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Operation of Cap Djinet desalination plant and dilution of brine with power station cooling water

Mourad Amitouche[a,1], Boualem Remini[b,*]

[a]*Department of Environmental Engineering, Boumerdes University, Boumerdes 35000, Algeria*
[b]*Department of Water Sciences, Blida University, Blida 9000, Algeria, email: reminib@yahoo.fr*

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ABSTRACT

The aim of this work was to describe the operation of the desalination unit at the thermal power plant of Cap Djinet (Eastern Algeria) and the management and characteristics of the brine. The desalination unit at the thermal power plant of Cap Djinet (Eastern Algeria) operates a multi-stage flash distillation (MSF). The desalinated water passes through a demineralization step to obtain water with characteristics according to a boiler feed water at high pressure. During rejection, the brine is subjected to dilution with cooling water. This causes a decrease in the brine water salinity from 70 to 40 g/l and conductivity of 85 to 56 ms/cm which is equal to the conductivity of seawater. For other parameters, we found the same results as seawater based on the results of various analyses, we can say that the rejection of brine diluted station Cap Djinet is similar to seawater as probably it does not affect the receiving marine environment.

Keywords: Algeria; Desalination; Discharge; Brine; Environment; Sea; Pollution

1. Introduction

Repeated droughts that hit our region in North Africa have significantly increased the difficulties to supply the population in water quantity and quality [1]. Algeria is a semi-arid climate and water resources often used intensively, suffer temporary water storage, with a high utilization of water resources, water demand is growing rapidly and the water available decreases [2]. Algeria has chosen the desalination of seawater to meet the demand for domestic and industrial water in the country.

Desalination of seawater is a modern way to get water; this is one of the most used techniques to produce unconventional water to overcome deficits in availability of conventional water. One major advantage of seawater desalination is securing water supply (potable or industrial) for consumers, because the resource does not follow the vagaries of the weather and can therefore produce permanently quantities that are needed.

Although desalination of seawater is a response to the needs of water (domestic and industrial), whatever the method used is not without disadvantages:

*Corresponding author.

[1]Laboratory of Larhyss, Biskra University, Biskra 7000, Algeria.

- Desalination plants are expensive and are characterized by their high energy consumption;
- The production of energy for these facilities emit of greenhouse gases, causing global warming;
- They may impact coastal areas;
- They may affect ecosystems, because they reject the waste called brine (heavily salted water), and some species are very sensitive to salinity increases [3–10];
- Presence of heavy metals in the brine 2020 [11]; and
- The discharges associated with the desalination units as the waters from cleaning (sand filters, membranes, and deposits) may contaminate the environment.

2. Desalination in Algeria

Desalination of seawater began in Algeria during the sixties. In 1964, a unit of demineralization was carried at Ouled Djellaba (Biskra). During the same year, three blocks of 8 m/h each were installed liquefied gas complex in Arzew (Oran). In 1969, a second plant was installed with a capacity of 4,560 m/d. The method used was multi-stage flash distillation. The company Algerian Water made 23 monobloc stations with a total capacity of 57,500 m/d, under an emergency program in the wilaya of Tlemcen, Oran, Tipaza, Algiers, Boumerdes, Skikda, and Tizi Ouzou. They also realized 14 large stations with a total capacity of 1,940,000 m/d in 2003 and 2005. The same company has developed other stations in 2009, 2010, and 2011. These stations are Skikda (100,000 m/d), Beni Saf (200,000 m/d), Souk Tlata and Honaine Tlemcen (200,000 m/d each), Mostaganem (200,000 m/d), and Fuka Oued Sebt Tipaza (respectively, 120,000 m/d and 100,000 m/d), and Cape Djinet Boumerdes (100,000 m/d). Other stations are being implemented in the provinces of Chlef (200,000 m/d), El Tarf (50,000 m/d). The largest station is under construction to Magtaâ (Mostaganem) with a production capacity of 500,000 m/d. According to experts, the production of desalinated water in Algeria rose from 500,000 m/d in 2008, 1.1 million m/d in 2009 and 2.26 million m/d in 2011 to 2,580,000 in 2020 [8,9].

3. Potential effects on the environment

The list of potential environmental impacts of desalination plants is long and in some aspects, such as land use, similar to other development projects. Effects more specific of desalination plants are the impingement and entrainment of organisms due to the intake of large quantities of seawater and the emission of air pollutants due to a considerable energy demand of the processes. A key concern of desalination plants is the concentrate and chemical discharges to the marine environment, which may have adverse effects on water and sediment quality, impair marine life and the functioning and intactness of coastal ecosystems. A general overview on the composition and effects of the waste discharges is given in detail in [12,13].

4. Concentrate (brine) management alternatives

Currently, the most commonly used methods for seawater desalination concentrate (brine) management include surface water discharge to the sea; discharge to sanitary sewer; and subsurface discharge through exfiltration wells and galleries. Discharge to sanitary sewer and exfiltration wells is typically practiced for small size desalination plants. Options for discharging brine to surface water include

- Direct discharge through new outfalls;
- Discharge through existing wastewater treatment plant outfall;
- The zero liquid discharge (ZLD) systems convert all feed water into drinking water or evaporate the residual water during the process [6], leaving only dry, solid constituents behind. ZLD incorporates the potential of providing desalinated water without any brine discharges and impacts on the marine environment. Solid wastes, however, need to be treated and disposed of in landfills. Recovery and commercial use of salts and other valuable minerals might also be taken into consideration.
- Discharge through existing power plant outfalls: collation involves using the cooling water discharge of an existing power plant as both the source of saline water for production of fresh water and as dilution water for mixing with the desalination plant brine [6,7,14].
- Discharge by-passing seawater to reduce the salinity of brine [15,16].

5. Presentation of the unity of desalination

Any central-type steam usually has a desalination and demineralization of raw water (seawater) to fire boilers. The daily desalinated water from the power plant is of the order of 1,100 m^3. The installation includes four desalination units independent of each other (three units are in operation and the fourth is uninstalled), operating on the principle of the flash distillation, which produces 500 m^3 of desalinated water a day each unit, which will be stored in two tanks of 2,700 m^3 (Fig. 1). The seawater is subjected to

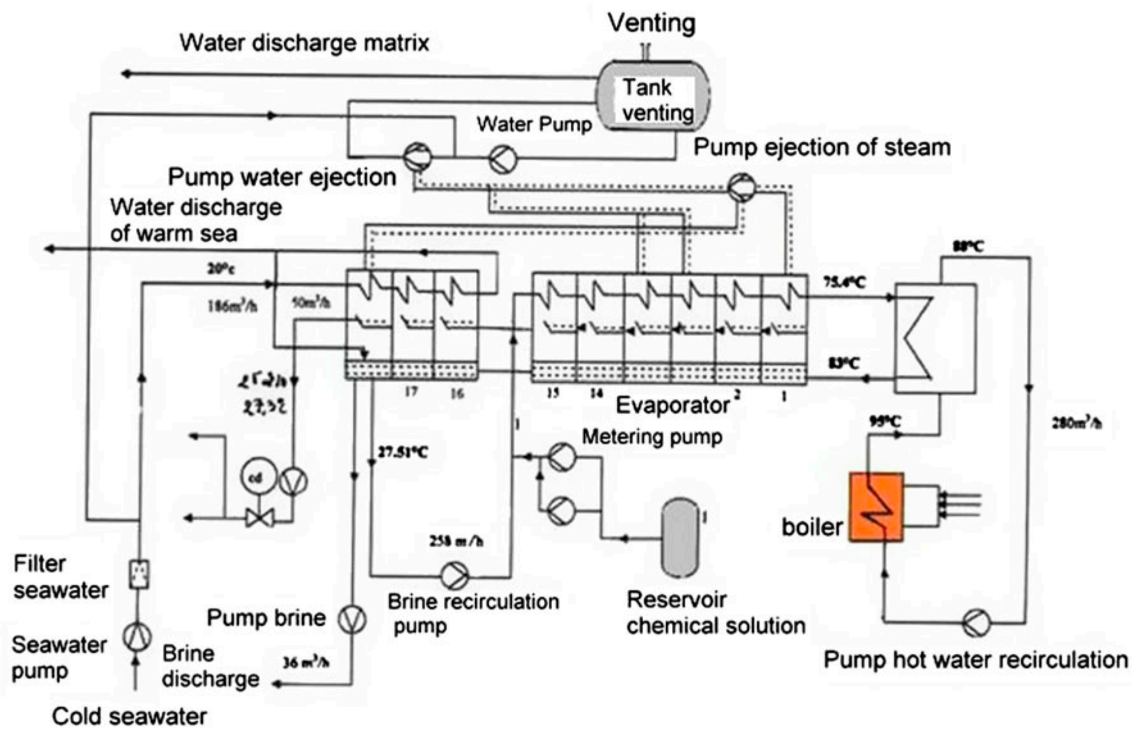

Fig. 1. Layout desalination plant of thermal power cap—Djinet [5].

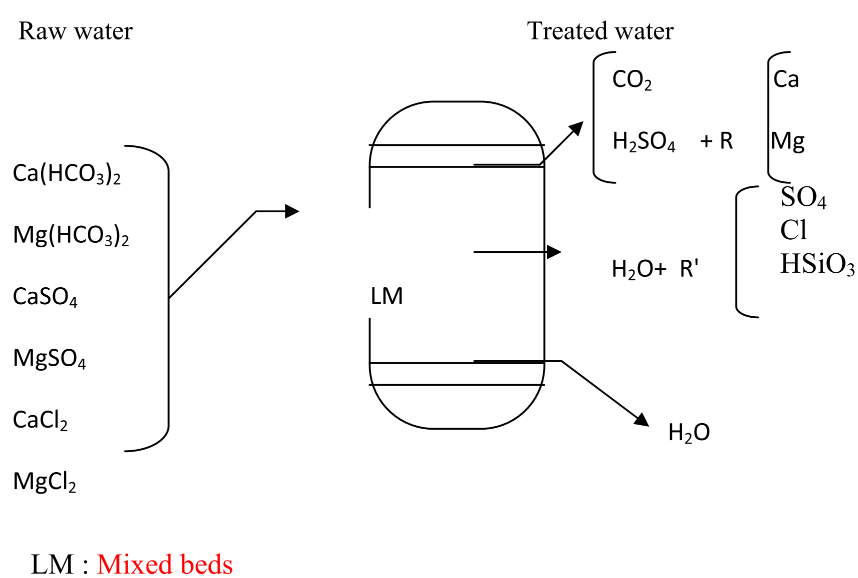

Fig. 2. Total mixed-bed demineralization.

pretreatment before being introduced into the desalination unit. During the operation of Cap Djinet thermal power station to reduce waste heat, large quantities of cooling water are needed 30 m/s. This water is taken from the sea at 7 m deep. The water intake is located 900 m from the side, and the water inlet to the pump station is via three concrete channels with a diameter of 2.7 m [5]. The height of the entrance station is 7.65 m below the level of the sea each input is a septic revision, all three channels is

Table 1
Results of physicochemical analyzes of seawater

Parametres	Unit	A	B	C	Average
pH		7.88	7.80	7.98	7.88
Temperature	°C	20.90	20.80	20.80	20.83
Conductivity	μs/cm	56,100	55,900	55,900	55,967
Salinity	mg/L	39,825.32	38,757.60	38,815.52	39,132.81
Turbidity	NTU	1.30	1.20	1.30	1.26
TH	°F	840	780	900	840
TH_{Ca}^{2+}	mg/L	601.20	561.12	480.96	547.76
TH_{Mg}^{2+}	mg/L	1,678.08	1,556.48	1,896.96	1,710.50
Chlorides (Cl^-)	mg/L	21,600	20,200	19,700	20,500
TA	°F	00	00	00	00
TAC	°F	13.2	13.03	13	13.08
HCO_3^-	mg/L	161.04	159.00	158.60	159.55
Nitrates (NO_3^-)	mg/L	00	00	00	00
Nitrites (NO_2^-)	mg/L	00	00	00	00
Sulfates (SO_4^{2-})	mg/L	3,075	3,080	3077.5	3,077.5
Phosphates (PO_4^{2-})	mg/L	0.208	0.208	0.208	0.208
Fer (Fe^{3+})	mg/L	0.070	0.070	0.070	0.070
Sodium (Na^+)	mg/L	12,182	11,781	12,048	12,003.67
Potassium (K^+)	mg/L	418	420	431	423

Note: A, B and C are samples taken at different time.

Table 2
Results of physicochemical analyzes of the treated water (desalinated water)

Parametres	Unit	A	B	C	Average
PH		6.8	7.4	7.0	7.06
Temperature	°C	27.30	27.40	27.30	27.33
Conductivity	μs/cm	17.28	17.18	17.05	17.17
Salinity	mg/L	16.90	15.17	16.55	16.21
Turbidity	NTU	0.01	0.02	0.01	0.013
TH	°F	0.8	1	1.2	1
TH_{Ca}^{2+}	mg/L	0.80	1.60	1.60	1.33
TH_{Mg}^{2+}	mg/L	1.46	1.46	1.95	1.62
Chlorides (Cl^-)	mg/L	7.53	6.42	7.32	7.09
TA	°F	00	00	00	00
TAC	°F	0.18	0.15	0.10	0.14
CO_3^{2-}	mg/L	00	00	00	00
HCO_3^-	mg/L	2.19	1.83	1.22	1.75
Nitrates (NO_3^-)	mg/L	00	00	00	00
Nitrites (NO_2^-)	mg/L	00	00	00	00
Sulfates (SO_4^{2-})	mg/L	1.68	1.68	1.68	1.68
Phosphates (PO_4^{2-})	mg/L	0.064	0.064	0.064	0.064
Fer (Fe^{3+})	mg/L	0.015	0.015	0.015	0.015
Sodium (Na^+)	mg/L	2.32	1.83	2.45	2.20
Potassium (K^+)	mg/L	0.01	0.03	0.01	0.016

Note: A, B and C are samples taken at different time.

equipped with a cofferdam. The pumping station is a reinforced concrete structure with upper edge sealed to more than 7.5 m above the level of the sea and consists of a catchment of four lanes of filtration and suction chambers for pumps of the desalination plant, chlorination, and fire pump.

Table 3
Results of physicochemical analyzes of demineralized water

Parameters	Unit	A	B	Average
PH		7.22	7.20	7.21
Conductivity	μs/cm	0.07	0.04	0.05
TA	°F	00	00	00
TAC	°F	00	00	00
Fe^{2+}	mg/L	0.0016	0.0012	0.0014
SO_4^{2-}	mg/L	00	00	00
TH	°F	00	00	00
Cl^-	mg/L	00	00	00

Note: A and B are samples taken at different time.

6. Results and discussion

6.1. Injection of chemicals

Injection systems of chemicals are intended to protect the desalination of seawater against scale, dirt, and foam formation (Fig. 1).

6.1.1. Protection against scale

Scaling is a mineral salt deposit that tends to form on the exchange surfaces, the item Belgard of

Ciba-GEITY polymer-based maleic is the most used [14,17–19]. The control unit has injection instrument of Belgard EVN to 35 mg/L. The Belgard EVN is a polymer called carboxylic acid of formula polymaleic:

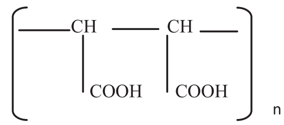

Table 4
Results of physicochemical analyzes of the brine

Parameters	Unit	A	B	C	Average
pH		8.44	8.49	8.49	8.47
Temperature	˚C	27.50	27.40	27.50	27.46
Conductivity	ms/cm	85.30	85.00	84.80	85.03
Salinity	mg/L	69,840.12	69,252.76	69,567.68	69,553.52
TH	˚F	1,190	1,250	1,240	1226.66
TH_{Ca}^{2+}	mg/L	761.52	841.68	801.60	801.60
TH_{Mg}^{2+}	mg/L	2,432	2,529.28	2,529.28	2,496.85
Chlorides (Cl^-)	mg/L	34,500	34,100	35,400	34,666.6
TA	˚F	2.4	2.9	2.8	3
TAC	˚F	20.20	19.80	19.60	19.87
CO_3^{2-}	mg/L	28.8	34.8	33.6	32.4
HCO_3^-	mg/L	187.88	170.80	170.80	176.49
Nitrates (NO_3^-)	mg/L	00	00	00	00
Nitrites (NO_2^-)	mg/L	00	00	00	00
Sulfates (SO_4^{2-})	mg/L	4,950	5,360	5,155	5,155
Phosphates (PO_4^{2-})	mg/L	0.229	0.229	0.229	0.229
Iron (Fe^{3+})	mg/L	0.045	0.045	0.045	0.045
Sodium (Na^+)	mg/L	25,365	24,562	25,416	25,114.33
Potassium (K^+)	mg/L	850	842	890	860.67

Note: A, B and C are samples taken at different time.

Table 5
Results of physicochemical analyzes of the brine diluted with cooling water in the discharge channel

Parameters	Unit	A	B	C	Average
pH		7.82	7.74	7.80	7.79
Temperature	˚C	21.3	21.3	21.3	21.3
Conductivity	ms/cm	56.7	56.6	56.6	56.6
Salinity	mg/L	40,200.20	40,893.80	40,581.40	40,648.46
Turbidity	NTU	1.80	1.62	1.94	1.78
TH	˚F	750	780	760	763.33
TH_{Ca}^{2+}	mg/L	521.04	480.96	530.4	510.8
TH_{Ca}^{2+}	mg/L	1,507.84	1,605.12	1,532.16	1,548.37
Chlorides (Cl^-)	mg/L	21,200	21,600	21,400	21,400
TA	˚F	00	00	00	00
TAC	˚F	12.4	12.6	12.2	12.4
CO_3^{2-}	mg/L	00	00	00	00
HCO_3^-	mg/L	151.28	153.72	148.84	151.28
Nitrates (NO_3^-)	mg/L	00	00	00	00
Nitrites (NO_2^{2-})	mg/L	00	00	00	00
Sulfates (SO_4^{2-})	mg/L	3,450	3,450	3,450	3,450
Phosphates (PO_4^{2-})	mg/L	0.128	0.128	0.128	0.128
Iron (Fe^{3+})	mg/L	0.035	0.035	0.035	0.035
Sodium (Na^+)	mg/L	12,781	12,940	13,200	12,973.7
Potassium (K^+)	mg/L	490	514	540	514.6

Note: A, B and C are samples taken at different time.

Its maximum temperature of use is 120˚C [17].

6.1.2. Protection against dirt

Dirt is a major cause of under deposit corrosion and deterioration of the heat exchange capacity. Between 6 and 12 months, it will be necessary to clean the heater end with hydrochloric acid [14,17–20]. The cleaning agent used in the plant is hydrochloric acid 5% to about 290 kg of HCl solution and assayed by cleaning and injected by a metering pump at a rate of 35.25 kg/h for 8 h, either in seawater or in brine circulation next area to be cleaned [5]. The cleaning process is based on the pH value, must be identical to the input and the output of the area to be cleaned [5].

6.2. Protection against the formation of foam

Seawater, subject to a seasonal increase in organic content products, may tend to foam when treated in desalination plant [8]. Part of this foam can happen to the distillate and make it unusable in this case the chemical called (Belite to 0.1 mg/L) can be dissolved and dosed with the inhibitor overlay [12–14,19,20].

6.3. Neutralization of chlorine

Seawater, for the power plant, is treated with chlorine; this process destroys organisms in seawater. Excess concentration of active chlorine in seawater desalination plant feeding the negative impact on the process [18–20]. The chlorine content is measured and if its content increases, we add sodium bisulfate (Na_2SO_3) in seawater for feed water, which neutralizes chlorine [12,13,21].

6.4. Technical data

Technical data on installations producing 500–600 m/d.

Production of distillate: 20.83–25.00 m/h;
The distillate impurity: less than 15 mg/L;
Maximum temperature of salt: 83–91˚ C;
Quantity of seawater: 239–256 m/h;
Maximum salinity of seawater: 39,400 mg/L;
Maximum salinity in the brine: 65,300 mg/L;
Recirculation debit: 239–256 m/h;
Debit of salt: 31–37 m/h;
Water flow power: 52–62 m/h [11].

6.5. Consumables

(1) Inhibitor overlay Belgard EVN:
 (a) High dose 3.8–5.8 mg/L;
 (b) Power consumption 0.2–0.36 kg/h;
(2) Product antifoam M33 BELITE:
 (a) Dosage seasonal 0.1–1.0 mg/L;
 (b) Power consumption 26 g/L;
(3) Fuel 202–250 kg/h;
(4) Gas 242–300 m^3/h (15˚ C–1,0 bar).

6.6. Demineralization

The distillate of the desalination plant of the seawater that is stored in two reservoirs of 2,700 m^3 is pumped to the station for the demineralization and it is sent back to the mixed-bed filters [1,2,11–14,17–22]. The two beds are provided with mixtures a net capacity of 40 m^3/h each, and in general operate in alternate mode (Fig. 2), one is used for demineralization and the other for reserve [2].

The demineralized water is fed to the two storage reservoirs of 1,500 m^3 everyone. It is injected into the inlet pipe of two storage tanks of ammonia to raise the pH of demineralized water at more than 9.5 [1,2,11,17].

6.7. The physico-chemical analyses of different samples

To evaluate the effectiveness of water treatment adapted for the power central, it is necessary to follow the evolution of physicochemical water characteristics during treatment. Tables 1–3 present the characteristics of:

- Seawater (raw water);
- Desalinated water (distillate);
- Distilled water.

Results shown in Tables 1–3 indicate that the pH is neutral for the three samples, and then, we see that the distillation does not affect the pH. The conductivity of seawater is varied between 56 and 55 ms/cm. After distillation, most of this conductivity is eliminated, leaving only 17 μs/cm in the distillate, the remaining is excreted by the mixed bed, there are only 0.05 μs/cm. The value of seawater HT (Hydrometric Title) is very high; it is 840˚F. After distilling off most of the hardness is removed 1˚F.

Seawater is charged (intake) with chloride concentration of 20,500 mg/L; the fact remains that after distillation 7.09 mg/L, after demineralization chlorides are eliminated completely. Much sodium is excreted by the 12,003.67 distillation process; there are only 2.32 mg/L. The salinity of the seawater is reduced by the process of distillation.

Analysis of iron ions is significant at the station because they can cause corrosion of pipes through which they pass. Most of these ions are removed by the distillation process. For other parameters, we note that distillation removes most of their content. So, we can say that the distillation process is effective, distillation removes most of the mineralization and the rest is eliminated by the mixed bed.

To make a comparison between the characteristics of the environment (seawater) and those releases (brine), we carried out physico-chemical analyses of the brine and diluted discharge. The experimental results are shown in Tables 4 and 5.

Following Tables 4 and 5, we note that the pH is neutral for the three samples (seawater, distillate, and brine discharge), then, we see that the distillation process does not affect the pH. For boiler water, the measured value of pH is 9.05; this increase is due to the injection of ammonia in the water supply. The boiler is fed by deionized water with a pH > 9. For the brine recirculation, the measured value is equal to 8.03; this increase is simply due to injection of chemicals (antiscalant, antifoaming). The five samples have a pH according to the standard required by the plant.

The conductivity of the seawater is very high (53,300 μs/cm), after distillation of most of this conductivity is eliminated, leaving only 15.58 μs/cm in the distillate. We can say that the process is effective. The boiler is fueled by deionized water whose conductivity is less than 0.6 μs/cm, and, so this increase (78 μs/cm) is due to the increase in temperature (95˚C).

So, we can say that the conductivity is a function of temperature, it is more important with increasing temperature. The value of the conductivity of brine discharge (84.2 ms/cm) is less than the recirculation brine; this decrease is due to the dilution (an addition of seawater) of the brine in the region of heat dissipation. When extra seawater must maintain a certain level of brine in the evaporator, this system has a pump that sucks the excess brine, this excess is called brine discharge. The conductivity value of five samples does not exceed the limits required for the central.

The TA (simple alkalinity titration) value is zero, which means the absence of OH^- ions and CO_3^{2-} in water. Measurement of TAC (complete alkalinity titration) indicates that the brine recirculation and brine discharge contain HCO_3^-.

Copper is an indication of corrosion, the tank of the distillate and the condenser are made from copper and nickel (Cupro Nickel $CuNi_{30}Fe$) [14]. The value of copper is less than the limit value, which indicates that the pipes are not corroded [5].

We observe that the average salinity of the brine is about 69 g/l. After dilution with cooling water in the discharge channel, the concentration decreases to 40 g/l which is almost equal to the ambient salinity of the sea water (39 g/l) [3,4].

7. Conclusion

Based on analyses we conducted, we found that the final water is demineralized and degassed. Analyses of rejection of the desalination plant into the marine environment show that probably it has no harmful effects on the receiving environment after the dilution of the brine with cooling water (Tables 1 and 5) since the values of the discharge after dilution are similar to that of seawater. However, a monitoring of the discharge [23] will be needed to confirm this aspect.

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