fertility of the earth is a very important element of human life. All the history of human life is found in a row of rivers or on land that is easy to get water. Another proof is that people now living in areas with easy access to water are more fertile and prosperous. Meanwhile, humans who live in barren areas, their lives do not get balanced nutrition. That is the reason God sends rain as fertilizer. Raindrops contain certain substances that can give fertility to dead soil.

Raindrops contain revitalizing ingredients known as "surface tension droplets". These materials are covered by a vaporized sea surface layer. The salt that falls along with rainwater is a miniature of the fertilizers commonly used in agriculture (sodium, potassium, potassium). Heavy metals in the air form elements that can increase productivity during plant growth and fertilization. Rain in this context is a very important source of fertilizer which within 100 years, nutrient-deficient soil can collect all the elements needed to grow plants. Forests grow and obtain their necessities of life from all chemicals that come from the sea. The Qur'an also describes water as plant and animal life. Plants in the world of living things are generally producers because they make their own organic materials as the building blocks of their bodies, from organic materials directly from nature, such as CO, nitrogen, phosphorus, and water (Qs. ar-Rum/30:24). The verse emphasizes that water is a solvent compound that plays an important role in life so that the absence of water for the survival of living things cannot develop.

The Qur'an describes water as human life, especially for drinking (Qs. Al-Mursalat/33:27). The need for clean water to drink is a primary need in human life, livestock, other animals, and plants. Water is the origin of life and the origin of its eternity, as well as a natural mediator for life. In various places in the world, there is a shortage of water due to the water cycle is not balanced. In the dry season, there is a drought so that the soil becomes barren. Meanwhile, in the rainy season, excess water is wasted and is wasted, it even becomes a disaster for human life, livestock, other animals, and plants caused by the terrible flood. This last phenomenon needs to find a solution to overcome it because the rain was created as a blessing for living beings.

Islam as described in the Qur'an specifically describes the function of water for humans. First, the ecological function. The ecological function of this water can be seen in several aspects.

1. Water as an environmental enabler. Water is proven as the main means of life such as using the sea for water transportation, using water to water plants and others. Water in this context is a source of sustenance in environmental cultivation (Qs. Ibrahim/107:32). Water is used for the development of environmental empowerment, such as agricultural cultivation and other businesses in the community. The Qur'an repeatedly encourages improved management of water resources.
2. Water as a source of energy. Reality proves that almost all technologies use water as a counterweight such as a radiator cooling in engines, hydroelectric power plants and nuclear power development. The use of water as a means of generating energy is described in Qs. al-Baqarah/2:164. This verse awakens human reason to understand the benefits of water in life in a wider area, such as for the development of energy generating sources.

The Qur'an, through its description of the water, has led humans to realize the essence of life.

Second, water as a means of purification (Qs. Al-Maidah/4:6). This verse describes water as a means for purification such as ablution, bathing, and washing (Jawhari, 2004). Islamic Ethics has discussed water in the context of *mahdhah* worship as a prerequisite for prayer. Each chapter of Fiqh begins with a discussion of taharah (purification). Purification is the essence of the conversation about water, starting from the various types and the rules for using it. In the Islamic world, ash-Syafi'i (150-204 H) is one of the prominent Islamic Ethic thinkers who divides water into four parts: holy water that purifies, holy water does not purify, unclean water, and makruh water (Sahri, 2019). Islam seen from this aspect has placed water as something essential to maintain health, individual hygiene, and general health.

The discourse on the water in matters of worship emphasizes Islamic teachings that respect, at the same time considers water as the "heart of life" for humans. Water plays a role in the metabolism of the human body. The structure of the water molecule consists of a water molecule, a negative valve on Oxygen and a positive valve on Hydrogen causing the water molecule to be polar. This is different from other liquid molecules, such as benzene or hexane which are not polarized (nonpolar compounds). Polar compounds from water are very beneficial for human life because water can dissolve all polar mineral compounds. The polar nature of water, in addition to supporting the absorption of minerals, vitamins and sugars in the human body also need minerals in nature. Metabolism or chemical biophysical reactions in the body can only occur in the presence of water.

Water discourse in Islamic teachings is related to social regulations regarding three things whose ownership and management are protected which cannot be monopolized, namely: water, grass, and fire (Abu Dawud). The mention of water at the beginning of the hadith emphasizes water as a basic need (*al-asas al-awwal*). The reason water should not be monopolized, according to Muslim scholars is that the law of origin of the water is in the public interest. According to Caponera (1973), the hadith confirms that Muhammad had built a water community. It is natural in Islam that water as a renewable nature should be preserved and preserved (Amery, 2001).

Relating to water in any context needs to be maintained and preserved as part of nature. It is necessary to build awareness that to make peace with nature (earth) one must make peace with the spiritual order, the spiritual order (sky) (S. H. Nasr, 1968; Suwito, 2017). Based on the experience and learning process of modern science as well as traditional religious knowledge about nature, it is suspected that the main factors causing the environmental crisis, including water, are related to spiritual problems. The rapid development of science and technology has resulted in the secularization of the cosmos which has separated humans from their environment. The desacralization and secularization of the cosmos throughout the centuries made humans develop a character of conquest over nature, causing a serious environmental crisis (S. H. Nasr, 1968). According to Nasr, the earth is bleeding from the wounds it has suffered due to the actions of humans who are no longer friendly to it. Secular views and science and technology that are uprooted from the spiritual roots of religion, make the earth experience more and more crisis and continue to approach the point of its destruction.

A theory that has developed in the Islamic world to explain the future sustainability of nature is called eco-Sufism which builds spiritual awareness by interpreting interactions between systems of existence, especially in nature (Ituma, 2003). The position of nature is used as a way to get closer to God (Bisri, 2011; Suwito, 2017) (Suwito, 2017; Bisri, 2011). Eco-Sufism seeks the process of transformation from spiritual awareness to ecological awareness with the aim of universal harmony and harmony between Sufi behaviour and God. This condition then results in mutual love between humans and God, humans and humans, and humans and

the universe. Eco-Sufism ethics conceptually encourages human behaviour to live in harmony with God and nature. Eco-Sufism recommends that humans can care for and preserve nature, including water. Water should be well preserved to balance the water supply and water demand.

Unfortunately, nowadays, more than one-third of the population deal with the challenge of water shortage. This ratio will continue to grow to two-thirds by 2025 (Elimelech & Phillip, 2011). To overcome this issue, many industries around the world have been developing the water treatment technology rapidly, complying with the increase in population rate and climate change. There is considerable constrain on both industry and academia which leads to a serious global problem of water shortage. In most nations, the agriculture and food industries are the sectors responsible for the largest water consumption. The sectors are demanding 100 times more water than the domestic sector (Qadir et al., 2007). The United Nations predicted that 2-7 billion people will face water shortage by the middle of the century (Subramani & Jacangelo, 2015), and 3.5 million people die annually from the shortage of water supply and sanitation as the result of the decrease in the freshwater per capita (Fig 1). The shortage of freshwater, large-scale industrial water use and other sectors water demands have made the limit on water availability. In that critical condition, the conservation of water availability becomes an urge.

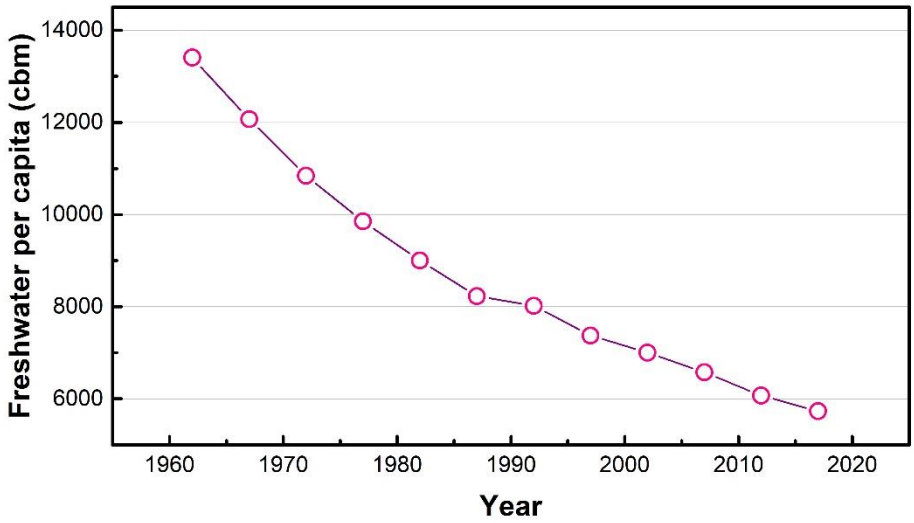
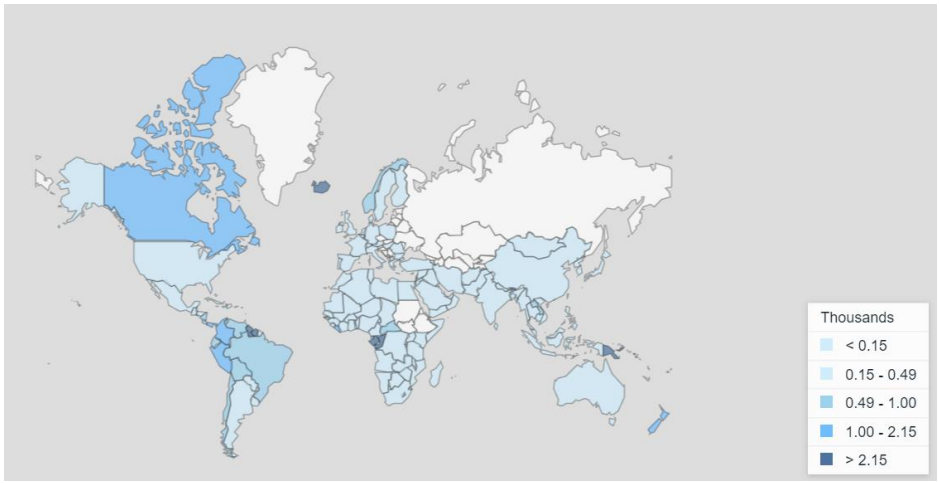


Fig. 1. Renewable internal freshwater resources per capita from 1962 to 2017. Data taken from (Worldbank, 2021).

The implementation of adequate strategies and technologies on water treatment is a mandate. The water should be recycled as much as possible by any means of approach. Conventional paths relying on rivers and rainfall are no longer sufficient to meet human needs. Figure 2 showed the comparison on the global distribution of renewable internal freshwater resources per capita in 1962, 2002, and 2017. NESCO estimates that in developing countries in Asia, Africa and Latin America, public water withdrawal represents just 50-100 liters (13 to 26 gallons) per person per day. In regions with insufficient water resources, this figure may be as low as 20-60 (5 to 15 gallons) liters per day. People in developed countries on average consume about 10 times more water daily than those in developing countries. UN estimates that many areas of the world are already experiencing stress on water availability. Due to the accelerated pace of population growth and an increase in the amount of water a single person uses, it is expected that this situation will continue to get worse. The ability of developing countries to make more water available for domestic, agricultural, industrial, and environmental uses will depend on better management of water resources and more cross-sectorial planning and integration. A shortage of water in the future would be detrimental to the human population as it would affect everything from sanitation to overall health and the production of grain. Freshwater use by continents is partly based on several socio-economic development factors, including population, physiography, and climatic characteristics. It is estimated that in the coming decades the most intensive growth of water withdrawal is expected to occur in Africa and South America (increasing by 1.5-1.6 times), while the smallest growth will take place in Europe and North America (1.2 times). The Commission for Sustainable Development (CSD) has reported that many countries lack adequate legislation and policies for efficient and equitable allocation and use of water resources. Progress is, however, being made with the review of national legislation and enactment of new laws and regulations (Worldbank, 2021).

To address the water scarcity issues, scientists around the world are constantly committed to finding new inventions and advanced technology, such as desalinated water, to conserve and recover the water supply. Freshwater recovery from saltwater sources is developing since the recovery process is environmentally friendly and expected to play a key role in reducing the water demand-supply gap. Research efforts in the area of water desalination have recently received stunning attention (Jones et al., 2019). Seawater desalination accounts for over 55.7 million m^3/y of freshwater production, whereas brackish water, river water, wastewater, and brine water desalination account for over 19.9 million, 9.2 million, 7.8 million, and 213,159 m^3/y of freshwater production, respectively (Yusuf et al., 2020). The United Nations (UN) has recently expected wide-scale wastewater reuse as a sustainable path to deal with freshwater stress. In 2017, The UN organized World Water Day to create awareness for water security themed "Wastewater" (UnitedNations, 2017).





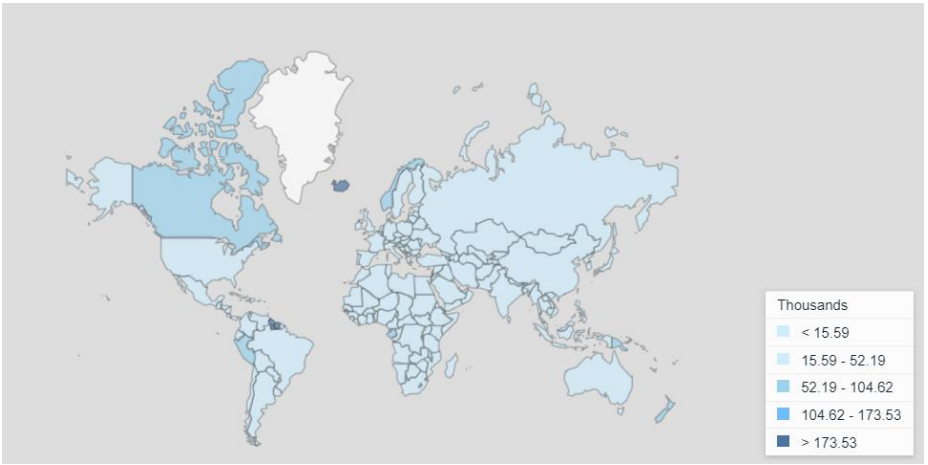


Fig. 2. Global distribution of renewable internal freshwater resources per capita in: (a) 1962, (b) 2002, and (c) 2017 as taken from (Worldbank, 2021).

Among several water treatment technologies, membrane-based processes have received the most consideration in the water treatment process through desalination of seawater due to sustainability, environmental impact, ease of use, promise for energy minimization, improved performance and flexibility compared to other techniques (Sarkar & Chakraborty, 2021; Subramani & Jacangelo, 2015). Desalination is the process -of removing salts from water to produce water that meets the quality prerequisite of different human uses (Darre & Toor, 2018). There are a lot of published review papers on the water treatment technology, however, there was a lack of comprehensive view on how the water treatment could be used widely by the world community, the challenges faced so far, and especially, on how the Islamic perspective could provide brighter and more convincing prospect since the need of water is a strategic problem that concerns the lives of many people. It is the responsibility of the state to be able to provide water needs for all its citizens. This mini-review highlighted the feedwater resources, selection of cutting-edge technology relevant to water treatment. The conventional and emerging approach in water treatment technology is chronologically discussed in Section 2, followed by global outlook associated with the corresponding issues and its future works direction in Section 3. Islamic narration on this field is also discussed by introducing the Islamic-based policy and management to give a general Islamic perspective in the final section. The conclusion is established to summary the point discussion in Section 4.

2. Recent Status on Water Treatment Technology

2.1 Desalination Technologies

Figure 3 showed the trends in the research history of desalination in the wide world. Since 1980, there were more than 16,500 publications were found on the desalination topic (Jones et al., 2019) . There has been an increase of literature discussing alternative aspects of desalination when the expanse of desalination literature focusing on technological aspects is still high which is about 72%, especially related to economics and energy and environmental interests. An adequately increase in recent decades was found from less than 400 in 2000 to less than 5000 in 2018 on the number of publications concerning economic aspects of desalination. Only 118 publications were found before 2000 corresponded to the environmental impacts of desalination which indicated neglect of environmental effects. Though, it is now increasing at a higher rate, with an addition of about 2000 publications since 2000. However, the number of publications concerning the sociopolitical aspects of desalination technology is relatively low. Since the technology continues to turn into a more common water resources management technology in the future, the number of publications across all categories, and notably related with the environmental and sociopolitical points of view, is expected to increase rapidly (Jones et al., 2019).

Among the others, RO is the most popular technology which the number of publications was highest from the early 1980s till the present as shown in Fig. 3. This is due to the several advantages of this kind of technology, such as high water recovery and less consumption of energy (Subramani & Jacangelo, 2015). MED and MSF were the least studied technologies though they contributed to the significant share in the amount of desalinated water production.

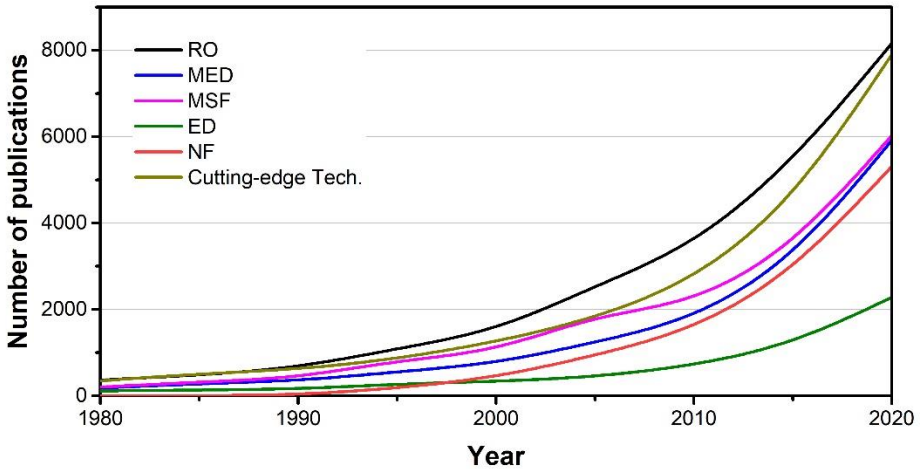


Fig. 3. The number of desalination publications by desalination technology. Cutting-edge technologies refers to Membran Distillation (MD), Forward Osmosis (FO), and Nanofiltration (NF).

Figure 4 shows the trends in global desalination by number and capacity of total and operational desalination facilities and operational capacity by desalination technology. There are 95.37 million m^3/day of total desalination capacity produced by more than 15 thousand operational desalination plants. The dominance of membrane technologies outnumbered thermal technology (MED, MSF) since the early 1990s. The volume of desalinated water produced by thermal technology increased linearly since 2000. Surprisingly, both the numbers of publications and desalination capacity of RO increased exponentially. This technology is now accounting for 69% of the desalinated water volume production. The desalination facilities are widely distributed in the United States, China, Australia, Europe, North Africa and the Middle East. The industrial sector is the most consumed (North America, Western Europe, East and Pacific regions) after the municipal sector (Middle East, North Africa regions).

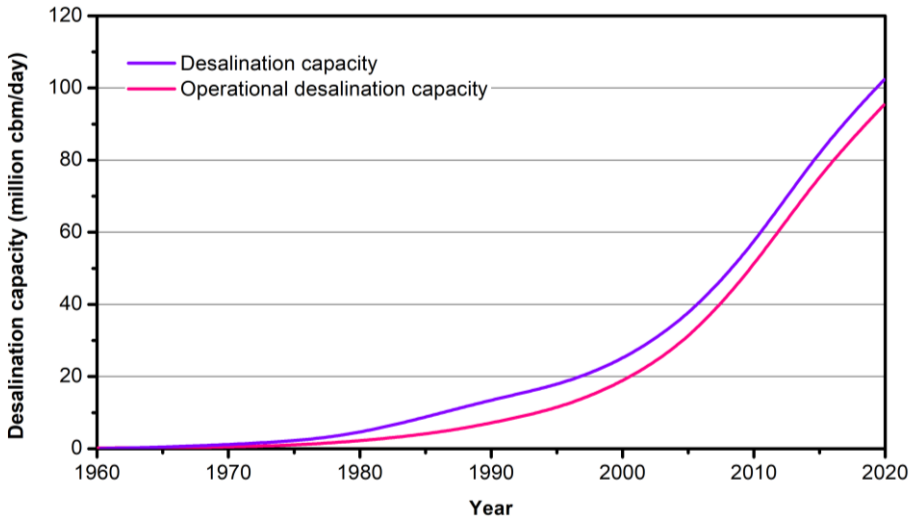


Fig. 4. Trends in global desalination by capacity of total and operational desalination facilities, figure adopted from ref. (Jones et al., 2019).

Figure 5 shows the number and capacity of desalination plants by geographic region, country income level and sectoral use of desalinated water. Almost half of the global water desalination capacity is produced in the Middle East and North Africa Regions (47.5%). Meanwhile, 18.4% and 11.9% of the global desalinated water is produced in East Asia and Pacific and North America regions, respectively. Southern Asia, Eastern Europe and Central Asia only contributed to a limited amount around 3.1%, 2.4%, and 1.9%, respectively (Jones et al., 2019). Figure 6 showed the freshwater production of various feedwater resources. Seawater and brackish water are the dominant feedwater resources among others. Figure 7. depicted the desalination technologies classification by working principles.

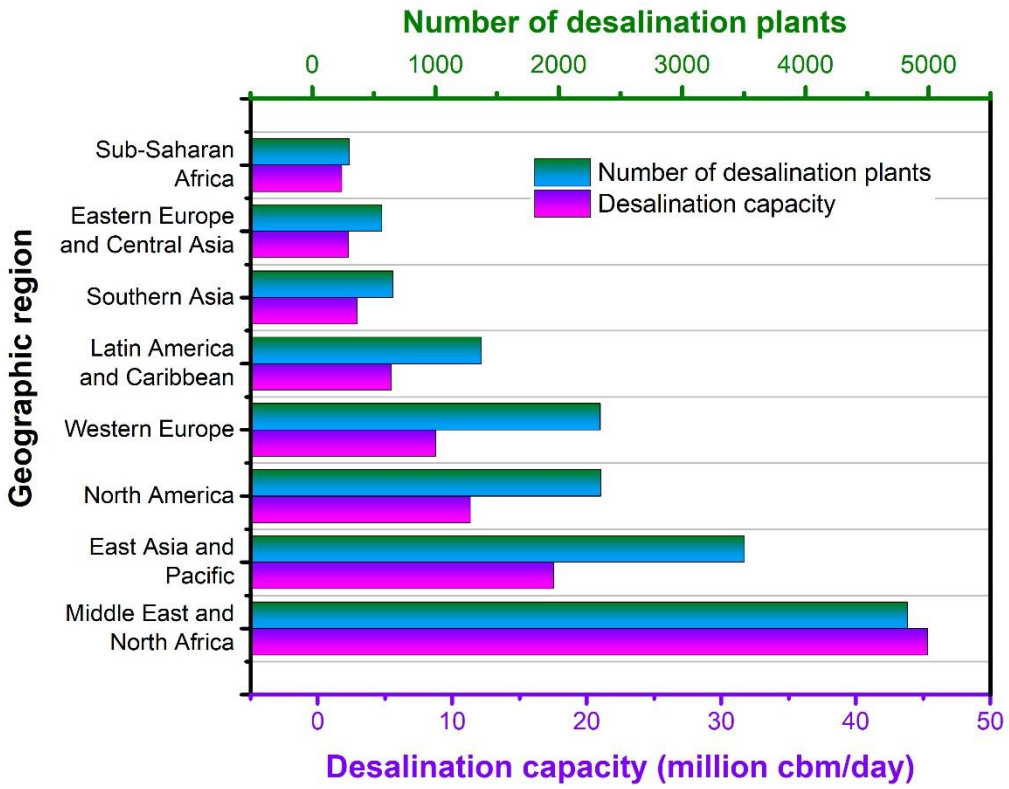


Fig. 5. Number of desalination plants, capacity and global share by region, country income level and sector use. Data taken from (Jones et al., 2019).

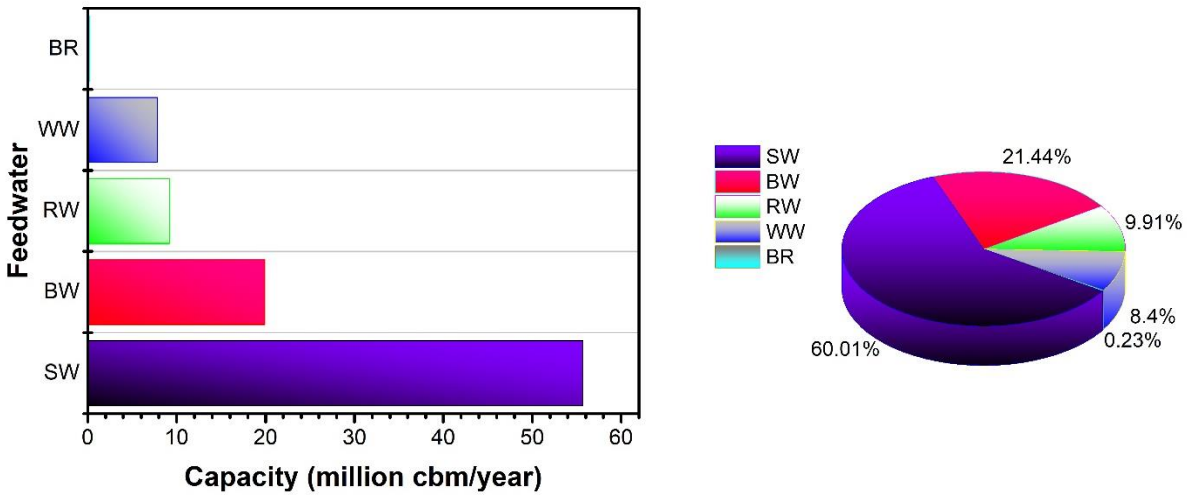


Fig. 6. Freshwater production of various feedwater resources. Data taken from (Jones et al., 2019).

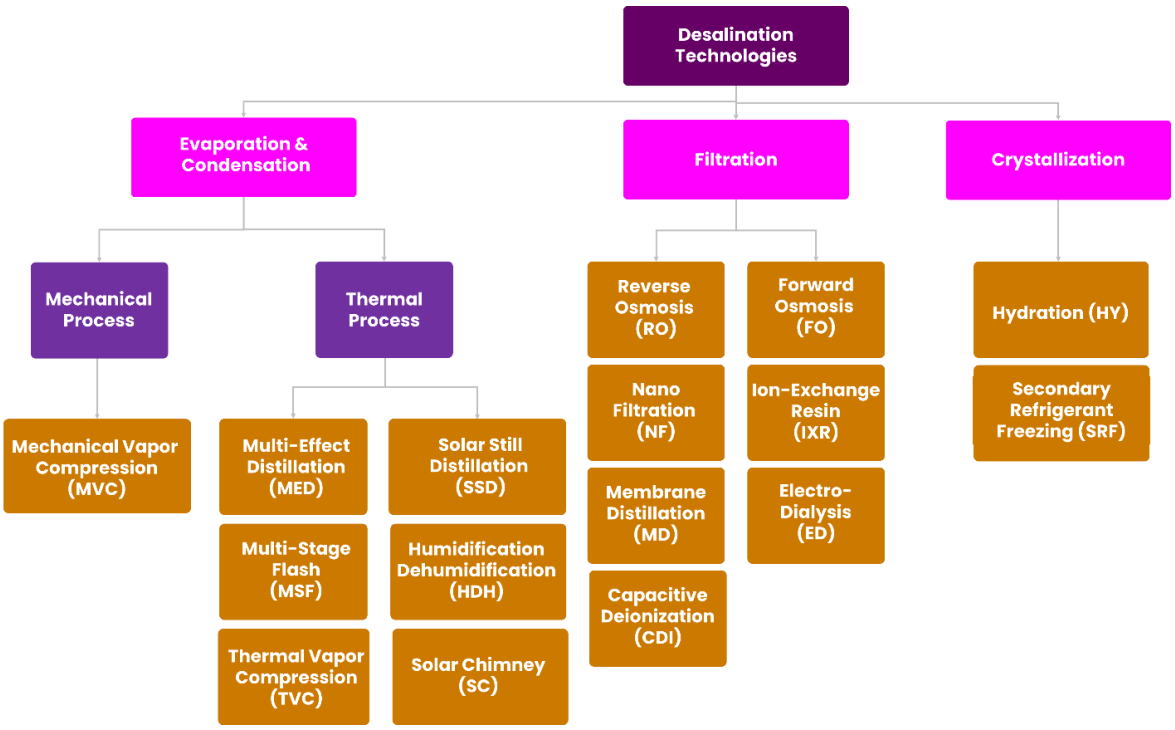


Fig. 7. Desalination technologies classification by working principles as adopted from (Curto et al., 2021).

Thus far, RO technology is the most dominant process (84% of the total number of operational desalination plants). It can produce 69% (65.5 million m^3/day) of the total global desalinated water, as shown in Fig. 8a. The two based-thermal technologies (MSF and MED) produced the remaining desalinated water with market shares of 18% and 7%, respectively (Fig 8a). RO, MSF and MED account for 94% of the global total desalinated water. Meanwhile, the NF, ED and EDI account for 3%, 2%, and 1% of the global total desalinated water, respectively. Figure 8b showed that SW desalination accounts for 61% of desalinated water. The next dominant feedwater sources are BW and RW that account for 21% and 8%, respectively. The remaining 10% of produced water are from WW, PW, and BR with a market share of 6%, 4%, and 1%, respectively.

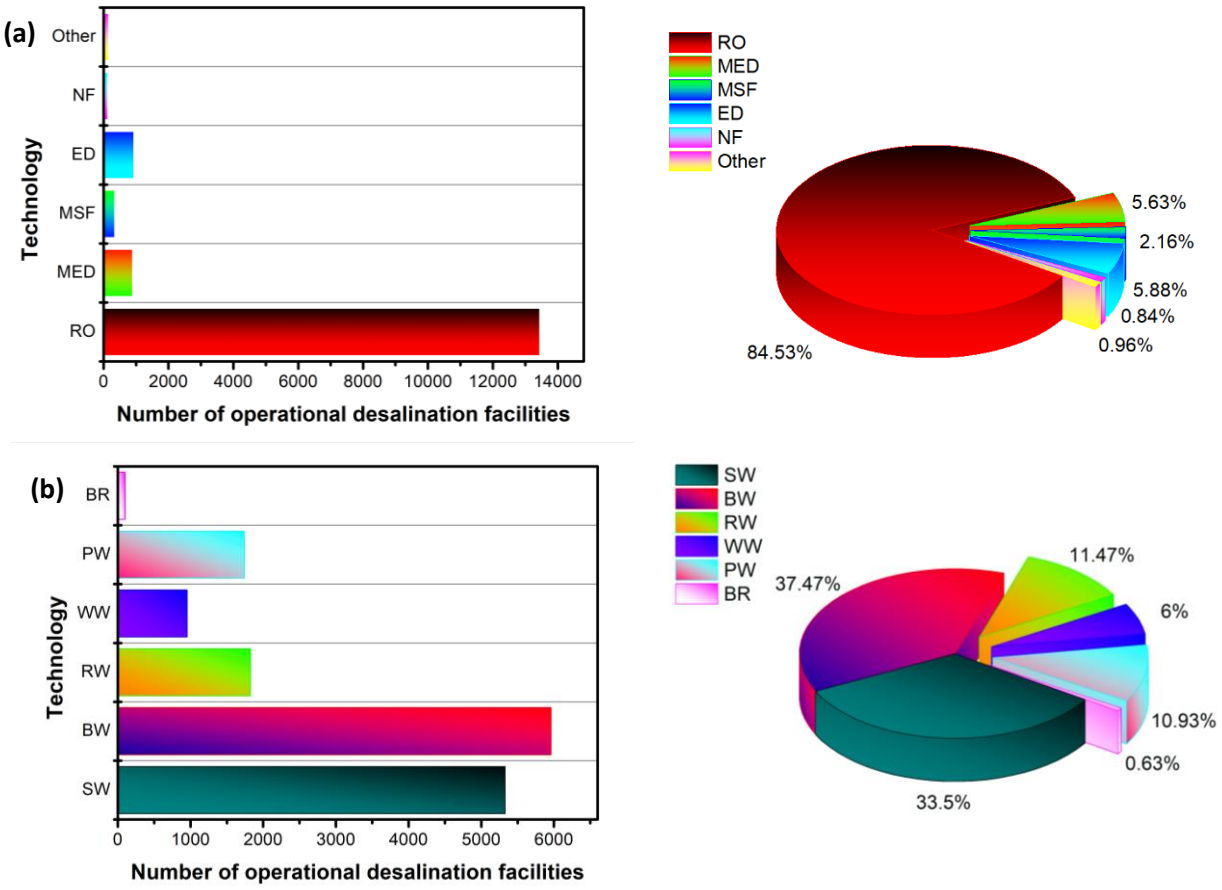


Fig. 8. Number and capacity of operational desalination facilities by (a) technology and (b) feedwater, figure adopted from ref. (Jones et al., 2019).

2.2 Membrane-based Technology

Several advanced water treatment methods are applied to provide high-quality consumable water include Microfiltration/Ultrafiltration/Nanofiltration, Reverse Osmosis (RO), and Advanced Oxidation. These methods have the better capability of removing various contaminants generally present in the water rather than the conventional methods. At the first step, the contaminated water is flowed to go through filtrations (Microfiltration/Ultrafiltration/Nanofiltration) which place tubes containing membranes of functional materials that can remove pathogens. At the second step, the water flows under high pressure to remove the rest of the pollutants (metal ions, organic contaminants) through the nanomembrane (reverse/forward osmosis). At the final step, the water is then purified through a Fe oxidation process under UV light which eliminates the rest of the impurities (Punia et al., 2020). Enhanced filtration methods are developed by using nanomaterials (nano adsorbents, nanomembranes, bioactive nanoparticles, nanoenzymes, nanometals, magnetic nanoparticles, photocatalysts, etc) for the treatment of wastewater. The current progress made particularly during the last two decades were reviewed by (Deshpande et al., 2020; Punia et al., 2020).

The role of current emerging membrane materials and their applicability in water production was reviewed by several researchers (Roy & Ragunath, 2018; Yusuf et al., 2020). They reviewed the opportunities for membrane technologies dealing with water and energy sustainability. They hinted that future direction should be addressed to fabricate novel membranes with tailored separation features to make membrane technologies a more sustainable solution. Apart from reviewing their sustainability benefits, their drawbacks were also discussed. Emerging trends (zero-waste, zero-liquid charge and economy solutions), emerging membrane synthesis materials (quantum dots, non-toxic solvents), emerging modelling approaches (molecular dynamics simulation, artificial intelligence approaches) are the keys for achieving sustainable desalination and wastewater treatment. Figure 9 showed some emerging trends in membrane science and technology for sustainable desalination and wastewater treatment.

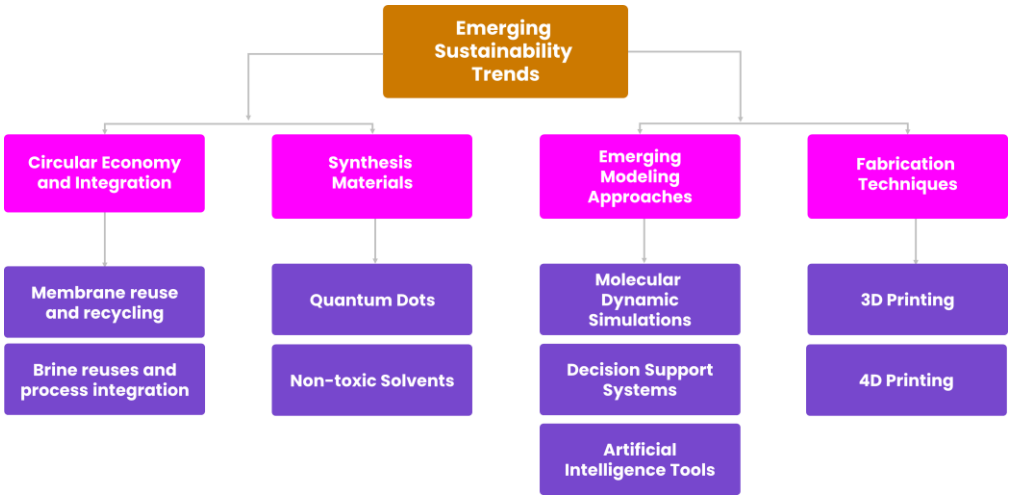


Fig 9. Some emerging trends in membrane science and technology for sustainable desalination and wastewater treatment, adopted from (Yusuf et al., 2020).

Since RO became the most widely used technology in water treatment and desalination technologies, RO technology has undergone notable developments in terms of synthesis materials, fabrication techniques, and modifications. Among various materials used for the synthesis of RO membrane, PA-TFC (polyamide thin-film composite) is the most frequent due to its outstanding water permeability high salt rejection, and stability. Nevertheless, a tradeoff between membrane permeability and salt rejection and membrane fouling has been a dominant barrier for the function of this membrane (Hailemariam et al., 2020). The surface modification of substrates and active layers of the RO membrane has been the most effective procedure for improving the surface properties of the PA-TFC membrane. Figure 10a shows the schematic diagram of the RO process. At the first step, the water flows from the area of low to high solute concentration. This equalizes the solute concentration on both sides of the membrane and produces osmotic pressure. The RO membrane is then pressured to reverse the solvent flow directions. When the applied pressure is greater than the osmotic pressure, the feed water passes through the membrane to come out as purified water and leave the salt and other minerals behind.

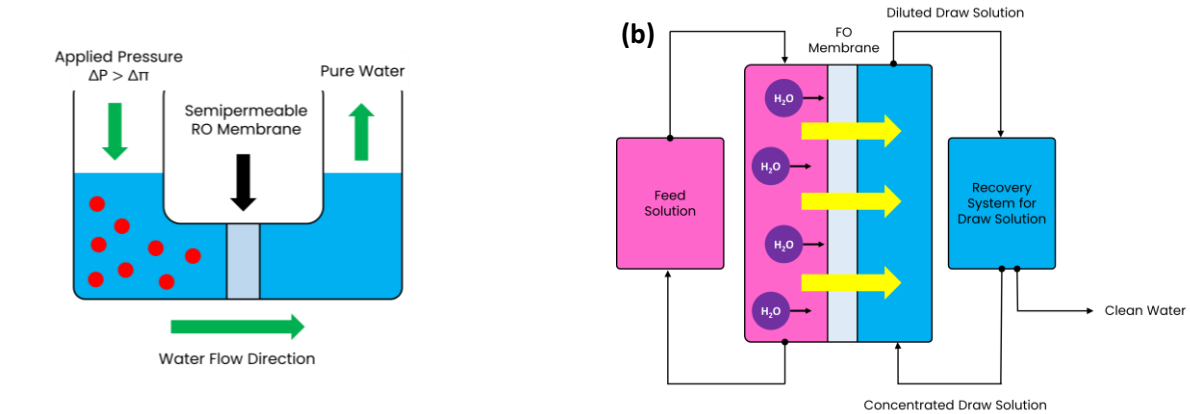


Fig. 10. The schematic diagram of: (a) the reverse osmosis and (b) forward osmosis process. Figure adopted from ref. (Hailemariam et al., 2020; Wang & Liu, 2021)

Despite RO process having several advantages, the high power consumption is the process's main disadvantage. With the Energy Recovery Instrument (ERI), an average of 3.5 kWh/m^3 is required for seawater desalination. In addition to RO, Forward Osmosis (FO) has attracted more attention in recent years. FO is driven by an osmotic pressure gradient to make the water pass through the membrane from feed solution (FS) to draw solution (DS) (Fig. 10b), which gives the FO process the advantages of high water flux, low fouling tendency, low energy consumption and strong adaptability. (Altaee et al., 2014). Although FO has a higher fouling effect, it offers superior water flux stability against fouling than RO. The major reason for the higher fouling effect in FO is due to the change of ICP and effective driving force in response to the evolution of fouling (Siddiqui et al., 2018).

Desalination and water recovery by using membrane technology is an adequate way to narrow the water demand-supply gap because it has the following advantageous: (1) Separation process occurs on the molecular level which results in high-quality water; (2) The absence of phase transition which avoids the energy loss; (3) Without any additional chemicals which minimize secondary pollution. Nonetheless, there are also a few adverse circumstances under the beneath of the advantages to the membrane separation technologies. The major issue is the fouling of the membrane which is caused by the deposition of materials on the surface of the membrane during the filtration process (Subramani & Jacangelo, 2015). This fouling effect occurs when the pore of the membrane are blocked gradually during the separation process and decrease the membrane performance. This phenomenon may be accelerated in the presence of hydrophobic material in the effluent (Mohammadi et al., 2003). Surface modification of the membrane is required to reduce the fouling effect by improving the hydrophilicity of the membrane. The fabrication of the organic-inorganic nanocomposite membrane has shown excellent thermal and mechanical performance to reduce the fouling effect (Sarkar & Chakraborty, 2021). This type of surface modification is very simple, less time-consuming. However, after certain cycles of operation, the nanoparticles are loosely attached to the membrane surface and result in the deteriorating performance of the membrane (Mahmoudi et al., 2019).

From the fabrication techniques point of view, there is a great significance of 3D printing for the future of membrane science with its sustainable, precise, low-risk, low-cost fabrication methods (Yanar et al., 2020). The current membrane surface research has successfully modified inkjet printing for enhanced surface properties for high selectivity and fouling resistance through the printing of nano-materials on the membranes' surfaces. Figure 11 showed the schematic diagram of the porous membrane with nano silica-filled PDMS ink. Most of the research is conducted at the macro or micro scale. However, recent studies show the promising potential of nanoscale 3D printed water treatment membranes. Furthermore, there are still drawbacks due to the situation of current technology, such as the inability of 3d printer to print with high resolution in x and y dimension which limit the porosity of the printed membrane, expensive 3D printer prices and printing time duration issue. Insufficient details on long-term performances of 3D printed membranes are still limited which makes this technology can not be completely clarified.

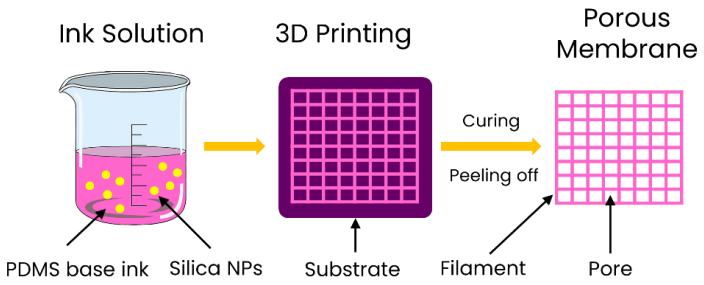


Fig. 11. The schematic diagram of the porous membrane with nanosilica-filled PDMS ink., figure adopted from ref. (Yanar et al., 2020).

3. Global Outlook and Islamic Perspective

3.1 Issues and Challenges on Water Technology

Instead of getting the full benefit from the advanced water technology, still, there were several problems to overcome. Figure 12 depicted several problems from the four points of view i.e., environmental issues, technological issues, cost issues, and policy and privatization issues. From the point of environmental issues, the production process involved a massive amount of energy which causes the greenhouse effect. The unintended effluent as a byproduct could also endanger organisms' lives in the water environment. Besides, after using several times, membrane quality undergoes decay on the quality that leads to poor performance. Hence, the membrane should be replaced periodically due to the fouling of filtered materials. In terms of cost issues, it was well known that installation for each processing unit is still high. Apart from being caused by the electricity usage, the usage of feed source was also high. For each gallon of fresh water produced, between 2-20 gallons of water are lost as waste. Furthermore, from the policy point of view, there were also several issues derived from privatization. Lack of political power on the ownership lead to shrinking public revenue, shifting from increasing access to water to increase profits to the private sector, Lack of control over the price of the water. As the result, only those who can pay extreme prices will have access to potable water (Lee, 2016; National Science & Technology Council, 2019).

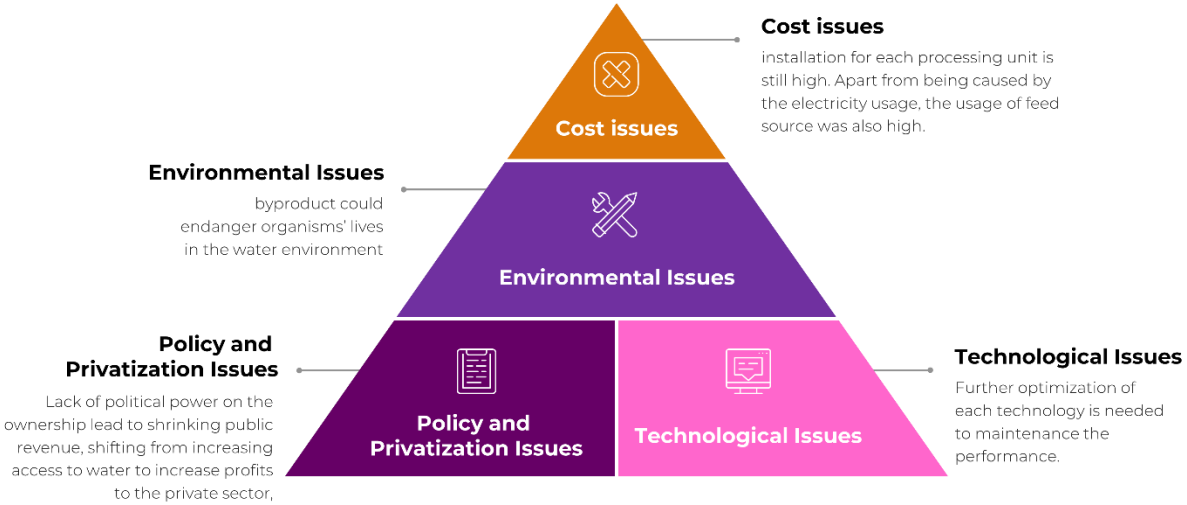


Fig. 12. Challenges on water technology development from various points of view.

3.2 Current Global Outlook

Several efforts have been proposed to overcome the water challenges by designing some frameworks that are incorporating the principles in policies, strategies, designs and operations. A comprehensive framework proposed by the staffs of The World Bank was published in 2021 as so called WICER which stands for Water in Circular Economy and Resilience (Delgado et al., 2021) The report described the key actions to achieve three main outcomes: 1) deliver resilient and inclusive services; 2) design out waste and pollution; and 3) preserve and regenerate natural systems as shown in Fig. 13 . The WICER framework is suggested to have a highly relevant to the world's Sustainable Development Goals (SDG) 6, (availability and sustainable management of water and sanitation for all) and is linked to several other SDG targets: reducing water pollution-related deaths, renewable energy, clean technology, sustainable management, reducing pollution and waste generation. To achieve those three main outcomes, they suggested concrete examples of the actions needed as follows: 1) Diversify supply sources. 2) Maximize the use of existing infrastructure. 3) Plan and invest for climate and non-climate uncertainties. 4) Be energy efficient and use renewable energy. 5) Optimize operations. 6) Recover resources. 7) Incorporate nature-based solutions. 8) Restore degraded land and watersheds. 9) Recharge and manage aquifers. Institutional and regulatory capacity needs to be established to impose the regulatory frameworks and promote the adoption of circular economy approaches. Enforcement of regulations is indispensable and can take place only with procedures for sanctions, and monitoring programs. Coordination with other sectors is also vital, especially with large water users or potential users of recovered resources such as agriculture and industry. Stakeholder need to include every group in the society, considering a range of solutions tailored to the realities of cities in developing countries. Applying the WICER framework provides not only environmental benefits but also social, economic, and financial.

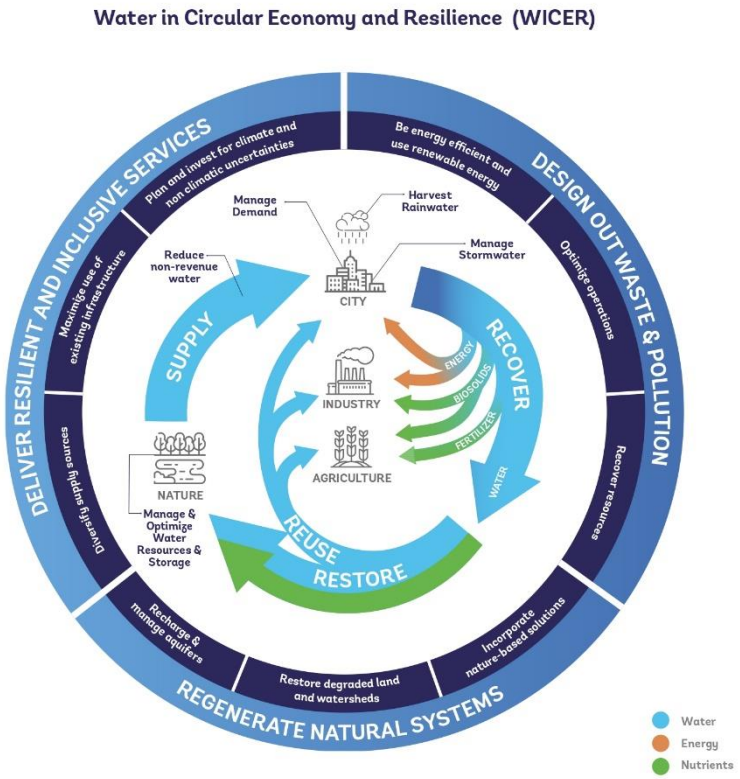


Fig. 13. Framework of Water in Circular Economy and Resilience (WICER) taken from (Delgado et al., 2021).

3.3 Islamic Perspective

An important appreciation of the Koran is that water is the origin of all organisms, including humans and animals. When these organisms exist, especially humans, it turns out that two-thirds of their physical weight is fluid, both in the form of blood, saliva, and lubricants for the joints and spinal cord, all of which regulate the temperature of the human body. No water intake is sufficient; all organisms will die within a few days. Water is provided by Allah SWT to drink humans and animals and to grow plants. Even minerals, such as soil, can increase their quality from dry or barren to fertile to benefit human life through the plants and fruits they produce. In addition, water is appreciated as a means of cleansing. To appear before Allah, to perform prayers, every Muslim must be pure, and here water has an important role, both in ablution and in bathing. Thus, Islam has placed water as something essential for maintaining health, individual hygiene, and general health (Nisa, 2017).

Talking about the concept of natural resource management, mostly water, Islam as a religion of "revelation" has regulated it in the concept of ownership and management of natural resources. The concept of ownership in Islam is different from the ideas of capitalism or communism. Neither of the two has succeeded in placing the individual in harmony with his social position. Private property is the basis of capitalism. Ownership of unlimited wealth is also responsible for inequality in the distribution of wealth and income is stark; the rich are getting richer, and the poor are getting poorer (Rahmawati, 2014).

Islamic appreciation that water (mà ') existentially as a source of life (QS. Al-Anbiya / 21: 30). Water is also the origin of all organisms, including humans and animals, so that everything that lives depends on the existence and sustainability of its life on water. (Surah Al-Hajj / 22: 5, Al-Wàqi'ah / 56: 68-70) When organisms are present, especially humans, it turns out that two-thirds of their physical weight is fluid, both in the form of blood, saliva, and lubricants for joints. and the spinal cord which all regulate the temperature of the human body. All organizations, when there is not enough water intake, die within a few days. Water in this context is provided by God for humans and animals to drink and to grow plants. In addition, minerals, like soil, its quality can be increased from dry or barren to fertile with water to provide benefits to human life through the plants and fruits it produces. soil conservation. Another Islamic appreciation, used as a means to purify. Every Muslim to face God like prayer, must be holy, so that water plays an important role, both in ablution and bathing. Water in reality is related to bathing and health. Islam, seen from this aspect, has placed water as something essential for maintaining health, individual hygiene and general health (Suwito, 2017).

The Islamic appreciation of water is considered complete because it covers all dimensions of time. The first category, water represents the lamau dimension which leads to awareness of the origins of life, especially humans. The last category of water implies a future time dimension that delivers awareness about the orientation of human life towards the pleasure of God. Categories two to five imply the dimensions of present time leading to awareness of the existence of life. These three consciousnesses, philosophically, are the essence of life. The essence of life is often described with a line (symbol of the existence of life), starting from a point of birth (symbol of the origin of life) and ending with another point, death (symbol of the purpose of life). Al-Quran, through its description of the water, has brought people to the awareness of the nature of life. A theory that develops in the Islamic world to explain the sustainability of the future of nature is called eco-Sufism which builds spiritual awareness by interpreting interactions between systems of existence, especially in nature (Ituma, 2013). The position of nature is used as a way to get closer to God (Suwito, 2017; Bisri, 2011). Eco-Sufism seeks a process of transformation from spiritual awareness to ecological awareness with the aim of universal harmony and harmony between Sufi and God behaviour. This condition then produces mutual love between man and God, man and man, and man and the universe. Conceptually, eco-Sufism ethics encourages human behaviour to live in harmony with God and nature. Eco-sufism recommends that humans are able to cultivate and preserve nature, including water.

Islam, besides explaining the concept of the creation of living things from water, regulates the human interest in water and simultaneously describes clearly the process of the water cycle (hydrology) and what is related to it as God's decree (Amery, 2001). Islam has also arranged it in the concept of ownership and management of natural resources. The concept of ownership in Islam is different from the thoughts of capitalism or communism. Neither of these two schools of thought has succeeded in placing the individual in harmony with his social position. For Capitalism, private ownership is the basis of capitalism. The ownership of unlimited wealth is responsible for the stark inequality in the distribution of wealth and income; the rich are getting richer, and the poor are getting poorer (Sukarni, 2014). On the other hand, ownership in the communist system is regulated based on collectivism or is entirely state property, leading to the abolition of private property. The principle of common property, although it can help eliminate unemployment and unfair distribution, it does not escape certain serious limitations regarding incentives and personal freedoms.

Islam provides an answer to the impasse of these two opposing thoughts. Islam recognizes private property rights and guarantees the widest and fairest distribution of wealth through established religious institutions and moral warnings. Islam proposes the correct concept of ownership. As a source of Islamic law, the Koran explicitly regulates the provisions regarding ownership in Islam (Sukarni, 2014). Ownership inherently belongs to God. "To God is the kingdom of heaven and earth and whatever is in between" (Surat al-Màidah / 5: 7. Ownership is differentiated in the hands of humans.

In contrast, the communist system is regulated based on collectivism, or everything belongs to the state. This led to the abolition of private ownership. Although the principle of collective property rights can help to eliminate unemployment and unfair distribution, it is not free from certain serious limitations, namely regarding incentives and personal freedoms. Islam provides an answer to the impasse of the two opposing understandings. Islam recognizes private property rights and guarantees the widest and fairest distribution of wealth through established religious institutions and moral warnings. Islam posits the correct concept of ownership. As a source of Islamic law, Al-Qur'an explicitly regulates the provisions regarding ownership in Islam (Santoso, 2010). Ownership is inherently Allah's absolutely. Allah SWT. said in QS. al-Maaidah (5): 7, which means: "*To Allah is the kingdom of heaven and earth and whatever is in between*."

Allah SWT gives authority to humans to control these property rights and give ownership permits to certain people who are real. Allah SWT. said in QS. al-Nuur (24): 33, which means: "Give humans a portion of the wealth of Allah that He gave you."
It is in human hands that the concept of ownership is distinguished. Islamic economic thinkers are trying to understand sharia arguments about this ownership issue, including Shaykh Abu 'Ubaid in his book al-Amwal. He classified this ownership into two categories, namely (1) movable objects (not fixed) attributed to individual ownership, and (2) immovable objects (fixed), which are attributed to joint ownership. It is slightly different from the concept of ownership in the perspective of Taqy al-Diin al-Nabhany, which is contained in al-Nizhaam al-Iqtishaady fi al-Islaam. Al-Nabhany classified ownership into three aspects, namely (1) individual ownership, (2) state ownership, and (3) public ownership (Rahmawati, 2014).

Public ownership is all the wealth assigned by Allah to the Muslims so that this wealth becomes the Muslims' common property. Individuals may benefit from this wealth but are prohibited from owning it personally. There are three types of public ownership, namely:

1. Public facilities are needed by all citizens for their daily needs, such as water, irrigation channels, forests, and energy sources.
2. Wealth whose origin is forbidden for individuals to own it, such as public roads, sea, rivers, lakes, fields, mosques, and others.
3. Abundant quantities of mining goods (natural resources), either solid, liquid, or gas.

Regarding this public ownership, Rasulullah saw. said: "The Muslims are united in three things: fields, water, and fire." (Narrated by Abu Dawud and Ibn Majah). Humans are united (have a share) in three cases: water, pasture, and fire (fuel, gas, electricity, and others.). (HR Ahmad and Abu Dawud). In the hadith, apart from mentioning water, grasslands, Rasulullah saw. Also mentions the word "fire," which means energy, such as electricity, fuel, gas, coal, nuclear, and so on. Thus, the various resources mentioned in the above hadith fall under the category of public ownership. According to the Islamic perspective, water is a natural resource in the area of public ownership. Therefore, access to public ownership is open to the public (Muslims), but the state regulates the regulations in a trustworthy (*Amanah*) and professional manner (technically well manage). This wealth is a source of state income. The state will manage these resources and spend them in the public interest somewhat with the people's control through the income distribution mechanism (Amery, 2001). This is according to the word of Allah SWT. in QS Huud (11): 61, which states: "He created you from the earth and made you prosperous."

Besides that, according to an Islamic perspective, natural resource management stipulates that water is a natural resource in the territory of public ownership, so privatization in this sector is not allowed according to Islam. Apart from that, all forms of individual (private) ownership, both foreign and domestic, on industries that produce public goods must be canceled and returned to the state as the ummah mandate holder, which becomes public property. The state should take over these industries and manage them as well. Therefore, all investments or assets owned by individuals (private), both foreign and domestic, will be returned. Similar to companies or legal entities that manage businesses that fall into the category of public ownership, namely goods that cannot be monopolized by individuals, goods that control the lives of many people, or goods that have large volumes such as oil and gas, then ownership individual (private), both foreign and domestic in this context it should be canceled. Islam also emphasizes that humans as God's mandate are in charge of managing the earth, not the owner. As a commitment to the teachings of tawhid, which place nature and humans as a unit and have an equal position (God's creation), with God's mandate, humans must actively maintain the harmony of nature (Imamudin, 2012). Because God provides all-natural resources, including water, for the welfare of all people, in its utilization Islam encourages equitable distribution, and prohibits selfishness and injustice.

4. CONCLUSION

We have attempted to review the technology and challenge of water. The report summarized the state-of-the-art technologies for producing freshwater from several feed water resources using reverse osmosis, multi-effect distillation, electrodialysis, multi-stage flash, nanofiltration, etc. The membrane technology as the leading and most dominant technology in water treatment was discussed. The future direction should be addressed to fabricate novel membranes with tailored separation features to make membrane technologies a more sustainable solution. We also emphasized Islamic perspective related with the water management system since water and its maintenance are integrated with Islam. In Islam, water is a natural resource in the territory of public ownership, Islam gives a high appreciation of water and provides guidelines on utilizing and maintaining natural resources, including water. Islamic teachings and values have provided the foundation for attitudes and actions that humans should carry out as the caliph of Allah towards water and the environment. Islam provides guidelines on how to use and maintain natural resources, including water. Management of water resources must be holistic from various perspectives. Ethical-religious, social and economic approaches that involve all human components are needed. The development of technology related to proper water use and treatment can support the ease of managing these water resources.

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