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Study of Environmental Impact of A Desalination Plant in Semi Arid Regions

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Abstract: Ddesalination has long been a major source of water in some parts of the world and has become an industry in constant evolution. This form of virtually unlimited water resources consumes energy and it has impacts on the environment. These impacts are mainly caused by chemical residue from the desalination processes. For this, the authorities concerned with the protection of the environment require special vigilance and a scientific assessment of possible impacts on the environment chosen to release this. All facilities generating industrial liquid waste discharges must be designed, constructed and operated so that their emissions do not exceed the output of the installation limit values for discharges defined by legislative enactments and must be equipped a processing device appropriate to limit the load of pollution discharged. In our study we found that the failure to take into account the impact of discharges from station on the environment is a serious problem. It turns that even with the strict application of the regulation; the authorities are struggling to consider all the problems associated with environmental impacts of such a facility.

Key words: Desalination · Releases · Legislative Enactments · Environment

INTRODUCTION

Desalination and demineralization of water can remedy the shortage of water and thus could help to remedy its lack. However, the effects generated by this technique could be serious and important and their impact on the environment is very harmful especially because of the concentrate (brine) produced during the operation and the effects of releases of chemicals used in the processes [1]. Processes based on separation by membranes know in this framework a big development. They become very powerful tools for desalination and water recycling for a "zero waste". Demineralization projects are a solution to a problem that lasts, however they produced many negative effects on the environment. There is no doubt that countries using desalination to meet their needs for fresh water should implement guidelines and processes appropriate for disposal of brine [2]. Examples of adverse effects associated with these discharges are numerous in the world: the region of Khon Kaen, Northern Thailand for rice land [3], Canada where there are saline soils that exacerbate the problem of deep groundwater [4] and Saudi Arabia where the role of reject brine from Salbukh water desalination plant has contribute to deteriorating the soil chemical properties [5]. In Algeria, the palm plantation of Ouargla is episodically threatened by discharges of drainage water. In the Mediterranean basin, Spain is also affected by this phenomenon in Almeria. Australia, USA and many other countries are largely affected by what we might call ecological disaster. Excessive concentrations of sodium and chloride ions in discharged water can cause toxicity in the plant [6]. However, saline soils are often more fragile and prone to degradation because salinity reduces plant cover leaving the soil susceptible to wind or water erosion. In Algeria, the problem of water started to become increasingly acute in the last decade characterized by persistent drought, low rainfall and irregular in space and time causing the decrease of water resources. Under the Economic Recovery Plan, the Algerian government has boosted public investment for the integrated management of water resources and should continue to devote the next 10 years significant resources to this sector.

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Seawater desalination plants at Alger, Beni Saf, Skikda and Arzew Industrial Zone was held in June 2004. The desalination plant of El Mactaa (western Algeria), the largest in Africa, will be commissioned in 2014. With a production capacity of 500,000 cubic meters per day, the station of El Mactaa, which extends over 17.4 hectares, will allow Oran to ensure self-sufficiency in drinking water. This station will certainly completely change the environment in which it will operate

For the Western region and particularly in Oran, the implementation of the desalination of brackish groundwater in Bredeah was decided May 25, 1998 and became operational September 10, 2005. The project was very attractive but the consequences caused by the rejection of the desalination technique were deplorable, essentially in the absence of an efficient sewerage. The salt-laden water seeped into the ground and caused the degradation of vegetation and fruit trees.

Beyond the theoretical knowledge of the chemical process and operation of the conventional technique, the main objective is to study, taking in account the interaction between the different species present in the discharged water and wildlife surrounding the demineralization station given the similar experiences in the world, the impact of brine discharge on the environment.

The systemic approach provides a new comprehensive and promising analyzing method. Science can identify hazards, assess, control and manage the risks associated with various projects whose aim is to achieve a goal in any phase (from design to operation).

Environmental Impacts: Among the impacts from a desalination or demineralization plant, mainly because of the brine solution, there are those who are limited to the construction phase and those related to the exploitation phase. Impacts begin with the transformation of the site and then continue with visual impact and noise to be extended to air emissions and discharges into water or soil as well as potential damage to the environment.

The largest of these impacts relate to air quality and water quality then on flora, fauna and ecosystems. The main pollutants agents affecting the environment are:

- Effects of concentrate (brine)
- Effects of fouling control additives
- Effects of anti foam additives
- Effects due to corrosion products
- Effects of water withdrawals

In this study we focused mainly to the effects of brine.

Effects of Concentrate (brine): The total volume of brine released into the environment is crucial for the damage it can induce. A discharge of concentrated brine would require further careful of potential impacts on the environment even if it is a rejection in small quantities. Apart from the volume itself, the manner and location of the discharge are essential to the impacts that may result.

The effect on the physiology of plants can be summarized by a salinity (osmotic pressure), a concentration of Na^+ and a concentration of Cl^-, induce an anthropogenic and climate constraints that can be summarized as follows:

- Land degradation and plantations by waste residue.
- Stagnation-releases free rinse water demineralization station, flooding farmland by sewage residue and dieback of trees.
- Contamination of ground water, loss of natural vegetation and salinization of agricultural land.
- Loss of biodiversity and precarisation of ecosystems.

Knowing that soils, as essential to plant life, have a tremendous need for carbon, nitrogen, potassium and phosphorus and the different salts such as calcium sulfate, magnesium nitrate, ammonium, etc. The presence of salt, especially sodium chloride, has a negative effect on the storage of these elements and thus on the vegetation. Another risk is the proliferation of bacteria, coliform and pathogens which has a direct impact on humans' health. The livestock is affected and the whole culture made by farmers living in this kind of site. Health risks can be associated with the presence of pathogens in recycled water and probability of infection based on the tolerable intake derived from epidemiological studies. The concentrate is released continuously during production. The flow rate and composition of the concentrate are related to overall rates of recovery and separation. The rate of recovery is, in general, greater than or equal to 75%, the concentrate flow is at most 25% of the feed rate. Water rinsing and washing is discharged discontinuously. When the processing chain comprises additions of chemicals in raw water (coagulant, oxidizing acid, scale inhibitor, etc.), discharges of membranes contain besides substances present in raw water, the products injected for water treatment [1].

Fig. 1: Situation of the demineralization plant of Bredeah (google map).

Brine, usually discharged as wastewater, is the water stream in the desalination process that has higher salinity than the feed. Reject brine is the highly concentrated water in the last stage of the desalination process. Several types of chemicals are used in the desalination process for pre-and post-treatment operations. It is estimated that for every 1 $m^3$of desalinated water, 2 m^3 is generated as reject brine and for every 1 m^3 of demineralized water, 1 m^3 is generated as reject brine in average.

The Station of Bredeah: The pumping station of Bredeah, in operation since 1888, is in contact with two complex aquifer systems: one in karstic limestone formations, the other in interstices in alluvium and quaternary formations. The station (Fig.1) is located near a residential area and is surrounded by farmland. This station is located a few kilometers from the Sebkha Oran. From 1995, the pumped water became of poor quality and was qualified as “non-potable” water, with contents of minerals much higher than the drinking water standards. The origin of high salinity of this water is due to the proximity of the Sabkha. A demineralization plant was commissioned in 2005 to make Bredeah’s water potable. With a capacity of 35,000 m^3 station provided this average 20,000 m^3/day.

The brine, rejected in nature, can be estimated at about 20,000 m3 per day on average. During a three-year period (2009 and 2011) we have taken regularly samples and we have studied physicochemical properties of water used and discharged by this station. A sampling system was chosen to allow us to acquire representative data on the spatial and temporal variability of water quality and soil around the station. The pH was measured in the field using a pH meter WTW Field Meter ProfiLine pH 1970i. Cations and anions were analyzed in the laboratory of the National Water Resources Agency (ANRH). Chloride ions and sulfate ions were determined by liquid chromatography. The bicarbonate, the calcium and magnesium ions were analyzed by volumetry and sodium and potassium by flame photometry. The average values for three years (2009 and 2011) are shown in the Table 1. The results we obtained show that the brine's burden mineral is very important. We complete our study by a biochemical analysis of brine. The obtained results show a real environmental danger.

In Table 2 we summarize the average values obtained during the three years. It should be noted that all values greatly exceed the values tolerated by laws and standards.

The station was commissioned in 2005; three years have been enough to affect the entire area surrounding the station and act both on fauna and flora. Adverse effects were seen on a large scale. From 2008 and further to findings made around of the site, we begin concern ourselves with risks created by this station [7].

In 2010, we conducted the first analyzes of the soil around the area of brine discharge.

Soil samples were collected 2 m from the brine spill point and analyzed; manual corers for unaltered soil sampling were used. The results (Table 3) show a pollution of the deep soil layers.

Table 1: Physico Chemical analysis for water used and discharged by the Bredeah Station.

Chemical Attributes	Water before treatment (mg/l)	Treated water and reequilibrated (mg/l)	Brine rejected (mg/l)
Ca^{2+}	65	30	85
Mg^{2+}	15	10	20
Na^{+}	3680	15.8	3785
K^{+}	7	2.1	8
Cl^{-}	5253	72	9701
SO_4^{2-}	96	23	105
HCO_3^{3-}	1380	265	1980
NO_3^{-}	120	15	245
pH	7.5	7.2	7.8

Table 2: Average values of brine compared with limit values tolerated by laws and standards.

Settings	Units	Limits	Average rejected values
Temperature	°C	30	34
pH		6.5-8.5	7.8
TSS (Total Suspended Solids)	mg/l	35	254
BOD5 (Biochemical Oxygen Demand for 5 days)	mg/l	120	275
COD (Chemical Oxygen Demand)	mg/l	35	176
Chlorinated Organic Compound	mg/l	05	27
Kjeldahl Nitrogen	mg/l	30	45
Total Phosphorus	mg/l	10	19
Bioaccumulative Toxic Substances	mg/l	0.005	0.012

Table 3: Composition of the soil in depth (g kg^{-1}).

Depth/Compound	surface	0.60 m	2 m	3 m
NaCl	6.03	7.95	8.24	8.05
Calcium Sulfate	0.34	0.39	1.24	1.23
Silica	4.03	5.12	4.04	5.58
Iron Alumina	1.87	3.56	2.97	2.94
$CaCO_3$ and CaMn	0.32	0.3	1.20	1.30

Table 4: Composition of the soil in surface around the station (g kg^{-1}).

Radius/Compound	5 m	25 m	50 m	100m	200 m	500 m
NaCl	7.13	6.65	7.24	6.05	6.50	6.42
Calcium sulfate	0.54	0.51	0.65	0.43	0.40	0.41
Silica	5.23	5.02	6.04	5.58	4.95	4.55
Iron Alumina	1.77	3.36	2.07	1.98	1.98	1.89
$CaCO_3$ et CaMn	0.30	0.30	0.40	0.45	0.41	0.40

Table 5: Determination of risk for different category.

Risk target	Code	Impact	Likely hood
Human	A	Moderate	Likely
Crops	B	Very high	Likely
Sol	C	Very high	Certain
Environment (flora and fauna)	D	High	Certain

This led us to investigate the radius of the pollution. We were able to collect samples around the station. The results obtained (Table 4) show the seriousness of the problem. During the few years of operation of the station and hence spill brine, saline pollution has spread throughout the surrounding space station.

This pollution is a risk for both the environment and for people who are located near this station.

Risks Assessments and Mitigating Measures: Risk assessment is the determination of quantitative or qualitative value of risk related to a concrete situation and a recognized threat. Quantitative risk assessment requires calculations of two components of risk: The magnitude of the potential loss or impact *(L)* and the probability *(p)* that the loss will occur (likelihood). Acceptable risk is a risk that is understood and tolerated usually. In this context it is possible to use a conversion table for qualitative assessments of probability, as the scale of Lichtenstein and Newman [8] (Fig. 2).

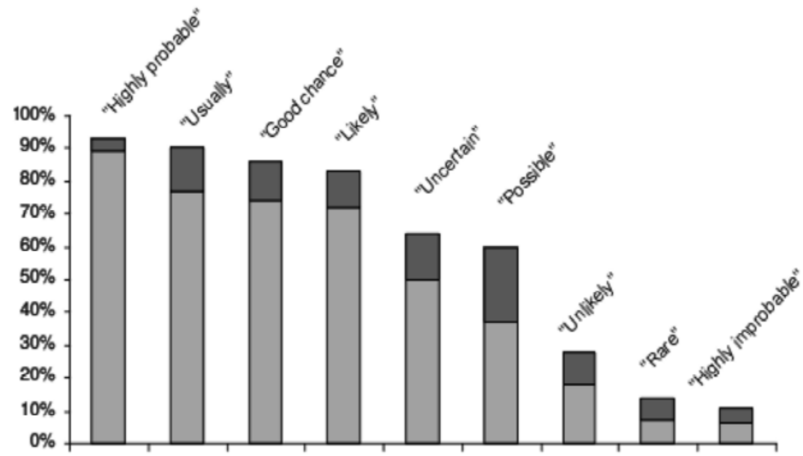

Fig. 2: Correspondence between probabilities and qualitative assessments.

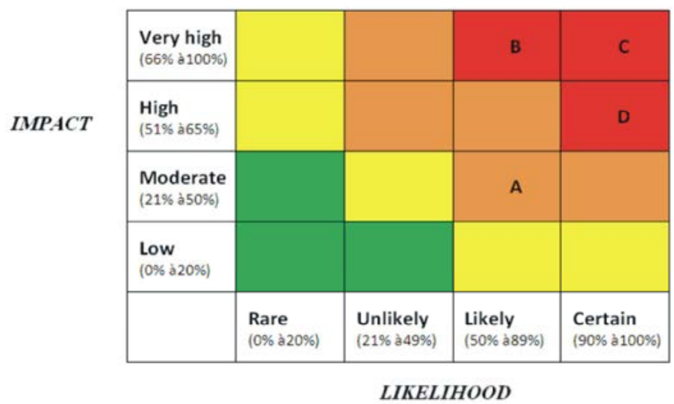

Fig. 3: Risk assessment matrix.

To assess any environmental impact a risk assessment matrix is used. The environmental risk matrix is the product of two factors, namely the probability of occurrence and severity of the effect. There may be various ways to determine the probabilities of situations. In the absence of data feedback, it is always possible to appeal to values of subjective probabilities evaluated by experts.

A questionnaire was given to four experts (chemist, geologist, biologist and water engineer) to help us extract some probabilities and based on the scale described in Figure 4; we deduce the possible values of different risk induced by the rejected brine.

The purpose of a risk matrix is usually not trying to obtain a precise estimate of the risk, or to determine the potential impact on objectives in great detail and any such attempts are rarely useful. When we use a risk matrix we are usually trying to assess and prioritize a list of risks. The use of red-yellow-green types of categorization reflects this broad classification of risks into high-medium-low priority.

This risk matrix is an invaluable tool for organizations seeking fast, effective and practical risk assessment processes but it cannot be used in isolation. Any assumptions or embedded judgments need to be clearly articulated. Despite its limitations, the risk matrix allows, however, to:

- Provide consistency to risk prioritization
- Encourage and facilitate robust discussion
- Provide a point of focus when assessing risks
- Present complex data concisely

The environmental risk matrix used in assessing the environmental impacts of desalination or demineralization is shown in Figure (3).

The results obtained show that it is the soil (C) that is most vulnerable to the consequences of releases, it will necessarily affect plants (B) in particular and environment in general (D).

All these factors have an impact on human health (A).

CONCLUSION

The pollution problem of the site will inevitably increase with disposal rate of rejected brine steadily going up. Applications of the standard and laws will lead to minimize the threat to the safety of water resources, environment and human health. The fight against pollution therefore depends on legislation and enforcement but also by improving techniques: use of less harmful products and in smaller doses (especially for agriculture), best performance of water treatment units. The failure to take into account the impact of discharges from the station on the environment caused a bigger problem for environment and population near the station. The authorities concerned must deal with the problems associated with environmental impacts by enforcing very strictly the regulations and find solutions satisfying the parties concerned. Zero discharge of brine can be obtained by means of an evaporation process that concentrates produced provides dried residues. This technique requires a large increase in capital investment and energy consumption. Therefore, this choice is only applicable when there is no alternative to discharge of brine. Similarly, it should take into account the noise pollution from the operation of a desalination plant, especially when facilities are near populated areas. We must also consider the impact on the landscape caused by both facilities themselves. Countermeasures and suggestions were proposed for the above situation:

A. *Improve drainage and water quality standards from human health:*

Water quality standards should take *in account* all the toxic and hazardous pollutants that are the threat to human health into the regulatory framework. Drainage and water quality standards which will have been perfected should agree with Standards *water quality* and provide the necessary basis for the management of water resources.

B. *Make planning for drainage and water supply facilities:*

The industrial layout of the station and the discharge of special pollutants and the mutual influence relation between upstream and downstream station should be take into consideration when the planning of water pumping and discharge facilities is complied because pollutants have the characteristics of dynamic migration and superposition in soil. The consideration can avoid the adverse effects which are caused by not enough dilution and degradation on the safe production of water resources.

C. *Establish the list of priority pollutants from the safety and security of water resources:*

A dynamic list of priority control pollutants in rejected brine should be established in order to make full use of the limited monitoring capacity for the complex hydrological conditions and pollutions around the station.

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