AquaChar Latin America S.A.

Guatemala Desalination Plant Proposal

AquaChar Latin America S.A. is seeking to collaborate with the Government of Guatemala to co-develop a strategy to progress plans for supplementing the groundwater supply with seawater desalination to ensure water security for the region into the future without destroying the ecosystems that will be directly affected by the construction and operation of a desalination plant for decades to come.

This following paper presents an overview of the cost of desalination and the main components of associated capital cost (**CAPEX**) and operation and maintenance cost (**OPEX**). Examples of desalination facility costs have been presented to illustrate the range of costs that can be expected and to aid in conceptual planning and

development of desalination projects.

The most prevalent forms of desalination can be divided into two technology types:

1. **Thermal desalination** (using heat energy to separate distillate from high salinity water), represented primarily by Multiple Effect Distillation (MED) and Multi-Stage Flash distillation (MSF). Mechanical Vapor Compression (MVC) is primarily used to desalinate high TDS (> 45,000 mg/l) and/or industrial wastewater for the purpose of reuse and not necessarily potable uses.
2. **Reverse Osmosis (RO)** membrane separation, which uses a membrane barrier and pumping energy to separate salts from high salinity water (typically < 45,000 mg/l).

The cost for Multi-Stage Flash Distillation (MSF) to desalinate water has approximate unit costs of ranged from $0.29 to $0.66 per m3 of capacity ($1.09 to $2.49 per thousand gallons) for a medium size **10 MGD MSF** plant.

Whereas, the cost for Saltwater Reverse Osmosis to desalinate water has varied widely in the range of $0.79 to $2.38 per m3 ($3.00 to $9.00 per thousand gallons) of capacity for a larger **35 MGD SWRO** plant.

The predominant type of desalination technology used today is **Reverse Osmosis (RO).** The use of RO has been a tradeoff between low OPEX (using electromechanical energy vs. typically more expensive thermal energy) vs. high CAPEX (due to the cost and relatively short life of membranes, so high replacement cost).

Factors that have a direct and major impact on desalination cost include, but are not limited to, desalination technology, raw and product water quality, type of intake and outfall, the location of the plant or project, the type of energy recovery used, the price of electricity, post-treatment needs, storage, distribution, local infrastructure costs, and environmental regulations.

The technology selected will also determine the type of chemicals that will be used for pretreatment and post-treatment which impact operational costs.

The site where a desalination facility is constructed can have a major impact on the overall costs of the project. For example, for an **SWRO (Sea Water Reverse Osmosis)** desalination plant, the plant should be located as close as possible to the seawater intake source to avoid higher costs for intake pipelines and complex intake structures. Optimal project siting will also reduce the concentrated brine discharge line back to the sea.

From a construction point of view, careful considerations are recommended for items such as local soil conditions (may require new soil fill or structural concrete piles) and close proximity to a reliable power source to reduce the power transmission costs.

The site-specific raw water quality can have a major impact on the number and type of pretreatment steps required ahead of the desalination step itself, and the overall sizing of the desalination plant. The total dissolved solids (TDS) level of the source water directly impacts the operational costs, as higher operating pressures (RO) and temperatures (thermal) must typically increase as raw water salinity increases. Higher raw water salinity may also reduce the feasible product water recovery per gallon of raw water for both RO and thermal systems. In the case of SWRO, in areas such as small bays, gulfs or channels, seawater currents, and the resultant natural mixing from the larger body of seawater (i.e., the ocean) may be minimal. These areas can have higher local salinity levels, higher total suspended solids, higher temperature variations, and higher organic loadings and biological activity compared to water in the open ocean. All of these factors add design and construction complexity and, therefore, can significantly increase both CAPEX and OPEX costs.

The type of intake and outfall selected for a desalination plant is one of the most important technical considerations for a plant's cost-efficient design and optimum operation. Important factors need to be evaluated such as the most suitable intake type (submerged vs. open intake), the distance of the intake relative to the plant, the type of intake screens, the type of intake structure, the type of intake pipeline (buried vs. above ground), and environmental considerations with regards to impingement and entrainment of marine life. Each of these items has a significant cost impact. The cost of the intake system can vary from a low of $0.13MM per thousand m3/day ($0.5MM per MGD) of capacity for an open intake to $0.79MM per thousand m3/day ($3.00MM per MGD) for complex tunnel and offshore intakes.

To illustrate the potential significance of intake and discharge structure costs, SWRO plant discharges located close to marine habitats that are highly sensitive to elevated salinity require elaborate concentrate discharge diffuser systems, with costs that can exceed 30 percent of the total desalination project expenditures. In contrast, the desalination plants with the lowest water production costs have concentrate discharges either located in coastal areas with very high natural mixing or are combined with power plant outfall structures, allowing good initial mixing and better discharge plume dissipation. The intake and discharge facility costs for these plants are usually less than 10 percent of the total desalination plant costs.

Pretreatment costs are impacted by the type and complexity of the pretreatment system. The type of pretreatment required depends on the raw water quality at the project site. Some raw seawater or brackish surface water sources have a high level of organics and biological activity and require more robust pretreatment technologies, such as DAF (Dissolved Air Flotation) and UF (Ultrafiltration). Other raw water sources that use submerged intakes or well-based intakes may require less pretreatment, such as a single-step media filtration or MF (Microfiltration).

Pretreatment costs will typically range from $0.13MM to $0.40MM per thousand m3/day ($0.5MM to $1.5MM per MGD). At the lower end of this range, conventional single-stage media filtration systems are adequate. Pretreatment costs increase as additional pretreatment steps are added, such as two-stages of media filters or media filtration followed by MF or UF systems.

Local energy prices, transmission distance, connection fees, and possibly tariffs at the proposed location of the desalination facility play an important role in determining the supply price for connected power. For very large thermal desalination plants, consideration of co-locating the facility with a power plant may be promising due to the inherent advantages of such a combination.

Post-treatment steps add additional costs. The need for a second RO pass to achieve very low TDS levels or reduce the concentrations of specific ions, such as boron or chloride, to acceptable levels can be an expensive option. A two-pass RO system will typically be 15 percent to 30 percent more costly than a single pass RO system.

Also, **stabilization of the product water** typically requires a pH adjustment and the addition of bicarbonate alkalinity, which can be done using a combination of carbon dioxide, lime and/or sodium hydroxide and, again, this adds additional cost.

COST COMPONENTS – CAPEX is subdivided into the two major categories of direct and indirect costs. Direct costs include equipment, buildings and other structures, pipelines, and site development, and are typically in the range of 50 percent to 85 percent of the total CAPEX. The remaining indirect costs include financing interest and fees, engineering, legal and administrative costs, and contingencies. The typical CAPEX cost and components for most desalination plants can be further divided into nine parts, as follows: intake and raw water conveyance; pretreatment; desal treatment; post-treatment; product water pumping and storage; electrical and instrumentation system; plant buildings, site and civil works and balance of plant; brine discharge and solids handling; and miscellaneous engineering and development costs. Other costs, such as financing fees and other commercial related fees, also have to be considered. Figure below shows one example of a CAPEX cost breakdown for an SWRO plant.

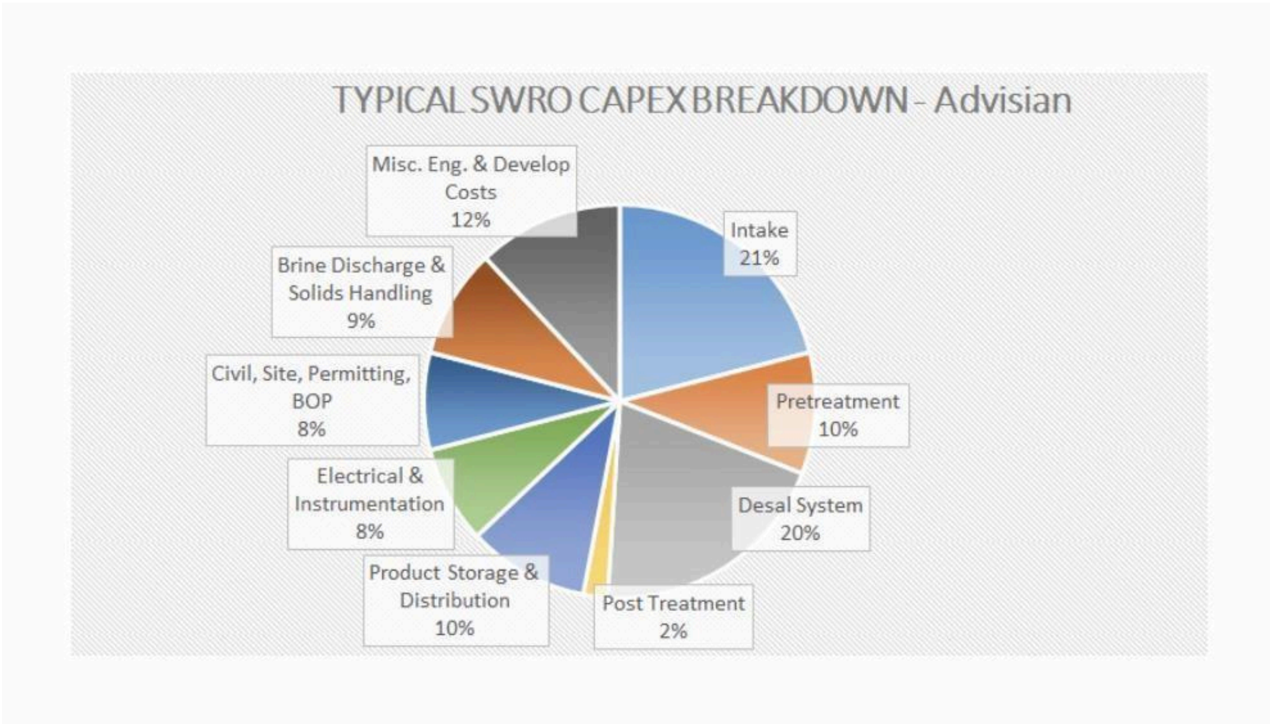


Figure above shows a **Typical SWRO desalination plant CAPEX breakdown**

CAPEX, to a significant extent, depends on scale with larger desalination plants costing less per million gallons of installed capacity.

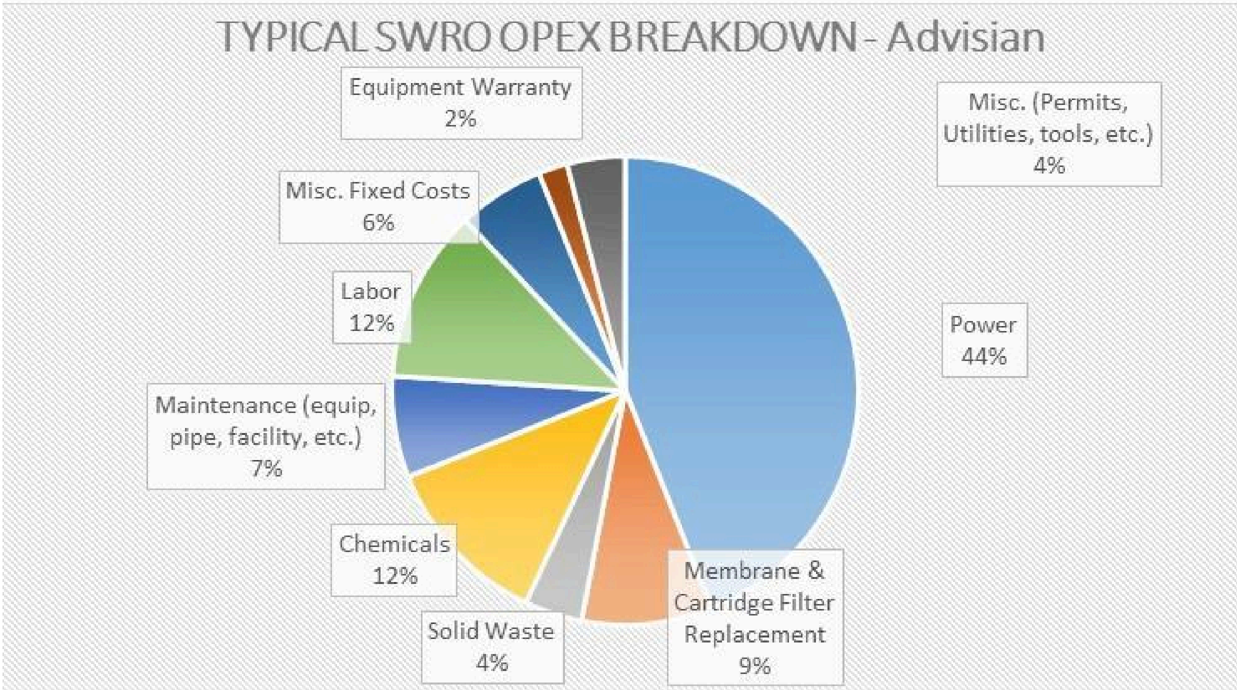
Based on Figure below, **a medium size 10 MGD SWRO plant would cost about $80 million to build and a larger plant capable of producing 35 MGD SWRO would cost $250 million**.

Figure below - Unit construction cost vs. capacity for SWRO plants [Source: Ref. 3]

Cost Components – OPEX

Operating costs (OPEX) generally fall into two broad categories: fixed costs (such as labor, administrative, equipment and membrane replacement costs, and property fees/taxes [as applicable to the locality], etc.) and variable costs (such as power, chemicals, and other consumables. (Arroyo, et al., 2012). The typical OPEX cost and components for most desalination plants can be further subdivided into nine parts comprising the following: power consumption, consumables, solid waste, chemicals, labor, maintenance, equipment warranty, balance of plant & utilities, and other fixed costs (administration, spares, contingency, etc.), as shown in the Figure below:

Figure - **Typical SWRO desalination plant OPEX breakdown**



Total cost to desalinate water

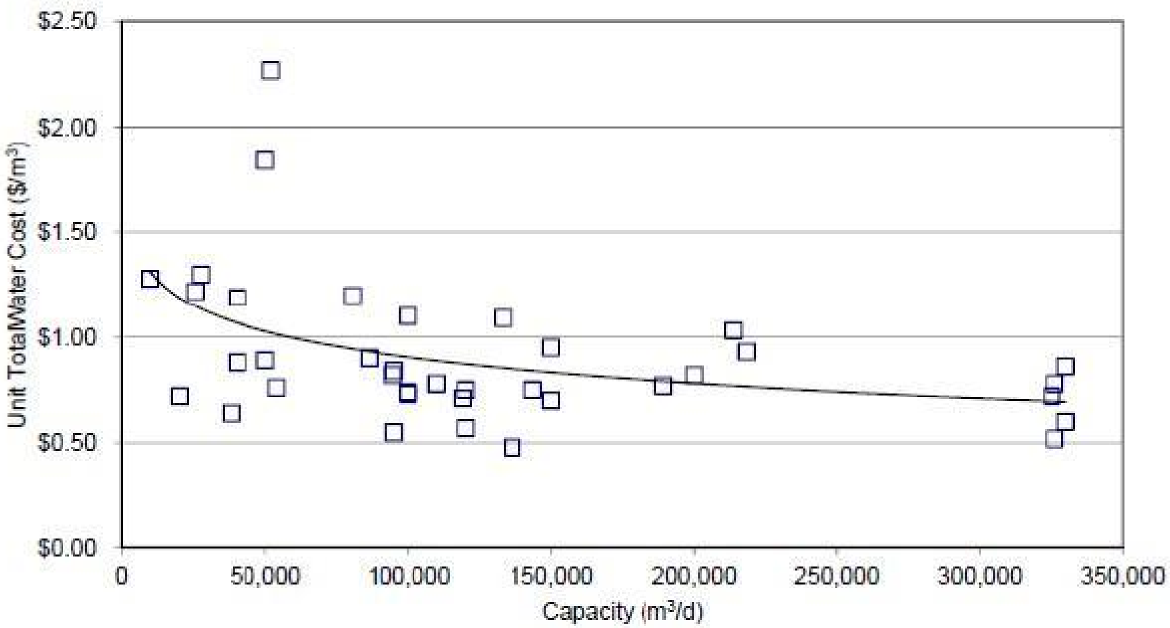
Life cycle cost, also called unit production cost or annualized cost, is the cost of producing a thousand gallons or cubic meter of water by desalination and considers all CAPEX (including debt servicing) and OPEX, and may be adjusted by a predicted or actual plant operating factor. Because of all the variables involved, these annualized costs can be very complex, and unit production cost differences among projects may not be directly comparable. At best, predicting future costs using past plant cost information will typically only result in ballpark estimates.

Figure 9 shows that annualized costs for various types of completed RO projects have varied widely. The average costs, represented by the best fit line in the data shown, are about $0.70/m3 ($2.65 per thousand gallons) for very large plants (325,000 m3/day) and rise to $1.25/m3 ($4.75 per thousand gallons) for small plants (10,000 m3/day).

However, costs can range as high as $3.20/m3 for very small capacity plants (less than 4,000 m3/day or 1 MGD) that have costly site-specific intake, discharge, and conveyance peculiarities. Removing the effects of intake, discharge, and conveyance reduces and narrows the annualized cost range to $0.53/m3 to $1.58/m3 ($2.00 o $6.00

per thousand gallons) for SWRO plants and $0.11 to $1.10/m3 ($0.40 to $4.00 per thousand gallons) for brackish water RO plants (WRA, 2012).

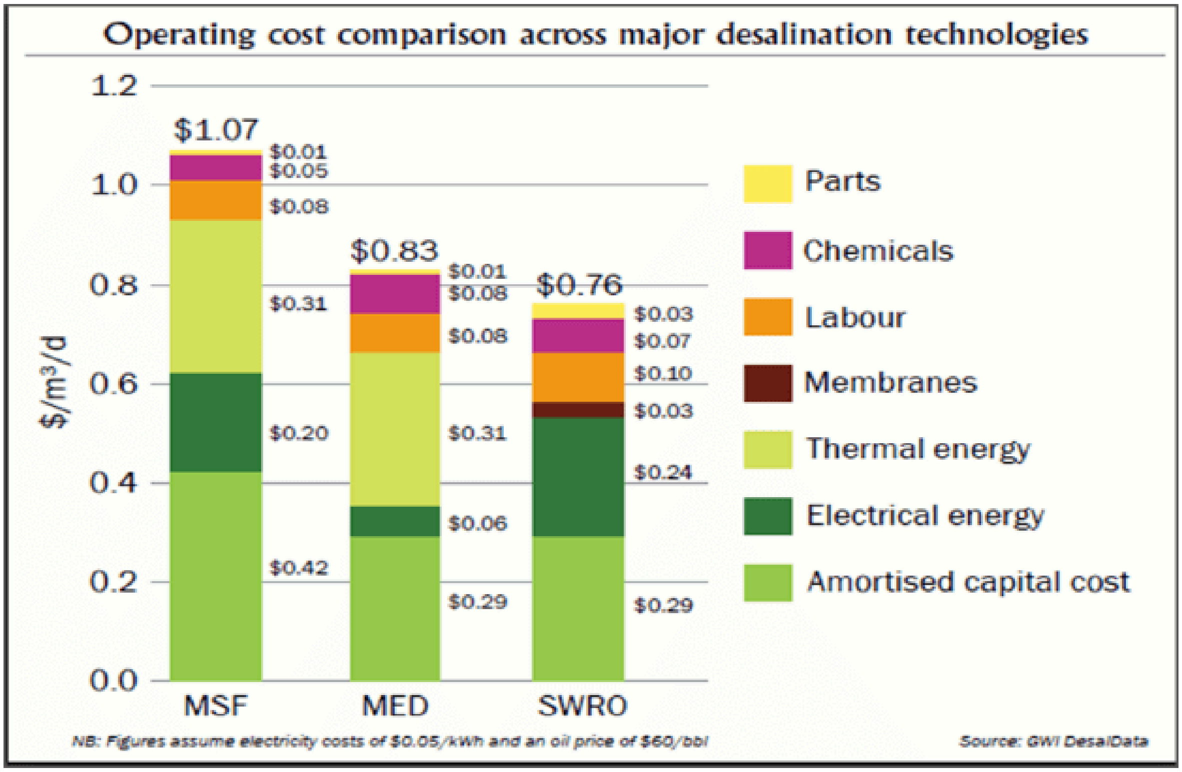
Figure – RO plant unit production cost vs. project capacity [Source: Ref. 9]



The cost to desalinate industrial wastewater for reuse can be much greater than this. For example, WorleyParsons conducted a study to develop the CAPEX and OPEX for a 35,000 m3/day desalination plant located in the Arabian Gulf region and being fed with oil field produced water and producing boiler feed water. Based on budgetary CAPEX and OPEX costs generated in that study, the unit production cost was roughly four times higher than would be predicted using Figure 9.

Figure below shows a typical life cycle cost comparison of MSF, MED, and SWRO to produce one cubic meter (264 gallons) of water per day. As shown, MSF and MED, which are thermal desalination technologies, require steam (thermal energy) in addition to electrical energy, which is the main reason why they have higher total water life cycle costs compared to SWRO.

Figure – Unit production cost of water for desalination technologies [Ref. 7]



As noted in this paper, the cost of developing, constructing, and operating a desalination facility depends on the location of the plant, the raw water type and quality, type of intake and outfall, the desalination technology and energy recovery systems used, the cost of electrical power, any required post-treatment and storage, distribution costs, and environmental regulations. These differences can make a large plant built in one region of the world more expensive than a smaller plant built in another region of the world and result in significant differences in OPEX.

Conclusion

Desalination is <u>not</u> the only Solution to water scarcity. It's one of the options that can narrow the gap between water supply and demand. To date, there are approximately 16,000 desalination plants located across 177 countries. Yet the design and cost of each plant is different because there are different conditions in countries with different oceans. And the results are not always as planned - The Desalination Plant in San Diego, CA at a cost of $1 billion provides water to only 1/10th of the population of asan Diego County that's 300,000 people or 112,000 homes. The plant burns 840 MEGAWATTS a day (enough to power 30,000 homes) with a price tag of 1 billion dollars **- Actual Construction Cost** ended up being 4 times the Original estimate of $250,000,000.

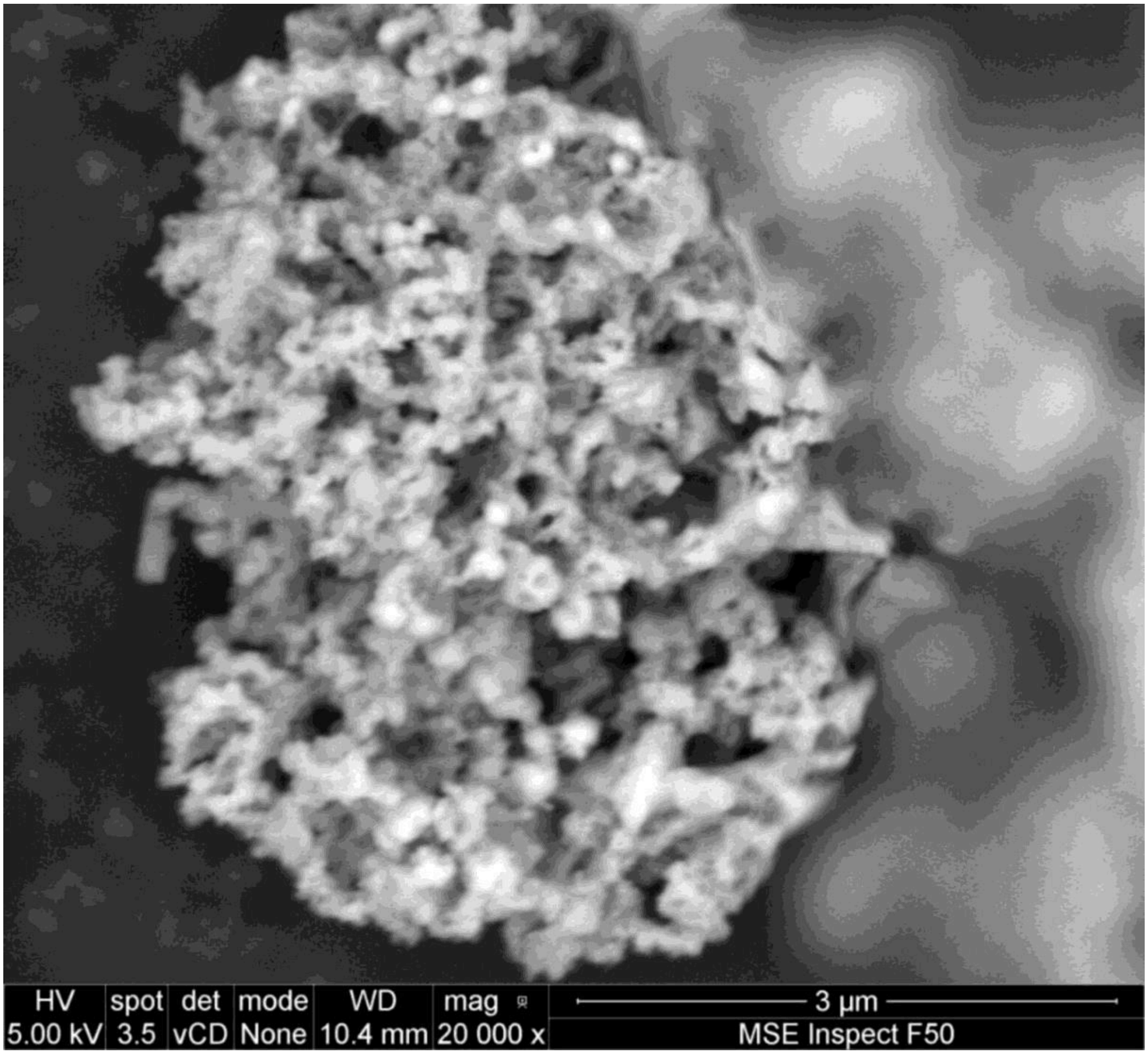
Environmental impact of Desalination Plants

1.5 liters of brine is produced for every liter of desalinated water being produced on a daily basis. Dumping that amount of brine into the ocean reduces oxygen levels overnight suffocating fish and corals.

The Solution Is A Diversified Nationwide Water Strategy That Includes Desalination As Well As Decontamination Of Rivers.

And when it comes to decontaminating wells, rivers and waterways, AquaChar has proven itself to be on the cutting-edge of Science by developing “Graphene

Composites" capable of decontaminating any source of water - Fresh or Saltwater. That is because AquaChar's Graphene Composites are among the most porous materials in existence today and can be made in Guatemala from Agricultural Waste.



Sub-micron, 3-D porosity at 20,000x SEM demonstrates the preserved surface area used to breakdown waste & contaminates leaving only un polluted river water.

Recommendations

We are recommending that careful consideration be taken into account by The Government of Guatemala when it comes to selecting the type of desalination plant that can best meet its needs for decades to come.

AquaChar Latin America S.A. offers a way to "bridge negotiations" with the hundreds of companies around the world that design, build, and operate desalination plants. Our recommendation is that the Government of Guatemala allow us to take the time required to analyze the strengths of each contractor - only then, upon completion of our due diligence, can we recommend awarding contracts in accordance with those strengths.

Making the right choices requires knowledge of the different aspects of a plant's design, development and management. That is key to determining the criteria needed for the Design, Build, and Maintenance of a desalination plant in Guatemala.

Take for example, the conditions of the intake of the plant or the level of pollution in the area. All of these affect the costs associated with the pretreatment of the water and the overall design of the entire plant.

What we are proposing is A Diversified Water Strategy To Include Desalination along with A Plan For Decontaminating All Of The Rivers, Streams, Lakes, and Reservoirs in Guatemala

The first step is to determine the location, type, and size of the desalination plant along with the cost and identify the source of funding. With that, we can calculate any additional costs to infrastructure associated with the distribution of the newly acquired water supply. **At best, a Medium size SWRO (Salt Water Reverse Osmosis) plant will be able to produce 138,950,000 Liters/Day.**

But that is barely enough to supply the needs of the areas immediately surrounding the plant with a 50 KM radius.

That is why initiating a Comprehensive Action Plan to also Decontaminate the River Water is so important.

By installing jetties (or micro-dams) that divert only a portion of the river water to BioDigesters filled with BioMedia we are addressing the bigger problem of distributing desalinated water to rural areas that already have access to rivers that are currently polluted with garbage.

By remove pollutants from rivers we are restoring the ecology that supports life both in and along the rivers while addressing the problem of cleaning up and recycling garbage along the rivers.

As part of our Proposal, we will be providing access to Portable Organic Waste Recycling Units (POWRUs) capable of processing and converting raw garbage into Organic Fertilizers and Construction Materials.

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