2021

Winds of Change

Latin America Centre of Asia-Pacific Excellence

University of Otago

THE WATER HUNT!

Desalination Plants for Fresh Water Supply

By Pamela Jordan, Daniel Cárcamo & Nathalie Edwards

What is The Water Hunt?

In the immensity of the blue Pacific Ocean that unites Chile and New Zealand, we see problems and solutions that could be shared together, as key points of a better future for the planet.

For New Zealand, the problem of water scarcity may sound close, but nothing like what Chile has been experienced, to the point of starting to take water from the sea to supply basic human and industrial needs.

The Water Hunt! is the constant search for drinking water at the hands of desalination plants in the midst of a global water crisis.

This investigative analysis by leading professionals, invites you to take a critical and humane look at the implementation and development of desalination plants in Chile and New Zealand. Offering as a potential solution, to work on a unified legislative framework that ensures the safety of the oceans, the life of all living beings, along with the climatic and social impacts.

Only in this way will we understand that the sea, the oceans and all their living beings are an ecosystem that provides resources to the entire planet, and therefore, cannot be seen or treated as prey to be hunted.

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The Water Hunt! is the constant search for drinking water at the hands of desalination plants in the midst of a global water crisis.

Qué es The Water Hunt?

En la inmensidad del azul Océano Pacifico que une Chile y Nueva Zelanda, vemos problemas y soluciones que podrían ser compartidos en conjunto, como puntos claves de un futuro mejor para el planeta.

Para Nueva Zelanda podrá sonar cercano el problema de la escasez hídrica, pero nada como lo que ha vivido Chile, hasta el punto de comenzar a tomar el agua del mar para suplir necesidades humanas básicas e industriales.

The Water Hunt! es la búsqueda constante de agua potable a manos de las plantas desalinizadoras en medio de una crisis hídrica mundial.

Este análisis investigativo, realizado por profesionales destacados, los invita a poner una mirada crítica y humana, sobre la implementación y desarrollo de las plantas desalinizadoras en Chile y Nueva Zelanda. Ofreciendo como potencial solución, trabajar sobre un marco legislativo unificado que procure la seguridad de los océanos, la vida de todos los seres vivos, junto a los impactos climáticos y sociales.

Solo así entenderemos que el mar, los océanos y todos sus seres vivos son un ecosistema que proporciona recursos a todo el planeta, y por eso, no puede ser visto o tratado como una presa a la que se caza.

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Principles of Desalination Plants

Figure 1. Reverse Osmosis diagram.

Source: Yokogawa industries.

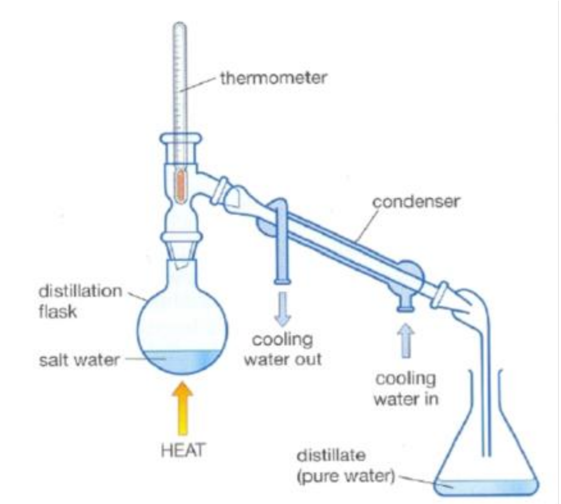
There are currently two main types of desalination plants that operate around the world - membrane (reverse osmosis) and thermal (MED, VC and MSF).

Reverse Osmosis desalination uses osmosis, “when molecules or atoms move from an area of high concentration to an area of low concentration…when a substance crosses a semipermeable membrane in order to balance the concentrations of another substance” .

The Reverse Osmosis desalination technique uses this principle to remove the salt from sea water by moving it through a series of semipermeable membranes to make it drinkable (Figure 1).

On the other hand, thermal desalination uses heat to evaporate and condense water in order to purify it. The heat used by thermal desalination plants is usually waste heat from power plants (Figure 2) . See comparisons between technologies in Figure 3.

Figure 2. Thermal Desalination diagram.



Source: Ctc technologies.

Available Desalination Technologies

Figure 3. Comparative table showing the type of energy, processes and names, behind the two desalination plants methodologies.

Separation mechanism	Energy	Process	Name
Water separation	Thermal + Electrical	Evaporation	Multi Stage Flash (MSF)
			Multi Effect Distillation (MED)
			Thermal Vapor Compression (TVC)
			Solar Desalination (SD)
		Crystallization	Freezing
			Formation of hydrates
		Evaporation and filtration	Membrane Distillation (MD)
	Electrical	Evaporation	Mechanical Vapor Compression (MVC)
		Ionic filtration	Reverse Osmosis (RO)
Salt removal	Electrical	Ionic migration	Electrodialysis (ED)
	Chemical	Others	Ionic Exchange (IX)
			Extraction

Source: CETaqua Water Technology Centre

Source: CETaqua Water Technology Centre

Environmental Impact Assessment for The Implementation of Desalination Plants.

The emissions produced by desalination plants (i.e. metals, antiscaling additives, halogenated compounds, etc.) fit the assessment criteria of Environmental Effects in the hydrology and water quality in relation with the "polluter source". Which is a crucial aspect of the current regulation, but this left behind important items such as the aspects in relation with oceanography, topography, plant structure, among others (within the environmental aspect). Moreover, even not mention the economic and social edges of the assessment.

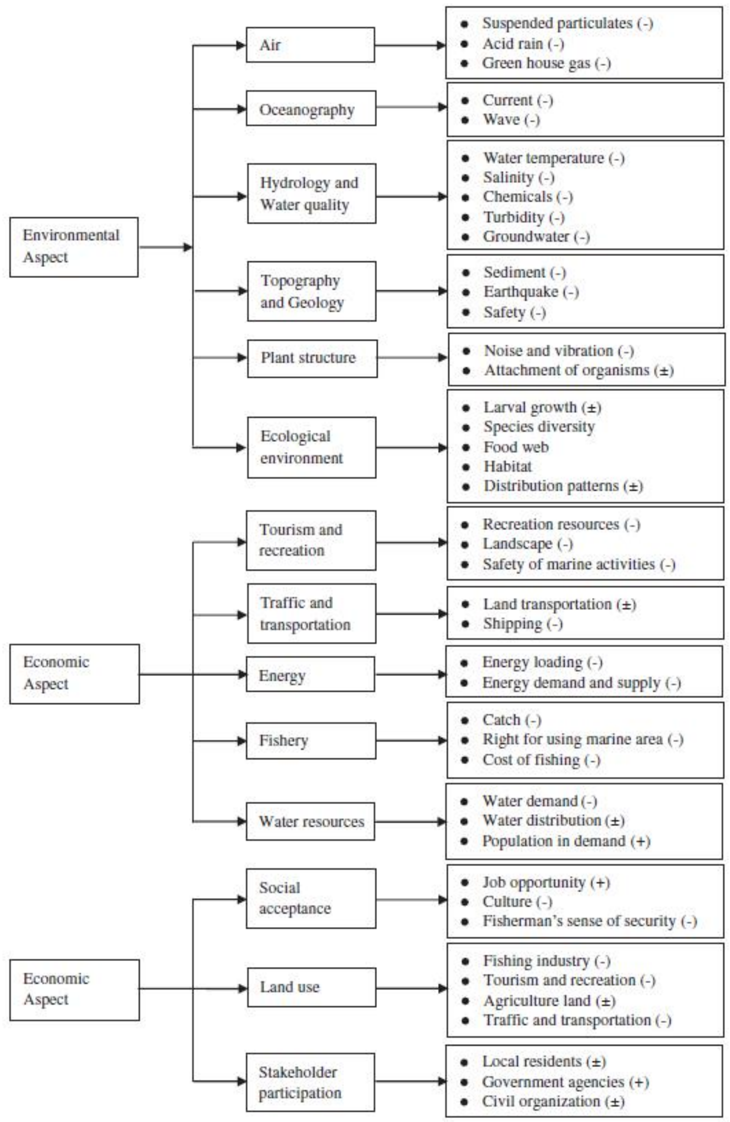
Since the beginning of the implementation of desalination plants and despite the country and its regulation, it has been some important and obligatory steps on which in general regulation entities/processes had been focused on , such as:

From the analysis of current EIA of seawater desalination plants/projects, researchers found across projects conducted in different countries that dust and air pollutants emitted from construction (physical and chemical environment) are the main contributors to air pollution.

Interestingly, across these international experiences, ecological assessment (in general) is done for both terrestrial and marine environments. Involving in the first case the information-collecting of birds, butterflies, reptiles, amphibians and mammals. For the second: zooplankton, phytoplankton, benthos, large invertebrates, fish and marine mammals. To fulfil these purposes the information is obtained from surveys (i.e. species, abundance, distribution, dominant species and habitats) .

Within the esthetics and recreation item, all the countries involved in the research evaluate the impact to landscapes and showed negative impact. Moreover, in relation with social economic impact and culture, each country has its own set of social economic assessment indicators and they differ greatly. Finally, all countries assess the impact on transportation. It is worth mentioning that this analysis was carried out in 5 countries with highly developed economies. The outcomes of the research and further information can be reach in the following link (https://www.sciencedirect.com/science/article/pii/S0011916413003251).

Figure 4. The criteria and indicator system for the integrated impact assessment of seawater desalination plant development



Remark: (-) negative impact; (+) positive impact; (±) positive and negative impacts

Source: Liu et al. 2013

Besides, the concept of Integrated Coastal Management (ICM) includes direct and indirect impacts from three aspects: environment, economics and social (principles), covering 14 criteria and 43 indicators . As seen in Figure 4.

The current EIA in Taiwan includes the environmental, economic and social aspects. This case represents a very good approach to what was previously defined as ICM.

Standing out for an extensive regulation which involves both direct and indirect aspects, representative of the best current model to contribute to solve the shortage of water by installing desalination plants. Figure 5 explains in detail the indicators and considerations in the integrated environmental assessment under ICM .

Figure 5. Comparison of current EIA indicators in Taiwan and the additional considerations in the integrated environmental assessment under ICM.

Category		The assessment indicators in the current EIA	Other considerations under ICM
Physical and chemical	Climate	1. Regional climate 2. Surface climate: Precipitation, days of precipitation, temperature, relative humidity, wind direction, wind speed, typhoon.	Based on the characteristics of regional climates and water resources development to evaluate the targeted water production and the necessity of installing the seawater desalination plant.
	Air	1. Air quality: Particulate pollutants (PM_{10} and TSP), SO_2, NO_x (NO and NO_2), CO, O_3, Pb, fallout, and hydrocarbons. 2. The existing pollution sources	In addition to current EIA indicators, cumulative air pollutants from the region are assessed for the allowable total maximum load; the indirect emissions are assessed.
	Noise and vibration	1. Categories of noise control areas 2. Source of noise and vibration 3. Sensitive recipients 4. Background noise and vibration level	In addition to current EIA indicators on residents, effects on other living organisms also assessed under ecosystem based management framework.
	Hydrology and water quality	1. Coastal waters: water quality, oceanography, hydrology, and sediment. 2. Groundwater: water quality, hydrology, pH, BOD, sulphate, nitrate, ammonia nitrogen, conductivity, iron, manganese, suspended solids, chloride, total coliform, total bacteria count, hydrology (water level, flow direction, and thickness and depth of the aquifer)	In addition to current EIA indicators, water quality parameters from the region are assessed for the allowable total maximum load to determine cumulative impact; the impact on groundwater contamination is also assessed.
	Topography and geology	Topographic classification, special topography, surface geology and soil distribution, special geology, earthquake and faults, geological disasters, subsidence in catchment, and land use	From the standpoint of the integrated land use in the region to assess the effects of geologic and topographic interactions and assess the impact on seabed.
	Soil	Topsoil and soil: copper, mercury, lead, zinc, arsenic, chromium, nickel, and cadmium content, pH	The same as the current assessment scheme.
	Wastes	1. Waste survey: types, nature, source, physical form, quantity, storage, removal, and disposal 2. Existing dumping sites, waste disposal and facilities survey	The same as the current assessment scheme.
Ecology		1. Terrestrial ecosystem: animals and plants. 2. Aquatic ecosystems: species, quantity, diversity, distribution, dominant species, indicator organisms, and special ecosystems.	In addition to current EIA indicators, principle of ecosystem based management is applied to emphasize the dynamic and inter-relationships in the ecosystem.
Landscape and recreation		Analysis of current tourism and recreational activities, scenic sites, landscape topography, geography, natural phenomena, ecological landscape, cultural landscape and visual landscape.	Evaluate the interaction of a seawater desalination plant and tourism and recreation, the impact on safety of marine activities, and their cumulative effects to conduct an integrated assessment of land use
Social economics		1. Current population, age distribution and migration status 2. Birth rate, death rate, and the annual increase rate near the site 3. Current structure of industries and population, status of the agriculture and fisheries 4. Status of land use in the site 5. Population affected by compulsive purchase of land and buildings 6. Current and proposed urban planning 7. Public facilities 8. Land ownership, price, and fluctuations 9. Community and living environment 10. Living standard	Additional criteria for both social and economic aspects are assessed. In the economic aspect, the criteria include: local tourism and recreation, traffic and transportation, energy demand, fishery economy, and water resource developments. The social criteria include: social acceptance, land use and stakeholder participations, which typically do not have direct relationships to conventional EIA.
Traffic and transportation		1. Current terrestrial transportation system in the neighboring area 2. Capacity and service level of each terrestrial transportation system 3. Type and number of vehicles 4. Parking facilities 5. Current road conditions	In addition to current EIA indicators that mostly focus on land indicators, the impact of coastal structure and undersea pipings on marine transportation systems are assessed under ICM.
Cultural environment		Monuments, historic sites, antiquities, folklore artifacts, special architecture, monuments and buildings worth preserving and the surrounding area	The cultural resources include: local culturally or educationally meaningful aspects such as local archeology, history, folk culture, architecture, and paleontology sites. Social acceptance towards the impact on cultural resources is further assessed under ICM.

Source: Liu et al. 2013

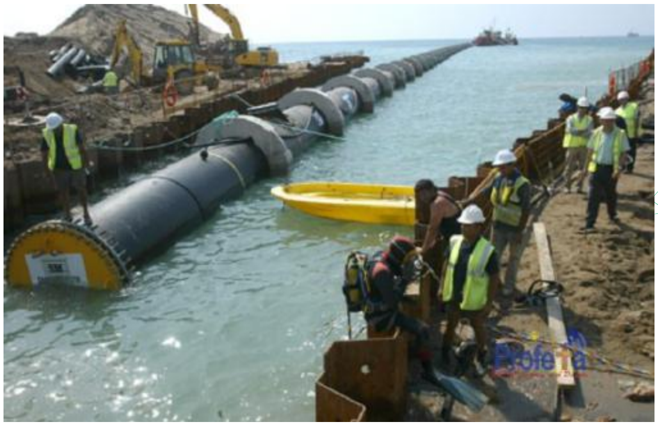
Although the installation of seawater desalination plants benefits the economics, the integrity of the coast cannot be conceded and the environmental impact must be assessed comprehensively. By applying the impact assessment tools, the indicator system can be used to identify and diagnose the status and possible impacts of a seawater desalination plant in order to guide the decision making in a precautionary manner.

Based on the framework of ICM, a more suitable model can be followed fulfilling with 14 criteria grouped in three aspects (44 assessment indicators were established under these criteria to assess the impact of development plans on coastal areas). The study in which this review was based showed that there is room for improvement of the existing EIA of seawater desalination plants.

POLLUTANTS PRODUCED BY DESALINATION PLANTS

The term pollution, commonly used in colloquial language, refers to the addition of any substance (solid, liquid or gas) or any form of energy (such as heat, sound, or radioactivity) to the environment at a rate faster than it can be dispersed, diluted, decomposed, recycled, or stored in some harmless form. Desalination plants (including those with thermal or membrane processes) can have negative effects on the environment and wildlife and often impacts human health and well-being.

In desalination plants, these types of pollution occur according to the desalination process used and the location of the plant. In plants located on the coast, water pollution is the main problem. In inland plants, the disposal of the rejected concentrated brine is the main factor of concern. If the desalination plants are of the Multistage Flash system (thermal type), air pollution problems arise. In this last type, large amounts of fuel are burned to generate the necessary energy for desalting.



Air pollutants are of the fuel combustion such as carbon monoxide, nitrogen oxides, unburned hydrocarbons and sulphur oxides. Desalination burners and power stations are the main source of sulphur oxides as high sulphur content fuels are usually used in the industrial processes. Gaseous pollutants from desalination stacks have serious effects on human health. For example, carbon monoxide (CO), is a poisonous gas which deprives the body tissues of essential oxygen. It combines with haemoglobin and forms carboxy haemoglobin (COHb). This reduces the oxygen carrying capacity of the blood significantly since haemoglobin has an affinity for CO of 210 times its affinity for oxygen. Causing headache, dizziness, vomiting, and nausea. If CO levels are high enough, it is possible to become unconscious or even die. Exposure to moderate and high levels of CO over long periods of time has also been linked with increased risk of heart disease. This is a direct harmful effect on communities in whose territory are housing desalination plants of the thermal type.

Water pollution of desalination plants is caused by the disposal of the hot brine. The world's oceans receive 3.86x10(^7) kcal (1.53x10^8 Btu) and 4.5x10(^16) tons of minerals from desalination plants daily. The rejected brine affects the sea's salinity and turbidity, it increases its temperature and causes water currents. Besides this thermal and saline pollution of the rejected brine, toxic effects are also caused by the use of different chemicals in the desalination pre and post treatment processes .

Disposal of desalination effluents are a problem for inland plants too. Some associated effects are, water stress, what can be observed in vegetation (plants), which therefore cannot extract water from the soil as the dissolution of the soil has a high concentration of salts. The second one, nutrition effects, since a series of important modifications take place, due, first, to the variations in pH that affect the availability of nutrients, and on the other hand, to the interactions caused by the presence in excess of certain elements. Finally, energetic balance, which proposes that plants, by increasing the osmotic pressure of the soil solution, are forced to an osmotic adaptation of their cells in order to continue absorbing water; adaptation that requires energy consumption that comes at the cost of lower growth.

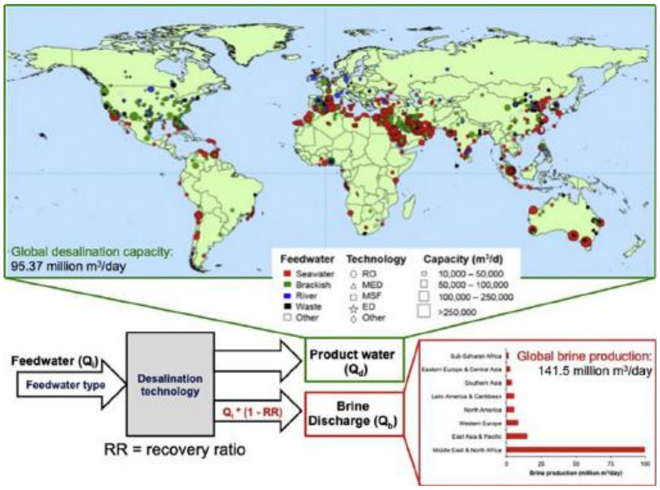
Interestingly, in relation to the marine biodiversity, account must be taken on the effects associated in different species (of different biological phyla). Consequences can arise at different levels of the marine trophic levels. For example, depleting the abundance of vertebrates in the area causing fish to migrate while enhancing the presence of algae, nematodes and tiny molluscs. A review of published data on Northeast Atlantic fish species representing different biogeographic affinities, habitats, and body size lends support to the hypothesis that global warming results in a shift in abundance and distribution (in patterns of occurrence with latitude and depth) of fish species . Which by the way can be associated with the effects of desalination plants, since they discharge brine at high temperature, a situation analogous to what climate change generates on a macro scale in relation with ocean

INTERNATIONAL LEGISLATION FOR DESALINATION PLANTS

Other expriences across the globe

The Spanish case involves a system of direct administration of desalination plants declared to be of general interest by the State. This allows them to be handed over to the communities or boards of users, after the execution of an agreement, so that they can benefit from the desalination plants.

Mexico, for its part, contemplates in its legislation a rule, without exception, by virtue of which all desalination plants, regardless of their purpose and flow of desalinated water, must enter the SEIA (Environmental Impact Assessment System).



Add short body of textGlobal distribution of desalination facilities and their capacities. (more than 1,000 cubic meters of water per day) by user sector of the water produced. Source: https://doi.org/10.1016/j.scitotenv.2018.12.076

There are desalination plants in more than 100 countries world wide!!!

Australia, currently has over 30 active desalination plants across the country . These plants desalinate water for many different purposes such as: agriculture, industry and human consumption.

State government policy determines the specific contractual arrangements regarding the ownership and operation of desalination plants within Australia.

The National Water Initiative (2004) is viewed as Australia's blueprint for water reform, it is through this National Water Initiative that state governments across Australia have agreed on actions to achieve a national approach to how water is managed within Australia . All water that comes from desalination plants in Australia must meet the Australian Drinking Water Guidelines (ADWG).

CHILE

As already outlined, despite the growing installation of seawater desalination plants in Chile, there is no specific regulation applicable to this activity, an issue that has been raised as a problem on more than one occasion to the government. However, in Chile the environmental impact assessment is regulated by Law 19,300. The detail of the current projects that have been submitted to the SEIA system in Chile is shown. Of the 24 projects considered in the review (between 1999 - 2015), 16 have been approved, equivalent to 66.6%.

Currently, there are about 44 seawater desalination plants in different stages of implementation in Chile, of which 24 operate mainly in the north and center of the country. They produce 5,570 liters of water per second and are expected to reach a volume of 14,468 liters per second in the next 5 years. These waters supply various purposes, such as: human consumption and sanitation; industrial processes; mining and agriculture.

In Chile, the special permit that regulates the use of an important part of seawater for desalination is a maritime concession. This grants the private use of portions of water inside and outside bays, rocks and seabeds, beaches and fiscal beach lands as necessary (within an eighty meter wide strip measured from the high tide line of the coast). The competent authority to grant a maritime concession is exclusively the Ministry of Defense through the Undersecretariat of the Navy. The way to do so is by means of a supreme decree that must be reduced to public deed. Precisely because the sea is not the domain of the State (only the "control, inspection and surveillance -of the use- of the entire coastline and territorial sea of the Republic" corresponds to the State), it is given to the Undersecretariat of the Navy under the Ministry of Defense.

It is important to note that the laws that will govern the desalination plants are just being discussed in the Senate. Depending on the ruling, this could affect all the desalination plants in the country, considering that they are almost 100% privately owned, mainly belonging to mining companies that obtain seawater to supply the mining processes, with high costs that only this industry can afford.

New Zealand's Future Options

At present, New Zealand does not have any regulations relating to seawater desalination per se, nor does it have desalination plants on its coasts. However, there is one main law that regulates water use: the Resource Management Act 1991 (RMA). This Act sets out exactly what can be done with water in New Zealand, whether it is impounding, diverting or taking, as well as water discharges (pollutants).

The RMA sets out the processes that councils must follow, the requirements they must meet and the things that must always be considered before any water-related action is taken. In addition, to the RMA the New Zealand government sets "national direction" in relation to water through national environmental standards, national policy statements and other such regulations.

The closest encounter New Zealand has had with desalination of its water was When WaterCare NZ studied the use of desalination during the 2019 drought in Auckland, it found that it would need about 50,000 liters of fuel per day to run the floating plant it had proposed.

Investing in safe sources of water, such as seawater desalination and water recycling, can enable quick and affordable solutions, but with an adverse environmental impact.

COLLABORATING ENTITIES

Regarding entities collaborating in the field of desalination plants, there are several public service companies more than private ones, which are willing to collaborate across borders. This is the case of some the following current entities that promote special and environmentally and socially conscious legislation.

Water Services Association of Australia

Water Services Association of Australia helps to influence national and state policies on the provision of urban water services and sustainable water resource management. They promote debate surrounding environmentally sustainable development and management of water resources, as well as the community health requirements of public water supplies.
Furthermore, establishes benchmarks and practices for safe sustainable water processes and fosters education, research, training and the exchange of information on water treatment and management.

EURECAT

Eurecat is a Spanish technology centre that provides technology and expertise to the industrial and business sectors, helping to boost their profiles in a fast paced world. Eurecat's SEA4VALUE project has the objective to "develop a Multi-mineral Modular Brine Mining Process (MMBMP) for the recovery of valuable metals and minerals from brines produced in sea-water desalination plants" . EURECAT currently has 15 European nations party to this initiative.

Veolia

Veolia is one of the world's leaders in desalination, producing around 15% of the worlds desalinated water. Their total treatment capacity is around 13 million m3 of water per day at over 2,300 sites in more than 108 countries. They have plants in Queensland and Sydney, that both use reverse osmosis technology. Veolia is committed to helping nations find the best water solutions for them with their ever evolving technology and expertise.

IDA

The International Desalination Association (IDA) is a non-profit association, IDA is associated with the United Nations as part of a growing international network of non-governmental organizations (NGOs).
IDA is the world's leading resource for information and professional development for the global desalination industry – and the only global association focused exclusively on desalination and water reuse technologies.

SUSTAINABILITY OF DESALINATION

From a sustainability perspective, a technological advance has been observed in desalination plants and the resources they use, such as renewable energies, new components to desalinate water and recovery of pollutants for the implementation of new projects that will continue to supply millions of people with drinking water.

While desalination plants are intended to purify water for human consumption, most of them have also been installed on the coasts to supply mainly industrial processes of mining and agriculture, collaborating to society from the economic reactivation.

However, even though there are so many desalination plants with considerable improvements to mitigate brine pollution and also pollutants from high energy consumption. The pollution and the complexity of its waste treatment is still the Achilles heel of this innovative technology, generating damage to the marine and terrestrial ecosystem and being highly detrimental to the flora and fauna of the 5 continents.

The truth is that the implementation of these projects has been increasing rapidly worldwide, with more than 16,000 desalination plants, which produce 95 million cubic meters of drinking water per day, as highlighted by the UN University in the study "The State of Desalination and Brine Production: A Global Perspective". It also notes its concern about the large quantities of brine returned to the sea (142 million cubic meters of hypersaline brine every day).

Although one of the main goals of the UN SDGs and for most countries in the world by 2030 is to combat water scarcity, desalination plants could become sustainable if the technology focused on mitigating damage to the ecosystem, as there are other methods related to the reuse of graywater, which are undoubtedly part of a regenerative process for both the environment and society.

In order to comply with the parameters promoted by the UN, such as maintaining special focus on oceans issues. New Zealand and Chile could work together as partner countries to support the priority goals in this area in order to obtain more effective results on the pollution of the Pacific Ocean that both share.

Future Solutions

Nowadays, water scarcity has become a serious problem, and the means of obtaining drinking water is the new investment that many countries are betting on. With different technologies, seawater desalination plants undoubtedly have an environmental impact that is still unknown in its depth, almost all countries in the world are using seawater to supply basic and industrial needs, but no one really knows how long this resource will be the one that quenches the thirst of the planet.

It is essential to raise a new mentality about the excessive consumption of water resources, whether for basic or industrial consumption, it is necessary to re-educate the global society to generate a commitment to the environment and a regenerative vision as a community that allows us to take care of all natural resources in a conscious way.

Considering that Chile and New Zealand share the Pacific Ocean and after the differences and problems that afflict each country and according to their own regulations, it would be necessary to make international treaties that regulate and unify the legislative criteria to strictly control the number of desalination plants per country, their location, their technologies and operations, as well as waste management and environmental studies.

IIn addition, it is important to regulate the purpose for which seawater is obtained, since industries and companies have the economic advantages of implementing desalination projects, due to their high costs, over governmental economic resources. Taking advantage of the use of water which many times is not to supply a basic need.

To Chile a modification to Article N°10 of Law 19,300 is necessary, expressly including desalination plants, but it is also recommended to study the establishment of a criterion of magnitude related to the amount of water extracted or rejected to the sea.

For this reason it is necessary to highlight the personal, private and NGO entities that carry out mitigation measures, such as technological and scientific advances (nanotechnologies) focused on improving desalination processes with low energy consumption and lower socio-environmental impact.

We need to understand that the sea, the oceans and all their living beings are an ecosystem that provides resources to an entire planet, so it cannot be seen or treated as a hunting prey.

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Thank you for reading us!!!