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Addressing Water Scarcity using Repurposed Oil Carriers

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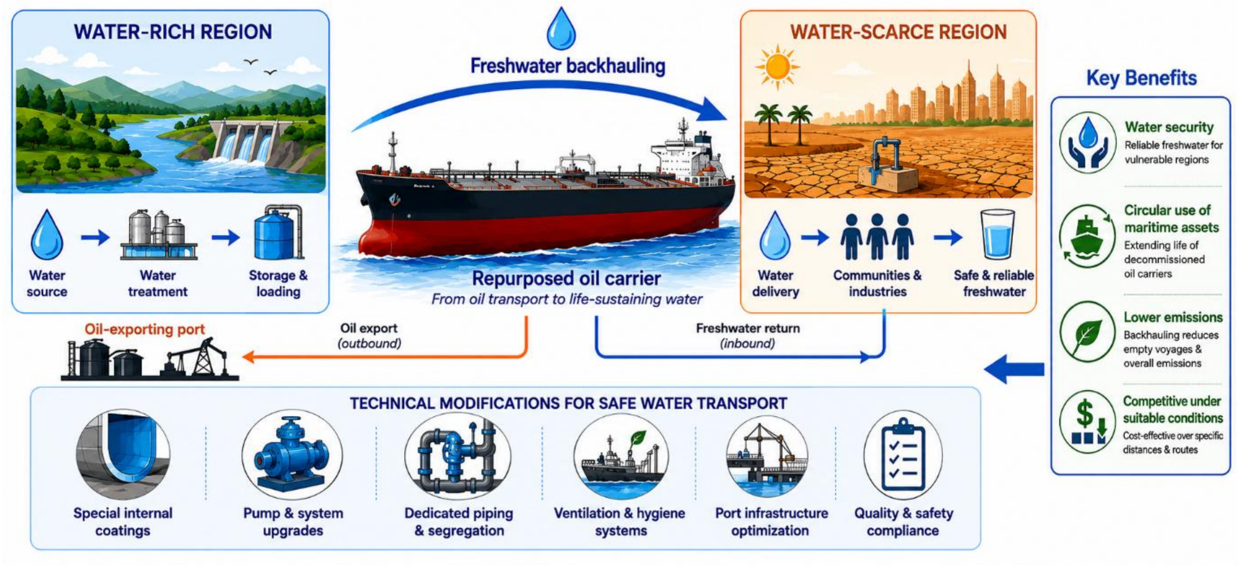
Graphical Abstract

Freshwater scarcity is an increasing global challenge, and repurposing decommissioned oil carriers for freshwater transport could provide a scalable and flexible solution to redistribute water between water-rich and water-scarce regions. This approach requires engineering modifications, dedicated infrastructure, and optimized operational strategies to ensure safe, efficient, and reliable water transport. Economic comparisons with desalination identify the conditions under which maritime freshwater transport becomes competitive, offering a practical framework for strengthening global freshwater resilience.



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Abstract: Freshwater scarcity causes social, economic, political, and environmental unrest. With unequal freshwater distribution globally, trading of freshwater can be a possible solution. But water trade, unlike oil trade, is not a recognized market. It would require a water trading fleet. Repurposed oil carriers as a scalable, flexible solution could be a first step. Engineering modifications, special internal coatings, environmental considerations, and port loading and unloading infrastructure optimization are examined. Cost-benefit analysis of capital expenditure and operational expenditure towards fuel, logistics, transportation, and maintenance are discussed. These are considered against known desalination costs to determine geographical and distance-based thresholds where maritime transport becomes competitive. By bridging gaps between decommissioned maritime assets and acute freshwater deficits, the study provides a comprehensive framework for policy makers, marine engineers, and economists to enhance freshwater resilience using the existing global shipping capacity.

Keywords: Water scarcity; Repurposed oil-carriers; Freshwater Backhauling

Introduction

Freshwater, a vital resource to sustain life and various industrial processes, is under stress globally. Today, over one billion people lack access to freshwater. An additional 2.7 billion living in developing countries face water scarcity that lasts for at least one month a year [1]. Water usage is unsustainable because there is a gap between demand and recharge rates. Driven by climate volatility, rapid urbanization, and industrial growth, the available freshwater in aquifers and surface ecosystems has reduced drastically [2]. If current mismanagement of freshwater persists, the world will see a 40% gap between freshwater supply and demand by 2030 [3]. This would put more than 4.5 billion people under stress with about 700 million becoming migrants by 2030 [4]. Probably, freshwater scarcity will increase exponentially because of climate change, extreme weather events, increasing population, industrial manufacturing [5] and water-intensive agriculture [6,7], and an increasing use of Artificial Intelligence (AI) that demands substantial water for cooling [8]. This has resulted in a greater push by the United Nations to improve management of existing aquatic ecosystems and encourage sustainable development [9]. Since no two nations are equally endowed with this natural resource, the situation is already grim in some countries. Bangalore (India), Beijing (China), Cairo (Egypt), Jakarta (Indonesia), and Tokyo (Japan) are steadily running out of freshwater [10]. Only if economy-wide conservation actions are initiated will it be possible to delay water scarcity.

Converting saline seawater into quality potable water using desalination technology has increased. This technology faces strict physical, environmental, and financial constraints [11]. It is energy inefficient [12], causes noise pollution, emits gaseous emissions and chemical spills, causes harm to the aquatic life owing to increased concentration of salts, temperature, and specific weight of waste brine [13], and disturbs the salinity of the region through discharge of tailings with high concentration of salt [14]. In addition, these plants require high investment for construction and operations. Nevertheless, nearly half of Israel's water requirement is met by desalination. Similarly, most countries of Northern Africa, the Middle East, and most Small Island Developing States (SIDS) in the Indo-Pacific, find desalination a relatively cheaper option than importing potable water. Such is the demand that studies have reported a 40% increase in the installed capacity of these desalination plants between 2020 and end of 2025 [15]. Currently, desalination of seawater seems to be the only available option for obtaining freshwater.

There is now need for a mix of new technologies, sustainable practices, and collective efforts mainly through conservation and public involvement. Some solutions that are currently used to address local water stresses include water trucking, water purification tablets, conservation techniques such as rainwater harvesting, water recycling, addressing leaks in water distribution systems, precision farming, and the use of smart technologies at home, and creating improved aquifers and water distribution systems both at the national and international level. Since supplementing water for water-scarce areas is a major concern, towing icebergs to arid regions has also been proposed [16]. In fact, the 2021 World Economic Forum (WEF) listed the harvesting of icebergs as one of the top five alternatives for addressing water stress. Though theoretically feasible, it requires significant energy and technology coupled with robust conservation and supply mechanisms. Other notable alternatives include use of solar-powered devices on the sea surface to evaporate and capture freshwater, use of advanced materials to absorb moisture from the air to provide localized drinking water, treating and reusing domestic wastewater, and deploying smart Internet of Things (IoT) networks and AI to detect leaks, optimize irrigation, and monitor municipal water networks in real time [17].

Akin to land-based water trucking, the use of repurposed oil-carriers to move water from freshwater-rich to freshwater-deficit areas has also been proposed. But their use has not been implemented because of economic and technological considerations [18]. It is important to understand that whereas global oil-shipping operates in a mature, standardized, and consolidated international commodity market, freshwater logistics are fragmented and restricted. Water is considered a low-value resource whose logistics are dictated by local geography, municipal infrastructure, and immediate regional scarcity [19]. It is thus essential to look at technological and economic challenges in the use of repurposed oil-carriers to address freshwater scarcity, especially for dry and arid regions of the world [20].

Using a desk-based qualitative research approach, the paper reviews and analyses the feasibility of using repurposed oil-carriers for meeting the requirements of water deficit countries by using freshwater backhauling. The work synthesizes open-source literature such as books, peer-reviewed papers, newspaper articles, study reports, policy documents, and websites. There is very little published on this topic. Hence, an ‘out-of-box thinking’ approach has been used to make educated estimations and conclusions with appropriate justification provided for every inference drawn. As a result, the paper provides a feasibility study and conceptual review that uses an exploratory case study approach for use of repurposed oil-carriers for the water trade. The study aims to provide some food for thought for policy-makers and industry alike for using such repurposed oil-carriers to address the growing water requirements. Future research should aim to integrate semi-structured interviews with marine engineers, port authorities, and environmental policy makers to gain empirical insights into technical issues, regulatory bottlenecks, and transboundary water agreements that rudimentary literature analysis cannot fully capture.

The paper begins by providing the efforts made globally over the years to transport freshwater to regions with freshwater scarcity while examining the roles in which repurposed oil-carriers can be used in general and to address freshwater scarcity in particular. This will be followed by comparing existing oil and water logistics and understanding why oil logistics is successful but water logistics is not. Next, the paper examines the technical, engineering, and economic requirements to use repurposed oil-carriers in a freshwater backhauling role; and then a case study to strengthen the understanding and use of this method. A discussion and suggestions for ways ahead towards the possible use of repurposed oil-carriers will follow, before concluding the paper.

Transporting Freshwater by Sea

Oil-carriers or oil tankers, as they are usually referred to, are specialized merchant ships that are designed to transport oil products in bulk. They are broadly categorized into crude tankers (for moving unrefined oil) and product tankers (for moving refined petroleum products) to consumption markets. The tanker design is strictly governed by international maritime safety and environmental regulations. To minimize risk of oil spill caused by grounding, collision, or rupture of shell plating, double hull designs have become mandatory. The size of these ships varies according to the trade route and the canal dimensions they need to cross. Accordingly, they range from small coastal vessels to Ultra Large Crude Carriers (ULCCs) capable of carrying over 320,000 deadweight tons (DWT) of cargo. For efficient operations, these vessels require sophisticated cargo handling systems, including complex networks of pumps and piping for loading and unloading of their cargo; maintaining their stability by taking in seawater as ballast in specially designed tanks. As a safety measure, these ships use inert gas systems to replace atmospheric air in the cargo tanks with non-flammable gases to mitigate the risk of explosion of volatile hydrocarbon vapours.

Like all merchant vessels at sea, the operational lifespan of an oil tanker is strictly governed by regulations enforced by the International Maritime Organization (IMO), through the MARPOL Convention (Annex I), and typically spans 20 to 25 years unless explicit extensions are verified by flag state administrations. Once the design life of these vessels is completed, they need to be scrapped and broken down to be recycled.

After their design life of 20 to 25 years is completed, these ships are considered a hazard at sea that can cause oil-slicks and hence pollution if damaged. Their use in secondary roles is, however, possible. Accordingly, these oil-carriers are used in secondary roles such as floating wastewater plants, living space for seaside population, providing potable water and different kinds of water for targeted application by using their desalination plants, and as a cost-effective solution for land-based structures for solar plants, wind-farms, and runways [21]. The tankers could even be converted into multi-storeyed car parks to address the growing problem of space for vehicles, or be converted into movable power stations by converting them into floating wave energy converters (WEC) [22]. Most of these innovation projects have been technically proven by EnvioNor [23] in partnership with the international aid organization Star of Hope International that educates children to create an impact on the world [24,25].

To supplement freshwater availability in remote regions, such as for small island states, water needs to be physically moved. This business of moving water in large quantities or bulk is broadly divided by source, transportation, and destination. The source is where water is available in plenty and is replenished naturally. The bulk transportation of this water is undertaken using ships and barges, but may be limited, owing to lack of loading and unloading facilities. Over the years this movement has shifted to barges as they are cheaper to operate and maintain. The destination of this bulk freshwater is the countries that lie in the hot arid regions or have been ravaged by climate-driven events that have resulted in water scarcity. Globally, many regions receive transported water nearly round the year. Nauru and islands in the Caribbean receive up to 30% of their water supply using tankers with that of the Caribbean coming from Andros Islands which are 60 km away [26]. Other noteworthy global water trade is by Turkey to North Cyprus [27], and the port of Marseille that supplied water to Spain and Italy in vegetable oil tankers suitably modified to carry water [28]. Several companies have used giant floating bags/ collapsible water bladders especially manufactured for water transportation to Greece since 1997. These bags/ bladders were towed by tugs but were prone to bursting [29].

Yet another way of transporting freshwater by ships is the use of oil-carriers which was first proposed in 1985 by the Japanese Classification Society, ClassNK, considering the movement of oil from Saudi Arabia to Japan and freshwater from Japan to Saudi Arabia [30]. These oil-carriers can be put to use to transport freshwater using the free cargo space and/ or segregated ballast tanks when the ship is returning to the oil loading port. This process is called freshwater backhauling (FWBH). Technically, FWBH is feasible after modifications and developing new shore-based infrastructure for loading and unloading of freshwater at both the oil loading and unloading ports. The freshwater may be carried either in ballast tanks or in the cargo tank itself. For corrosion protection, the ballast tanks require a glass reinforced or polyurethane coating. The cargo tanks will remain protected because of the existing oil film of cargo discharge prior to taking in freshwater. On reaching the destination port, the freshwater would be treated according to the regulations of the recipient country and the quality of freshwater transported [31]. Though the FWBH has not been brought into actual practice, a patent on the entire process was filed in 2011 by a French company after adding processes to treat and clean the freshwater on their return passage or prior to unloading of the freshwater. The patent has been registered under the World Intellectual Property Organisation (WIPO) [32].

The proposed use areas discussed here are all technically feasible but may not be economically viable as conservative estimates of transportation at US$ 1.50/m^3 (from Japan to Saudi Arabia) are much higher than the desalination cost of US$ 0.60/m^3. The bigger challenge is to find an agency willing to operate the vessel in its changed configuration and connect it to the shore utilities for the function proposed. Like all efforts of this magnitude, it requires the will and the policy push of the policy-makers to make the proposal a business model that is acceptable to the industry. Since the design was proposed by ClassNK in 1985, the safety of the vessel and the environment and its functionality is considered beyond doubt. With regard to the FWBH, it is not covered by any Classification Society to date and hence needs greater deliberation for greater understanding to emphasize the need for Classification Societies to support the use of oil-carriers in a FWBH role to meet the growing global water crisis. Accordingly, FWBH will be discussed in greater detail both from a technical and economic point of view to show that use of repurposed oil-carriers needs more detailed planning.

Beyond these, some maritime operators like Maersk have focused on micro-solutions. The shipping giant using innovative systems to optimize fresh-water generation onboard their vessels have begun producing and storing the produced clean drinking water during their regular transits. This stored clean water can be delivered in containers to remote coastal areas facing scarcity [33]. Table 1 shows a cost-benefit analysis of desalination that needs to be challenged by the FWBH. It is important to mention that these costs will change upwards in the event of conflicts as seen in US-Israel-Iran wherein desalination plants in Iran have been targeted and destroyed by the US forces [34].

Table 1: Desalination Cost-Benefit Analysis (Source: Author, from various resources)

Category	Specific Element	Details and Values (per m³)
Financial Costs	Capital Expenditure (CAPEX)	**\$0.25 – \$0.45**: High plant construction costs.
	Operational Expenditure (OPEX)	**\$0.15 – \$0.25**: Membrane replacement and chemical treatment.
	Energy Consumption	**\$0.20 – \$0.35**: High-pressure pumping (requires 3–4 kWh/m³).
Environmental Costs	Marine Ecosystem Impact	**High**: Discharges toxic, concentrated brine that depletes oxygen levels.
Logistical Benefits	Transportation & Logistics	**\$0.00**: Produced locally directly at the coastline, eliminating freight fees.
Strategic Benefits	Fresh Water Security	**Vital**: Provides a reliable, continuous alternative for water-parched regions.
Overall Economic Baseline	Total Financial Cost	**\$0.60 – \$1.05**: Currently cheaper and more viable than maritime backhaul shipping.

Comparing Oil and Freshwater Logistics

The first question is why oil trade is successful but freshwater trade never gained traction even though the Middle East countries are the most impacted by a freshwater crisis. The simple answer is that the entire supply chain of the oil industry is managed by a small network of national oil companies and specialized global shipping fleets. As a result, the pipeline, storage hubs, and other support systems are universal. This allows a tanker to deliver cargo to any port in any part of the world. All this is feasible because oil is traded via high global future contracts that allow logisticians to hedge transportation risks [19]. On the other hand, freshwater logistics are fragmented and not economically lucrative as water is a low-value commodity which has localized management with a subsidised pricing structure as access to freshwater is considered a fundamental right of all human beings. Being heavier than oil (1 litre of freshwater weighs 1kg but it is 0.85~0.95 kg for oil), it requires more energy to move, whether through pipelines, bags, or by barges [35]. Governments supply freshwater at highly subsidized rates because it is a basic necessity. This makes third-party investment in water transport unviable [36]. An unpredictable freshwater requirement makes usage of assets such as tankers and barges unpredictable, destroying any guaranteed return on investment. These factors have prevented development of intermodal infrastructure and use of modern digital infrastructure for tracking suppliers and distribution hubs for water transportation, leading to line losses and operational inefficiencies and hence reduced profits [37]. This furthermore makes a global spot price for freshwater impossible, with the rate being driven by the freshwater crisis prevailing in a region or country.

Although using repurposed oil-carriers may be a practical option for addressing water scarcity, this option is considered a stopgap arrangement to address local emergencies rather than provide a permanent solution. Even though oil-carrier ships have a high potential to carry freshwater because of their capacity, the amount of water carried in a Very Large Crude Carrier (VLCC) is only about 320,000 m^3 (2 million barrels or 320,000,000 litres) which is consumed by a major city (i.e., a large, heavily populated urban centre, serves as a primary hub for business, culture, and government, usually with a population of over 100,000) in a matter of days (at a global average of 100 litres per person per day). To add to this, ocean freight is expensive, cost increasing with distance travelled. Hence such movement of bulk water in ships becomes uneconomical over distances greater than 884 km [38]. Potable freshwater, when transported in active oil-carriers, is likely to be contaminated because of residual oil in the tanks. If these residues have to be removed, the cost associated with cleaning and making the tanks ready for carrying potable water will be very high and time consuming [39]. These added activities make logistics of freshwater movement by ships highly inefficient.

Technical and Engineering Requirements

Major oil exporting countries in the Middle East (i.e., those that extract more crude oil than they consume) experience arid conditions and have not been endowed with the natural resource of freshwater. Since the natural climate is 'dry' in the Middle East, these countries remain water deficient for most of the year. Saudi Arabia, UAE, Oman, Qatar, Kuwait, and Bahrain have no rivers or freshwater lakes. They do, however, have large reservoirs that geologically trap groundwater, which is the main source of freshwater for these countries. Small dams are also constructed to increase the groundwater recharge. With these countries experiencing economic growth from sale of oil, both their population and social development has seen an increased growth. This has resulted in increased demand for freshwater which is currently met by desalination. There have been plans to replace the existing desalted water with natural groundwater [40]. This has required looking at alternatives which include using shuttle tankers to get freshwater from Pakistan and Turkey [40].

Since oil tankers delivering crude oil to various parts of the world have to come back to the originating country without any return cargo, there is a possibility of filling freshwater in place of oil and ballast in the return voyage from the country where crude has been delivered. Such a mechanism is called freshwater backhauling (FWBH). It can effectively address the water shortage in oil-producing, water-deficient countries. While this procedure is possible for every type of cargo vessel, such as bulk carriers and container vessels, we will limit our discussion to oil-carriers. As mentioned earlier, the concept was researched extensively in the 1970 and 1980s during the turbulence in the oil markets, but ceased to get attention abruptly when the global economy recovered. FWBH reduces emissions in the return passage and solves the problem of movement of invasive species across maritime boundaries as the ballast water is now replaced by freshwater from the oil-importing nation [41]. Still, it has received little attention. With increasing focus on decarbonization of the shipping industry and control of invasive species, the subject needs to be revisited as it also addresses the issue of the global water crisis.

As discussed above, the use of dedicated tankers for freshwater transport is cost-prohibitive when compared to other options such as desalination. If turnaround time in port because of loading of freshwater is not high, freshwater transported as ballast would add minimally to the cost – making it cheaper than when dedicated vessels are used. In the case of segregated ballast tanks being used for carrying freshwater, the need for costly ballast water cleaning systems can be eliminated, an economic advantage. Since the existing design and construction of oil carriers do not make them automatically compatible for being used as freshwater carriers, these ships need to undergo technical modifications. Similarly, since the port-side infrastructure currently does not cater for handling loading and unloading of freshwater, this infrastructure too would require modifications. Accordingly, the minimum essential modifications required to make FWBH successful are now discussed.

Modifications on the Vessels

The existing oil-carriers are not aligned to carry potable freshwater as the coating used by oil carriers does not prevent water toxicity and contamination. Since the unloading and transfer of crude oil onboard is done by an independent system onboard, these too need to be examined and modified where required. The following modifications are considered critical to ensure that freshwater as a backhaul can be handled by the oil-carrier.

(a) *Pumping Head Enhancement*: Ballast pumps require an increased discharge head of 100–150 metres to transfer water to shore-based storage to cater for shore-side static heads, frictional loss in shore-based pipelines, overcoming back pressure from shore-based tanks, and high resistance of shore-based filtration systems. This requires augmenting capacity of existing pumps, installing intermediate deck pumps, or using independent submersible pumps of approximately 1,000 m^3/hr capacity.

(b) *Deck Manifolds and Piping*: A separate set of hoses and manifolds are required to be installed for freshwater handling. These manifolds must be installed on the deck near oil manifolds to avoid the need for installing new hose-handling davits for freshwater. Such dedicated hoses prevent water contamination and ensure purity of the freshwater.

(c) *Tank Vent Redesign*: With freshwater being used for ballast in place of sea-water, the tank venting systems needs to be structurally re-engineered to handle the new pressure dynamics and prevent failure of ship structure due to over pressurisation.

(d) *Anti-Corrosion Tank Coatings*: Ballast tanks are coated with copper and lead leaching paints to protect them against marine organisms present in the seawater used for ballast. If copper and lead are allowed to leach into the freshwater, it can make the water unfit for use. Hence, there is a need to recoat the ballast tanks with polyurethane or glass-reinforced plastic paints.

(e) *Strength of ships*. Freshwater has higher density than oil and so is heavier than oil. Since the oil-carriers are structurally designed for a lower density fluid, structural strength analysis for an increased density fluid would need to be undertaken prior to use for transport of water. Although the problem can be addressed by loading a lesser quantity of freshwater, this would result in sloshing and free-surface effect that would result in loss of stability of the ship at sea. Only detailed calculations would define the limitations over which these oil-carriers can operate with freshwater as cargo in place of crude oil.

(f) *Considering suggestions of patent*. The onboard water treatment and clean freshwater storage system proposed in the patent on FWBH taken in 2011 [32] and discussed earlier can be experimented with. Use of this proposed methodology will ensure that minimum treatment of the transported water is required after it has reached its destination port.

Improvement of Marine Infrastructure at Ports

To load and unload freshwater in an oil-carrier there is a requirement of providing specialized equipment that can handle freshwater without contaminating it. Currently, most large oil-carriers cannot come alongside conventional piers and hence operate from specialized mooring points which need to be augmented with specialized facilities to load and unload freshwater. Accordingly, some modifications would be required at these ports. Some of these modifications are discussed here.

(a) *Offshore Loading and Unloading*: To load and unload cargo from large oil-carriers that cannot come alongside conventional piers, specialized mooring points using Single Point Mooring (SPM) buoys or advanced offshore mooring technologies like HiLoad systems are used. Conventional SPMs are designed to handle only one single cargo. Advanced SPMs can handle multiple distinct products to avoid contamination. Hence, the existing SPMs would need to be modernized to handle multiple fluids.

(b) *Storage Reservoirs*: Crude oil is loaded in oil-carriers from onshore storage facilities that have a high-volume of buffering (typically 70,000 to 150,000 DWT per vessel). If freshwater has to be loaded/ unloaded from these ships, similar specialized facilities are considered a basic essential to ensure minimum time in port.

(c) *Water Treatment Facilities*: The freshwater unloaded from the ship would need to be purified prior to use and may require site-specific infrastructure. Infrastructure comprising removal of fine coalescence and polishing filtration activities for purification [42] is considered necessary to ensure effective use of the transported freshwater for drinking, agriculture, or any other purpose.

Using Segregated Ballast Tanks (SBT) and converted cargo spaces for FWBH.

By using both techniques, viz. SBTs and cargo spaces, the volumetric efficiency of Freshwater Backhauling (FWBH) can be enhanced. Each method requires completely different infrastructure modifications, pumping systems, and water treatment strategies.

Segregated Ballast Tanks (SBT)

SBTs are provided as isolated spaces exclusively for stability. They prevent direct contact of the cargo with the environment in the event of grounding, collision, or rupture of the shell plating. By using SBTs for freshwater, the likely contamination from oil residues can be avoided requiring lesser efforts for purification. Care needs to be taken to change the coating of these tanks from the currently used leaching paint to a glass reinforced plastic or polyurethane to avoid contamination of the freshwater. In addition, high volumetric pumps would need to be provided to maintain the desired discharge head.

Converted Cargo Spaces

By using the cargo space as additional space for transporting freshwater, an increased quantity of water can be transported. But use of this space introduces hydrocarbons as contaminants in the freshwater. Cleaning of these cargo tanks is cost prohibitive and would increase time in harbour This increases the overall cost of freshwater transportation, which is undesirable. The oil present acts as a barrier between freshwater and the tank structure avoiding any chances of corrosion. Since the main cargo pumps are of high capacity, they need no modification and can be used to pump out freshwater. But port facilities to receive, handle oil contaminants, and filtration of the freshwater using synthetic resins or ceramic blocks would need to be created. Freshwater carried in cargo space is considered fit for industrial and agriculture use after minimum essential purification.

Towards an Economic Viability Framework

No proposal or project is considered viable unless its economic viability can be ascertained. This can convince the investors that the proposal is economically competitive. Since the FWBH operation has numerous variables that depend on an array of parameters, the most appropriate method for economic viability assessment is to create a mathematical economic model. One such model for FWBH has been discussed by Sharma and Lande in their Norwegian Master's thesis [31]. Using this model, if we consider an average cost of desalination at US$ 0.70, a dedicated tanker transportation system would be difficult to operate since moderate to high rates of operating a dedicated tanker make the transportation uneconomical. But, Freshwater Backhauling (FWBH) is considered technically feasible and economically competitive as it will be able to deliver freshwater to arid regions at approximately US$ 0.83 to 1.16 per ton for trips between Japan and Saudi Arabia. This is calculated considering the movement of nearly 50-200 million tons of freshwater annually using double-hull Suezmax, VLCC, and ULCC tankers.

It is seen that this cost would reduce if freshwater would be carried in both segregated ballast space and in cargo tanks. The process is also much cheaper than building and operating dedicated freshwater tankers. This said, the cost of infrastructure – which is a one-time investment – has not been catered for in this calculation but is considered essential to be undertaken for FWBH to be successful. It is important to note that use of these oil-carriers in an alternative role depends on the prevailing global oil market conditions as the movement of these oil-carriers is driven by oil prices and geopolitical situations. The supply of freshwater to countries through FWBH may not be a completely reliable method for arid and water parched countries. The economic advantage of moving freshwater using repurposed oil-carriers would only increase when the cost of production of purified natural water rises, thereby reducing the cost differential between the produced and transported water [43].

The argument of economic viability is considered valid as long as alternatives of obtaining freshwater, say through desalination are available. If aggressors exploit ecological and infrastructure fragility during conflicts by damaging desalination plants to make them non-operational [34], as seen in the US-Israel-Iran conflict, the need for water trade by Iran becomes a necessity rather than a desire. It is no wonder that countries are looking at various alternatives to ensure water security including creating strategic storage capacities [20], use of nature based solutions [44], and import of water using pipelines [40]. It is recommended that along with these methods, FWBH can be actively considered as a means of achieving water security. With use of Sovereign Wealth Funds in water-scarce Middle East countries, experimenting with FWBH should not be difficult.

Other than these direct economic advantages, there are other advantages of using FWBH. These include disallowing movement of invasive species across maritime boundaries and reduction of carbon emissions as the return passage is undertaken in a fully loaded condition. These tacit advantages align well with the present efforts of the GCC countries to shift away from a fossil fuel based economy [45] and hence must be explored and used by them. Additionally, FWBH helps overcome the challenges of environmental degradation by desalination plants. It also ensures that job opportunities are created for people within the country through related projects and actual import of freshwater. A case in point is the US$ 700 million worth of infrastructure projects that

Israeli companies gained after the deal of freshwater trade was signed between Israel and Turkey [46]. Such exports can improve relations between two countries, and may also be used as a geopolitical tool if relations deteriorate.

Case Study

To strengthen the argument that use of repurposed oil-carriers should be encouraged for transportation of bulk freshwater from water-rich countries to water-deficit countries. Accordingly, we now discuss a case study of water supply from Turkey to Middle East countries from the Manavgat River using backhaul logistics. Turkey proposed the project. As part of the project, Israel agreed to purchase 50 MCM (Million Cubic Metres) of water annually for 20 years from Turkey in 2004.The agreement was subsequently shelved in November 2006 because the parties had neither settled the price nor selected the company to implement the water transfer. Rather than relying on water backhaul, Turkey chose a more reliable subsea infrastructure creation in the form of subsea pipelines to supply water to Northern Cyprus that allows movement of 75 MCM of water annually via a fixed anchor line [47]. Understanding the project helps understand the actual possibility and feasibility of repurposing oil-carriers to address water scarcity.

The Manavgat River Project

Manavgat River of Turkey discharges into the Mediterranean Sea. Approximately 6 MCM is considered 'lost' to the sea on a daily basis. Realizing that the entire Middle East consumes approximately 10 MCM of fresh water daily using desalination plants, Turkey has built maritime loading infrastructure at the mouth of the river to filter, store, and pump water directly into deep-sea vessels. The project commenced in 1992. Turkey's General Directorate of State Hydraulic Works (DSI) was permitted to develop water supply for domestic use. Accordingly, water from the river is pumped up to the purification plant using a pumping system. The purification plants undertake chemical and physical water treatment to meet WHO standards [48]. These plants are situated at a height of 67 metres above the mean sea level where a water tank of 500,000 m^3 stores half of the supplied water as treated water and the other half as raw water. The water from these tanks is supplied to two separate Single Point Mooring (SPM) points – one for raw water and the other for purified water – both by gravity. See Figure 1.

The Manavgat river freshwater supply project is designed to export 180 MCM of freshwater annually. The purification plant is capable of filtering 250,000 m³ of purified water daily – alongside an equal volume of raw water [49]. To support the movement of freshwater to the ships, dual undersea pipelines extend 12 km out into the Mediterranean Sea, terminating at two Single Point Mooring (SPM) buoys. These buoys permit large vessels (60,000 to 250,000 DWT) to fill their holds directly from the sea terminal [49].

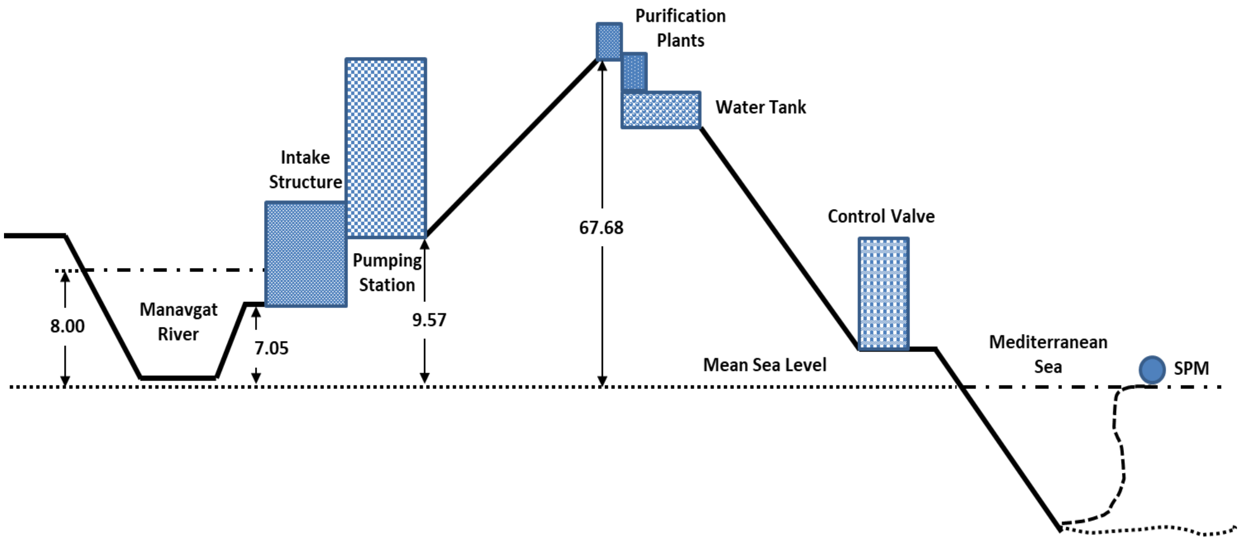

Figure 1. Schematic of Manavgat River Project [50]

The Manavgat River Backhaul Water Logistics

The deep-sea vessels used for transportation of water include converted oil supertankers, specialized towing bags (made of Medusa fabric), and crude oil, liquefied natural gas (LNG), and liquefied petroleum gas (LPG) tankers, that otherwise would sail from Turkey to Saudi Arabia completely empty after unloading their cargo in Turkey [46]. As part of the Backhaul Water Logistics strategy, these ships replace the seawater carried in ballast tanks for structural stability with freshwater from the Manavgat River [47]. As a result, the fleet usage is optimized by 30%, the water cost in Middle East countries can drop by 30%, and the cost of infrastructure creation towards new desalination plants can be saved. On the environment side, backhaul logistics have allowed reduced carbon emission from ships on their return passage. They have ensured that invasive species from the Mediterranean do not move to the Arabian Sea. Additionally, the ecological burden created by desalination plants of the Middle East has been reduced.

Limitations

Although the project is considered as an initiative towards increasing regional security and stability, dependence on an external sovereign country for a critical resource, freshwater, is something most countries would like to avoid. Such dependence gives the supplying country the option to use water as a geopolitical tool. The same cannot be said for oil wherein the possible suppliers are diverse. The limitation of this freshwater trade to remain economical is its distance, which is recommended to be less than 884 km [38].

This distance is maintained and the necessary ships are available, but care is required to ensure that the withdrawal rate of freshwater is lower than the charging rate for sustainable use. Furthermore, the impact of water withdrawal on sediment deposition and the health of the local ecology requires greater scrutiny. The environmental and social impacts from building and operating the freshwater transfer infrastructure need to be considered [51].

Economic Viability

The economic viability of backhauling freshwater from the Manavgat River is examined by comparing the total costs per cubic metre (m^3) transported via backhauling against Seawater Reverse Osmosis (SWRO) desalination, which currently provides a baseline price of water in the Middle East. With improvement in desalination technologies, this economic viability has become challenging [52]. Considering the CAPEX, OPEX, energy consumption, logistics, and transportation the comparative values as obtained for a backhaul and desalination methods is seen in Table 2 below. One notices that with the desalination baseline (US$ 0.60 to 1.05) being less than Manavgat Backhaul Shipping (US$ 0.70 to 1.40), the backhaul method is not viable economically – but still remains competitive in certain circumstances. It would become acceptable only if either the cost of local electricity in the Middle East rises above US$ 0.20/kWh or where there is an urgent need to meet freshwater requirements until a new desalination plant can be constructed.

Table 2: Comprehensive cost structure of water supply and production in the Middle East countries (Source: Author from various resources)

Cost Component	Backhaul of water from Manavgat River	Modern SWRO Desalination
Capital Expenditure (CAPEX)	**\$0.15 – \$0.30** (Low onboarding infrastructure)	**\$0.25 – \$0.45** (High plant construction costs)
Operational Expenditure (OPEX)	**\$0.10 – \$0.15** (Source water extraction & treatment)	**\$0.15 – \$0.25** (Membrane replacement, chemicals)
Energy Consumption	**\$0.05 – \$0.10** (Low-pressure pumping)	**\$0.20 – \$0.35** (High-pressure pumping: 3–4 kWh/m^3)
Logistics and Transportation	**\$0.40 – \$0.85** (Vessel charter, port fees, cleaning)	**\$0.00** (Produced locally at the coastline)
Total Cost	**\$0.70 – \$1.40 / m^3**	**\$0.60 – \$1.05 / m^3**

Discussion and a Way Ahead

Freshwater scarcity has been a challenge for many countries because of climate-driven events and an increasing population. This has forced countries to consider steps toward sustainable water resource management approaches. It is essential to educate people to conserve and judiciously use available water resources, and managing these resources equitably is also essential. This means transboundary cooperation and agreements. These complications and the fact that freshwater is an essential resource have tended to strengthen the argument for desalination. This has allowed the technology to reduce the costs in a high-capacity SWRO plant to be as low as US\$ 0.28 /m^3. With desalination having its own environmental concerns, freshwater trade should be investigated.

Even though export of water from water rich sources has been happening for many centuries, it has not been a formal trade because of the low cost of water and the costs and efforts in transporting water using dedicated vessels. To minimize the cost associated with specialized vessels, and to make optimal use of the return passage of an oil-carrier involved in export of oil, ClassNK undertook a feasibility study of using repurposed oil-carriers to transport water in segregated ballast tanks and oil cargo tanks in 1985. Such repurposing of oil-carriers was found to be technically feasible and economically competitive – but did not develop for lack of investors. The closest it reached reality was with the Manavgat Backhaul Water project of Turkey, where it aimed to supply water from the Manavgat River to the Middle East countries and Eastern Mediterranean countries including Israel. Turkey, under an agreement with Israel, modernized the infrastructure of its ports and supply systems but the agreement was shelved within two years of its signing. The main reason for this cancellation was Turkey's increase in the price of transported water. This increase was a result of the high global cost of fuel and increased cost of purification caused by the privatization of water treatment facilities by Turkey [53]. As a result, Israel shifted their focus towards developing desalination technology.

The threat to freshwater security is real, and demands action. With advances in technology, it is now possible to conserve existing natural water resources while transforming alternative ones into a source of high-quality freshwater. This effort requires political cooperation in conserving freshwater sources that may be in rivers, lakes, on surface, or in groundwater resources. But geopolitical considerations and fear that one country may use lack or abundance of freshwater as a geopolitical weapon to gain leverage against another impedes such cooperation. If the freshwater resources used for export are over-exploited, they may lead to freshwater scarcity in the exporting nation – thereby creating freshwater scarcity and even ecological damage for them. Turkey began by exporting freshwater from the Manavgat River but today finds that the water table of the country has reduced drastically. With a growing internal freshwater demand, if adequate corrective actions are not taken, Turkey too may end up facing freshwater scarcity [47].

The present study addressed the use of repurposed oil-carriers for transporting freshwater in order to meet global water scarcity. The study has shown that the entire process of using repurposed ships is technically feasible and economically competitive under certain conditions. But first there is a need for interested stakeholders and investors. As demand for freshwater increases with increasing populations and a greater demand for industrialization, agriculture, and rise of Artificial Intelligence, the time is fast approaching when water trade would become economically lucrative as oil is today.

It will probably not be long before water diplomacy and water trade becomes an independent branch of International Relations. Currently, freshwater is not a traditional commodity but it is traded for money globally within countries in the form of packaged drinking water [54]. Movement from intra-country trading to inter-country trading is a matter of time. It will entirely depend on how seriously sustainable means are used to preserve existing freshwater resources and the reclamation of wastewater.

It may seem unlikely that ship owners will accept enormous costs for fitting manifolds, pumping arrangements, and recoating segregated ballast tanks. The shore-based infrastructure to load and receive water from tankers may be non-existent and a costly arrangement. The odds for scrapping a 20 to 25 year old tanker may be high. As global temperatures increase through climate change, the demand for freshwater is only going to increase. This and the growth in world population will increase the stress on terrestrial freshwater resources making freshwater availability scarce.

Freshwater will then become an essential commodity within the world trading system. But if this trade in freshwater is not handled sustainably, it would only lead to environmental deterioration. It is thus imperative that adequate studies are undertaken to take the concept of FWBH to a logical usable conclusion. We may not use it immediately, but we will be ready when the time is ripe.

The present study shows that the FWBH concept needs to move from theory to practice. It is essential that a localized pilot project be launched as a scenario-specific project on a single route. This project needs to be between a freshwater-surplus oil-importer and a freshwater-deficit oil-exporter to monitor coating durability, cross-contamination, and pump efficiencies in real-time. The Manavgat River project can be considered as a model project for such studies. To take the concept forward as a formal standardized framework, public authorities and global trade bodies such as the International Maritime Organization (IMO) and the World Trade Organization (WTO) must become engaged with the reality of the problem, and its possible solution. Such involvement will help resolve the economic status of bulk freshwater and institute long-term, stable public contracts instead of volatile spot market agreements. Additionally, newly constructed ships and those undergoing major refits must align to FWBH design to let ship owners leverage freshwater transport as a compliance exemption, lowering operational treatment costs, and avoid cost of retrofitting at the end of service life.

As part of repurposing oil-carriers, ships that have lived their service life can be additionally used as floating wastewater plants, or to provide different kinds of water through desalination, for movable power stations using wave energy convertors, or living space to overcome non-availability of land, for creating land structures including runways in the sea, or as multi-storeyed car parks. Since most of these proposals have been proven as feasible, the need of the hour is public-private partnership to expedite change.

Conclusion

The study has examined the use of repurposed oil-carriers for addressing global water scarcity. Although a number of proposals have been found to be technically feasible, none of them has moved up the Technology Readiness Level (TRL) ladder so as to be proven as economically viable. Therefore, it is difficult to say whether FWBH is a feasible option in the global freshwater crisis or not. One realizes that this feasibility depends on the mode of operation, the market condition of global oil, the price of electricity in countries using desalination plants, the location of ports and terminals, as well as the influence of environmentalists to challenge the extensive use of desalination plants. When compared at the environmental scale, FWBH is an option superior to desalination. Still, no full-scale FWBH project has seen the light of day so far. The international trading of freshwater must become a reality. The present study thus makes an effort to accelerate thought towards implementing a localized pilot project to study the FWBH proposal closely and in real-time so as to be future-ready.

Disclaimer

The views expressed in the paper are that of the author. They do not reflect the views or policies of the Government of India or the Indian Navy.

References

[1] BBC News, 2018, *The 11 Cities Most Likely to Run Out of Drinking Water*. February 11. Available at https://www.bbc.com/news/world-42982959 (accessed 06 May 2026).

[2] Damania, R., Desbureaux, S., Hyland, M., Islam, A., Moore, S., Rodella, A.-S., Russ, J., & Zaveri, E., 2017, *Uncharted Waters: The New Economics of Water Scarcity and Variability*. Washington, DC: World Bank. https://doi.org/10.1596/978-1-4648-1179-1

[3] Rosa, L., & Sangiorgio, M., 2025, Global water gaps under future warming levels. *Nature Communications* **16**(1), 1192. https://doi.org/10.1038/s41467-025-56517-2

[4] UNESCO, 2016, *The United Nations World Water Development Report 2016: Water and Jobs – Facts and Figures*. Available at http://unesdoc.unesco.org/images/0024/002440/244041e.pdf (accessed 06 May 2026).

[5] Magara, Y., 2002, Industrial water. In Kubota, S., & Tsuchiya, Y. (Eds.), *Water Quality and Standards,* Vol. I. Encyclopedia of Life Support Systems (EOLSS). ISBN: 978-1-84826-480-9.

[6] King, R., 2025, *The Water Footprints of Food and Agriculture Trade*. Chatham House. Available at https://www.chathamhouse.org/2025/12/water-footprints-global-food-and-agriculture-trade (accessed 06 May 2026).

[7] D'Odorico, P., Davis, K. F., Rosa, L., Carr, J. A., Chiarelli, D., Dell'Angelo, J., Gephart, J., MacDonald, G. K., Seekell, D. A., Suweis, S., & Rulli, M. C., 2018, The global food-energy-water nexus. *Reviews of Geophysics* **56**(3), 456–531. https://doi.org/10.1029/2017RG000591

[8] Amara, 2026, *How Much Water Does AI Use? The Real Numbers for 2026*. Tool Discovery. Available at https://www.aitooldiscovery.com/ai-infra/how-much-water-does-ai-use (accessed 06 May 2026).

[9] UNEP, 2024, *Ministerial Declaration of the United Nations Environment Assembly at Its Sixth Session*. UNEP/EA.6/HLS.1. Available at https://docs.un.org/en/UNEP/EA.6/HLS.1 (accessed 06 May 2026).

[10] Kishor, M. S., & Agarwala, N., 2019, Sustainable desalination technologies: Avenues for cooperation in the Indo-Pacific. *Maritime Affairs* **15**(1), 78–92. https://doi.org/10.1080/09733159.2019.1628335

[11] Shkri, A., & Fard, M. S., 2022, A sustainable approach in water desalination with the integration of renewable energy sources: Environmental engineering challenges and perspectives. *Environmental Advances* **9**, 100281. https://doi.org/10.1016/j.envadv.2022.100281

[12] Eke, J., Yusuf, A., Giwa, A., & Sodiq, A., 2020, The global status of desalination: An assessment of current desalination technologies, plants and capacity. *Desalination* **495**, 114633. https://doi.org/10.1016/j.desal.2020.114633

[13] anagopoulos, A., & Haralambous, K.-J., 2020, Environmental impacts of desalination and brine treatment: Challenges and mitigation measures. *Marine Pollution Bulletin* **161**(Part B), 111773. https://doi.org/10.1016/j.marpolbul.2020.111773

[14] Zolghadr-Asli, B., McIntyre, N., Djordjevic, S., Farmani, R., Pagliero, L., Martínez-Alvarez, V., & Maestre-Valero, J. F., 2023, A review of limitations and potentials of desalination as a sustainable source of water. *Environmental Science and Pollution Research* **30**(56), 118161–118174. https://doi.org/10.1007/s11356-023-30662-x

[15] IDRA, 2025, *IDRA Desalination and Water Reuse Handbook 2025–2026*. Global Water Intelligence. Available at https://www.globalwaterintel.com/documents/idra-desalination-and-reuse-handbook-2025-2026 (accessed 06 May 2026).

[16] Condron, A., 2023, Towing icebergs to arid regions to reduce water scarcity. *Scientific Reports* **13**(1), 365. https://doi.org/10.1038/s41598-022-26952-y

[17] Koncagül, E., Tran, M., & Connor, R., 2021, *The United Nations World Water Development Report 2021: Valuing Water – Facts and Figures*. UNESCO World Water Assessment Programme, SC-2021/WS/3. Available at https://unesdoc.unesco.org/ark:/48223/pf0000375751 (accessed 06 May 2026).

[18] Constantine, K., Massoud, M., Alameddine, I., & El-Fadel, M., 2017, The role of the water tankers market in water-stressed semi-arid urban areas: Implications on water quality and economic burden. *Journal of Environmental Management* **188**, 85–94. https://doi.org/10.1016/j.jenvman.2016.11.065

[19] Siddiqui, A. W., & Basu, R., 2021, Disentangling the relationship between oil demand and tanker charter rates using frequency-decomposed components. *Research in Transportation Business & Management* **41**, 100623. https://doi.org/10.1016/j.rtbm.2021.100623

[20] Al-Damkhi, A. M., Al-Fares, R. A., Al-Khalifa, K. A., & Abdul-Wahab, S. A., 2009, Water issues in Kuwait: A future sustainable vision. *International Journal of Environmental Studies* **66**(5), 619–636. https://doi.org/10.1080/00207230903097552

[21] Wang, C. M., & Tay, Z. Y., 2011, Very large floating structures: Applications, research and development. *Procedia Engineering* **14**, 62–72. https://doi.org/10.1016/j.proeng.2011.07.007

[22] Gray, R., 2019, *How to Rehabilitate Old Oil Supertankers*. BBC Future. July 1. Available at https://www.bbc.com/future/article/20190627-turning-oil-supertankers-into-green-power-stations (accessed 06 May 2026).

[23] Environor, n.d., *Company Profile*. Available at https://thehub.io/startups/environor (accessed 06 May 2026).

[24] ReliefWeb, 2014, *Converted Oil Tankers Providing Fresh Water*. Press release, March 5. Available at https://reliefweb.int/report/world/converted-oil-tankers-providing-fresh-water

[25] Star of Hope USA, n.d., *Official Website*. Available at http://www.starofhopeusa.org/

[26] Priscoli, J. D., & Wolf, A. T., 2009, *Managing and Transforming Water Conflicts*. New York: Cambridge University Press. ISBN 0521632161, 9780521632164.

[27] Yavuz, H., 1997, The Manavgat Project of Turkey: Water, an Economic Good. *International Journal of Water Resources Development* **13**(4), 561–566. https://doi.org/10.1080/07900629749638

[28] Global Water Intelligence, 2005, Bulk transport: A solution to scarcity? *Global Water Intelligence* **6**(12). Available at http://www.globalwaterintel.com/archive/6/12/general/bulk-transport-a-solution-to-scarcity.html (accessed 06 May 2026).

[29] European Union (EU), 2012, *REFRESH (Green Technology for Fresh Water Sea-Transportation Based on a Flexible Containers System)*. CORDIS. Available at https://cordis.europa.eu/project/id/262494/reporting (accessed 06 May 2026).

[30] Sasaji, S., 1985, Research on the use of oil tanker's return space for transport of fresh water. *Technical Bulletin of Nippon Kaiji Kyokai* **3**, 71–79. Available at https://dl.ndl.go.jp/pid/10577281 (accessed 06 May 2026).

[31] Sharma, V., & Lande, P. B., 2010, *Use of Oil Tanker Return/Ballast Space for the Transportation of Freshwater*. Master Thesis, Norwegian University of Science and Technology, Trondheim. Available at https://hdl.handle.net/11250/237791 (accessed 06 May 2026).

[32] Syzdlowski, A., & Szydlowski, I., 2011, Method and system for conveying water on oil tanker ships to deliver drinkable water to destinations. Patent WO2013016440A1. Available at https://patents.google.com/patent/WO2013016440A1/en (accessed 06 May 2026).

[33] Maersk, 2024, *Maersk Employees Innovate a System to Deliver Fresh Water from Maersk's Vessels to Ports*. Press release, April 10. Available at https://www.maersk.com/news/articles/2024/04/10/maersk-employees-innovate-a-system-to-deliver-fresh-water-from-maersk-vessels-to-ports (accessed 06 May 2026).

[34] Lazard, O., & Bin, S. A., 2026, Ecological Statecraft in the Midst of War: Water, Regeneration, and the Future of Gulf Security. *Carnegie Endowment for International Peace.*

Available at https://carnegieendowment.org/research/2026/05/ecological-statecraft-in-the-midst-of-war-water-regeneration-and-the-future-of-gulf-security (accessed 06 May 2026).

[35] Hodges, A., Hansen, K., & McLeod, D., 2014, The economics of bulk water transport in Southern California. *Resources* **3**(4), 703–720. https://doi.org/10.3390/resources3040703

[36] Bajaj, A., Singh, S. P., & Nayak, D., 2022, Impact of water markets on equity and efficiency in irrigation water use: A systematic review and meta-analysis. *Agricultural Water Management* **259**, 107182. https://doi.org/10.1016/j.agwat.2021.107182

[37] Santos, E., 2024, Beyond leakage: Non-revenue water loss and economic sustainability. *Urban Science* **8**(4), 194. https://doi.org/10.3390/urbansci8040194

[38] Dore, M. H. I., 2005, Exporting fresh water: Is there an economic rationale? *Water Policy* **7**(3), 313–327. https://doi.org/10.2166/wp.2005.0020

[39] Stojan, S., Dražić, D., Antonic, R., & Kulenovic, Z., 2011, Washing process of cargo tanks on tankers for transportation of crude oil. Available at https://www.geocities.ws/icts_papers/Papers/Stojan,%20Drazic,%20Antonic.pdf (accessed 06 May 2026).

[40] Farooq, S., & Al-Layla, R. I., 1987, Study of water transportation to Saudi Arabia. *Journal of Water Resources Planning and Management* **113**(3), 392–406. https://doi.org/10.1061/(ASCE)0733-9496(1987)113:3(392)

[41] Costello, K. E., Lynch, S. A., McAllen, R., O'Riordan, R. M., & Culloty, S. C., 2022, Assessing the potential for invasive species introductions and secondary spread using vessel movements in maritime ports. *Marine Pollution Bulletin* **177**, 113496. https://doi.org/10.1016/j.marpolbul.2022.113496

[42] Ogunbiyi, O., Al-Rewaily, R., Saththasivam, J., Lawler, J., & Liu, Z., 2023, Oil spill management to prevent desalination plant shutdown from the perspectives of offshore cleanup, seawater intake and onshore pretreatment. *Desalination* **564**, 116780. https://doi.org/10.1016/j.desal.2023.116780

[43] Loshchenkov, V. V., & Knyazhev, V. V., 2021, Sea transport of fresh water. *Journal of Physics: Conference Series* **2096**, 012167. https://doi.org/10.1088/1742-6596/2096/1/012167

[44] Gebrael, K., Mitri, G., & Kalantzi, O.-I., 2024, Overview of nature-based solutions for climate resilience in the MENA region. *Nature-Based Solutions* **6**, 100159. https://doi.org/10.1016/j.nbsj.2024.100159

[45] Reiche, D., 2010, Energy policies of Gulf Cooperation Council (GCC) countries: Possibilities and limitations of ecological modernization in rentier states. *Energy Policy* **38**(5), 2395–2403. https://doi.org/10.1016/j.enpol.2009.12.031

[46] Gruen, G. E., 2007, Turkish water exports: A model for regional cooperation in the development of water resources. In: Shuval, H., & Dweik, H. (Eds.), *Water Resources in the Middle East*, Vol. 2. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-69509-7_15

[47] Glied, V., & Kaciba, P., 2021, Water scarcity and water trade: Turkish attempts to supply a drying region. *Acta Fakulty filozofické Západočeské univerzity v Plzni* **1**, 41–60. Available at http://hdl.handle.net/11025/44831 (accessed 06 May 2026).

[48] Victor, R., Kotter, R., O'Brien, G., Mitropoulos, M., & Panayi, G., 2008, WHO guidelines for the safe use of wastewater, excreta and greywater, Volumes 1–4. *International Journal of Environmental Studies* **65**(1), 157–176. https://doi.org/10.1080/00207230701846598

[49] EMT Erimtan Müşavirlik Taahhüt Ticaret A.Ş., n.d., *Manavgat River Water Supply Project*. Available at http://www.emt-erimtan.com/project-32/manavgat-river-water-supply-project.html (accessed 06 May 2026).

[50] Gürer, Ý., & Ülger, M., 2007, Manavgat River water: A limited alternative water resource for domestic use in the Middle East. In: Shuval, H., & Dweik, H. (Eds.), *Water Resources in the Middle East*, Vol. 2. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-69509-7_17

[51] Bianchi, A., Belmondo, W., Wreyford, J. M., Gerdessen, J. C., Dykstra, J. E., & Rijnaarts, H. H. M., 2021, Treatment vs. transport: A framework for assessing the trade-offs between on-site desalination and off-site water sourcing for an industrial case study. *Journal of Cleaner Production* **285**, 124901. https://doi.org/10.1016/j.jclepro.2020.124901

[52] Usman, M., Sharma, D. D., & Ernst, M., 2025, Seawater and brackish water desalination. In: Bullerdiek, N., Neuling, U., & Kaltschmitt, M. (Eds.), *Powerfuels*. Green Energy and Technology. Springer, Cham. https://doi.org/10.1007/978-3-031-62411-7_8

[53] Terra Daily, 2010, *Turks Cancel Project to Sell Israel Water*. July 17. Available at https://terradaily.com/turks-cancel-project-to-sell-israel-water-999/ (accessed 06 May 2026).

[54] Jiang, W., & Marggraf, R., 2023, Can international freshwater trade contribute to SDG 6? *Water* **15**(21), 3853. https://doi.org/10.3390/w15213853