Life cycle assessment of the use of biomass heat for the treatment of brackish water in isolated areas.

LIFE CYCLE ASSESSMENT OF THE USE OF BIOMASS HEAT FOR THE TREATMENT OF BRAKISH WATER IN ISOLATED AREAS

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Abstract

Access to freshwater is further restricted in dry regions of South America due to the high levels of arsenic and boron. To overcome this, desalination through multi effect distillation (MED) is a potential solution. However, the significant amount of heat needed in MED treatments can have significant environmental burdens. The use of biomass to produce heat is seen as a potential climate-change-friendly alternative to the use of fossil fuels. However, isolated communities may not have direct access to biomass and potential environmental trade-offs can occur associated to the transport. This study has analysed with life cycle assessment (LCA) the environmental sustainability of using biomass for the generation of heat with real data of a MED plant in Northern Chile treating brackish water with high levels of arsenic and boron. The functional unit considered is the production of 1 m^3 of distillate water and 13 impacts categories were estimated for two heat generation scenarios: i) by diesel generator and biomass (current operating situation) or ii) its combination with solar thermal fields (alternative scenario). Results show that the alternative scenario is the best option for all impact categories and for the use of biomass, the boiler and the distance of transport are the main environmental hotspots for the current situation.

Keywords (English): climate change; desalination; multi effect distillation (MED); sustainability; Chile.

Keywords (Spanish): cambio climático; desalinización; destilación multiefecto (MED); sostenibilidad; Chile.

Keywords (Portuguese): mudanças climáticas; dessalinização; destilação por múltiplos efeitos (DME); sustentabilidade; Chile.

1. Introduction

Fresh water is essential to sustain ecosystems and human activities. However, its availability has reached critical levels in many regions worldwide. This situation is further aggravated in the context of climate change since it may add uncertainty to the dynamic of global water cycles (Rodell et al. 2018). On top of that, human health concerns arose in Latin American regions known for their high concentrations of arsenic (As) and boron (B) in the water (Tagliabue et al. 2014).

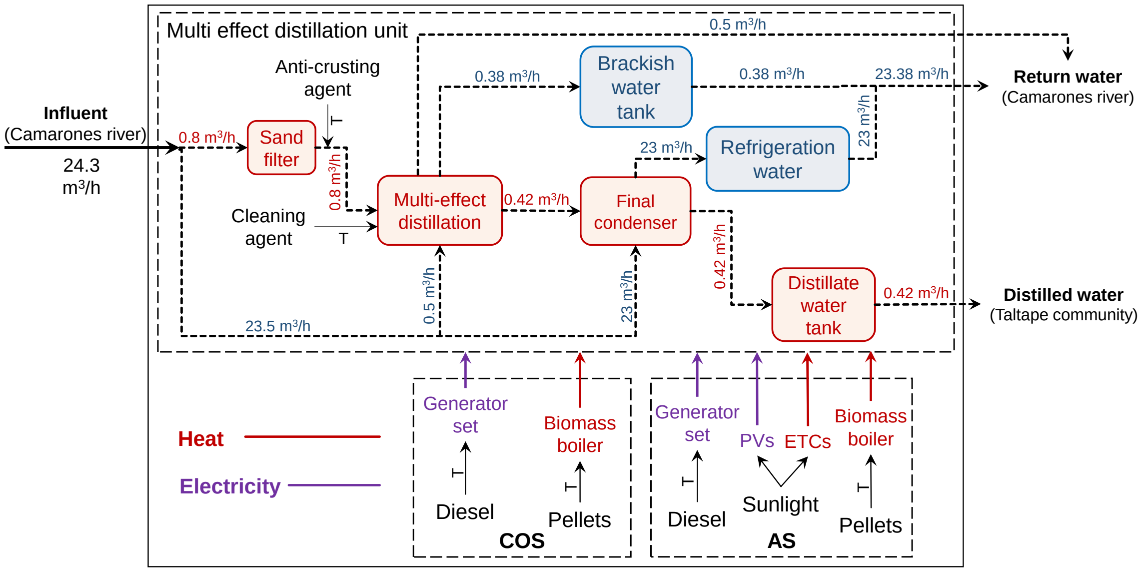
One example of the cited above is the Taltape community in the Camarones Valley (a region of Arica & Parinacota, Northern Chile), where nearly 30 people base their livelihood on agriculture and livestock. The drinking-water for the population is supplied by a tank truck, while water for irrigation and cattle comes from the Camarones River, which presents high natural salinity, and As and B content. These metalloids are consequently transferred to farming products and, therefore, their broad distribution remains a source of concern in the region (Cornejo-Ponce 2012).

The desalination of seawater and brackish water is nowadays a feasible source of fresh water. This process has become increasingly attractive economically due to technical developments experienced in the last decades. However, these techniques are not exempt of environmental and social problems (Tarpani et al., 2019). The life cycle environmental impacts of a small multi-effect distillation (MED) plant located in the Taltape community are evaluated in this paper. The system is currently operated with electricity provided by a diesel generator and heat from a biomass boiler. The current impacts have been estimated and compared to an alternative scenario where solar electricity and heat are generated at the site.

2. Methodology

The MED plant studied has a production capacity of approximately 10 m^3/day of distillate water. The influent is brackish water from a nearby water stream, the Camarones River, with an average total dissolved solids content of 1,900 mg/L (decreased to less than 20 mg/L in the final effluent). Presently, the current operation situation (COS) uses electricity from a diesel generator and heat from a boiler fed with biomass pellets. To assess the changes in environmental impacts from using solar energy and to assist the unit operation, an alternative strategy (AS) has been studied, consisting in the use of solar photovoltaic (PVs) and thermal fields (ETCs) to provide the necessary energy during daytime (i.e. 12 h/day). The functional unit (FU) of the study is “production of 1 m^3 of distillate for agricultural purposes using the brackish water from the Camarones River”.

The MED system and the options assessed for energy supply are presented in Figure 1.



PVs – Photovoltaic panels ETCs – Evacuated solar tube collectors T - Transport

Figure 1 - Scheme of the multi effect distillation plant flows in Taltape and options for energy provision for current operation situation (COS) and alternative strategy (AS)

Primary data of the life cycle inventory is based, unless otherwise stated, on information provided by equipment manuals, suppliers and measurements carried out onsite. Background data have been sourced from the from Ecoinvent v3.3. database (Weidema et al. 2013). The anti-crusting and cleaning agents are assumed to be produced in a nearby area (transportation distance to the MED unit of 200 km) and the same distance was assumed for landfilling of materials. The biomass pellets are produced in Bío Bío Region, Southern Chile (2,500 km distance from Taltape). To enable a fair comparison of transportation requirements to the MED unit, the diesel used for electricity generation was assumed being transported from one of the main oil suppliers to Chile, the Neuquén region in Argentina, at 3,000 km from Taltape (Gaete-Morales et al. 2018). The infrastructure, consumables and energy use for the COS and AS are presented in Table 1 (note that due the low impacts found for the MED unit materials these are not shown in the table).

The software Gabi 8.0 (Thinkstep 2015) was used for life cycle assessment (LCA) modelling and impact estimation. The ReCiPe 1.08 method (Huijbregts et al. 2017) hierarchical perspective has been applied to estimate the potential environmental impacts, considering the following mid-point impact categories: climate change potential (CCP), fossil fuels depletion (FDP), metals depletion potential (MDP), ozone depletion potential (ODP), photochemical oxidant formation (POFP), particular matter formation potential (PMFP), freshwater eutrophication potential (FEP), marine eutrophication potential (MEP), freshwater ecotoxicity potential (FETP), marine ecotoxicity potential (METP), terrestrial ecotoxicity potential (TETP), human toxicity potential (HTP) and terrestrial acidification potential (TAP).

Table 1 - Energy supply in the Taltape multi effect distillation plant per 1 m^3 of water

		COS	AS
	Diesel generator set (g)[a]	11.6	5.8
	Biomass boiler (g)[a]	6.8	3.4
Solar thermal field	Copper (g)[b]	-	1.7
	Glass tube, borosilicate (g)[c]	-	2.0
	Propylene glycol, 15% (heat transfer media) (g)	-	0.3
	Inert landfill (g)		4.0
Photovoltaic solar field	Photovoltaic panel, multi-Si (m^2)	-	$2.15E^{-4}$
	Batteries, lithium (g)	-	2.7
Consumables	Sodium phosphate (anti-crusting) (g)	80	80
	Sulfuric acid (cleaning agent) (mg)	1.36	1.36
	Lubricating oil[a] (generator set) (g)	19.6	9.8
	Diesel (kg)[d]	7.29	3.65
	Wood pellets (kg)	21.98	10.99
Road transport[e]	Diesel (t.km)	21.87	10.95
	Biomass pellets (t.km)	54.95	27.48
	Other consumables (t.km)	0.02	0.02

[a] Amount estimated from the Ecoinvent database; [b] Includes drawing of pipe; [c] Density 2.23 g/cm^3; [d] Density 0.832 kg/L; [e] Euro5: lorry 16-32 tonne.

3. Results and discussion

The results of the LCA for all the 13 impact categories are shown in Figure 2. Starting with CCP, the COS of the Taltape MED unit produced an impact of 47.0 kg CO_2-eq./FU. This impact is of 23.7 kg CO_2-eq./FU for the AS. The FDP of AS is 7.8 kg oil-eq./FU and of the COS is 15.5 kg oil-eq./FU. For the latter, the diesel generator and the transportation of diesel and biomass pellets contribute, respectively, 58% and 30% to the impact. The MDP of the COS is 1.35 kg Fe-eq./FU and for the AS 0.86 kg Fe-eq./FU. For the alternative option, the use of PVs and ETCs are responsible for around 10% of the total impact each, mostly due to the depletion of chromium, molybdenum and nickel. In general, for all the impact categories, the AS option has nearly half of the impact than COS. The contribution of the infrastructure for the MED subsystem has negligible contributions, below 5% in all categories.

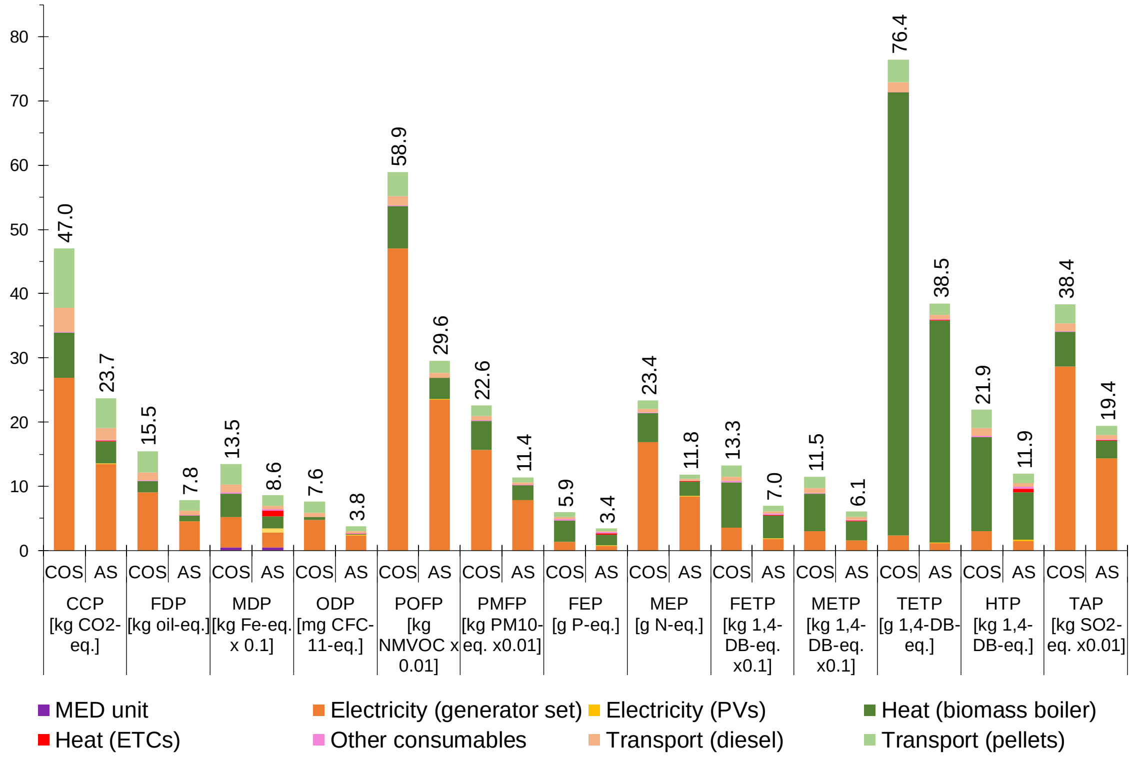


Figure 2 - Life cycle environmental impacts of the Taltape MED plant according the options for its energy supply. The values shown on top of should be multiplied by the factor shown in brackets for some impacts to obtain the original values. Results per m^3 of treated water.

The transportation of biomass and diesel to the Taltape MED plant have significant contributions (from 10% up to 70%) across all impact categories. The unfavourable environmental outcome of using biomass in desalination has already been suggested in literature (Eltawil et al. 2009). The decreasing in diesel and biomass pellet consumption and, therefore the transport associated, are the main reasons for the lowered impacts when coupling PVs and ETCs in MED process.

As the final distillate water available to the Taltape community contains metals and metalloids in levels below those required by Chilean regulations for safe use in agricultural purposes (Tarpani et al., 2019), the results suggest that the MED treatment of brackish water using solar energy is an environmentally viable alternative for improving the availability of freshwater to the Taltape inhabitants.

4. Conclusions and recommendations

This paper assessed the environmental implications of substituting the current energy supply of a small MED plant, located in an isolated community in Taltape (Northern Chile). Based on the findings, the Taltape MED plant would greatly benefit, from the environmental standpoint, from the use of solar energy.

Previous studies have demonstrated that the plant is effective in removing As and B found in the Camarones river to limits below required by Chilean regulations. Thus, the use of solar energy for MED treatment of brackish water in isolate desert communities can be considered an environmentally suitable alternative.

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