ENVIRONMENTAL AND SOCIAL ASSESSMENTFOR EXPANSION OF DEIR AL-BALAH SEAWATER DESALINATION PLANT

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Abstract - Worldwide, in order to overcome the gap in conventional water resources, desalination of seawater through reverse osmosis is considered the most promising technique to provide freshwater for regions suffering from water shortages. In order to alleviate the problem of freshwater deficit in Gaza Strip, it is intended to expand the existing seawater desalination plant of Deir Al-Balah by lifting its desalinating capacity to 6,000 m^3/day. The expanding of Deir Al-Balah seawater desalination plant could have potential environmental and social impacts. This study employs numerical modelling approach to assessthe environmental impact (EIA) of the discharged brine through an alternating disposal system into sea, the simulation result shows that the applied disposal system is an efficient mitigation measure todecrease the potential negative environmental impacts of brine disposal where the excess salinity at the edge of the mixing zone in the worst dilution pattern was 7.67% (2930 mg/l) above the salinity of seawater and this result meets the specified limit (less than 10%) by UNEP regulations. Furthermore, questionnaires were distributed to 200 inhabitants live near the desalination plant to assess the social impacts of the desalination plant on the society, the results of social impact assessment (SIA) refer that the expansion of the desalination capacity could decrease the rate of unemployment and improve the status of public health where providing reliable freshwater decreases the spread of waterborne diseases. The survey of SIA demonstrates that most of the interviewed residents (89%) get domestic water from the municipality, most of them (86%) describe the quality of water as very bad, the quality of received water is not satisfied according to 58% of surveyed people. Hence, most of the people (70%) support the expanding of Deir Al-Balah seawater desalination plant to enhance the quality and quantity of water services in the region and also 55% of the people are willing to pay the fees of supplied water, however the social results show that significance percentage of 42% are not willing to pay due to the bad economic situations, however it is expected to decrease this percentage in the case of a well-structured tariff system is exploited to guarantee fair distribution of freshwater.

Keywords - Desalination, ESIA, Environmental, Social, Brine, Gaza Strip, Impact.

I. INTRODUCTION

Water is a vital resource to human beings, yet decreasing freshwater supplies have become crucial problems that seriously affect a large population of people and our environment (Jacobson et al., 2011). In the twenty-first century, water scarcity crisis has emerged as one of the most pressing problems (Mehta, 2006). Water stress in some form threats nearly 80% of the human population and about 65% of continental discharge feeds habitats that face moderate to high biodiversity threats (Vörösmarty et al., 2010). Sixteen years ago, more than 18 countries around the world were classified as water scarce and the majority of these countries are in the Middle East and North Africa (Bremere et al., 2001). In effort to alleviate problem of water shortages, new freshwater sources must be identified, for instance, through desalinating seawater or brackish water, especially for some areas where seawater is readily available but freshwater sources are limited (Zhang and He, 2013). Seawater desalination is considered the most promising technique for supplying freshwater in the regions suffering water scarcity (Oh et al., 2009). Seawater reverse osmosis is the most important desalination technology, but one of the main challenges that face that technology is compromised by brine disposal challenges, while these methods reduce total dissolved solid levels to produce potable water, large volumes of brine are redirected to the coastal waters (Palomar et al., 2012a; Morillo et al., 2014).

Beside energy, the most environmental problem that faces the designers and operators of seawater desalination plants is the brine disposalthat is normally discharged directly into the sea, forming a very dense plume of water that spreads out over the sea floor following the steepest gradients and affecting the benthic communities encountered along the way; the impact of brine discharges on the marine ecosystem increasingly needs further attention and study, particularly in relation to seagrass (Sánchez-Lizaso et al., 2008; Portillo et al., 2013). The potential harm of brine on the environment yields from either its higher than normal salinity of ambient, or due to pollutants that otherwise would not be present in the receiving waterbody. These include chlorine and other biocides, heavy metals, antiscalants, coagulants, and cleaning chemicals (Miri and Chouikhi, 2005; Lattemann and Höpner, 2008; Ladewing and Asquith, 2012).

To safeguard a sustainable use of desalinationtechnology, the impacts of desalination process, specially the wastes of brine, should be investigated and mitigated as far as possible using adequate instrument for this purpose under the frame

of environmental impact assessment (EIA) by developing appropriate mitigation measures and alternatives, such as modifications to the process or alternative project sites (Lattemann and Höpner, 2008).

Linked toEIA of desalination plants, the social impact assessment (SIA) on the society near the desalination plant should be taken into consideration to determine how much the desalination plant could enhance the people's lives, the quality of suppliedwater as well as to survey their acceptance on the desalination process according to the quality of the provided services by the plant. In this regard, this study provides an integrated study about the environmental and social impact assessment (ESIA) for the expanded seawater desalination plant of Deir Al-Balah.

II. STUDY AREA

The Gaza Strip (Fig.1.) is a strip with 42 km long, between 6 and 12 km wide, and covers an area of 365 km^2. The Gaza Strip consists of five governorates: North Gaza, Gaza, Deir Al-Balah, Khanyounis and Rafah governorates. The estimations of the Palestinian Central Bureau of Statistics (PCBS) for the year of 2017, show that the population of Gaza Strip was 1.94 million inhabitants (PCBS, 2017).



Fig.1. Location of the Gaza Strip

The Gaza Strip is located in the south-eastern of the Mediterranean, in the transitional zone between the arid desert climate of the Sinai Peninsula and the semi humid Mediterranean climate along the coast. The average daily mean temperature in the Gaza Strip ranges between 25.8°C in summer and 13.4°C in winter (CMWU, 2012). The average rainfall rate over the Gaza Strip is about 317 mm per year (CMWU, 2011). The daily relative humidity fluctuates between 65 and 60 % in the daytime and 85 and 80 % at night in the summer andwinter, respectively (MEnA, 2001). In summer, sea breeze blows all day and land breeze blows at night, and wind speed reaches its maximum value at noon period and decrease during night. During the winter, most of the wind blow from the Southwest and the average wind speed is 4.2 m/s. In summer, strong winds blow regularly at certain hours, and the daily average wind speed is 3.9 m/s and come from the Northwest direction (CMWU, 2012).

The coastline of the Gaza Strip was formed over 15 thousand years ago by the deposits coming from the Nile originated in the first place from the mountains of Africa; therefore, two main factors have created the beach of Gaza: the availability of sand and the motion of waves (Perlin and Kit, 1999). The estimations indicate that the net annual alongshore sediment transport on the beaches of Gaza is about 190,000 m^3 (Abualtayef et al., 2013). The coastal profile of the Gaza Strip consists ofsand, and erosion-resistant formations of rock and kurkar protrude, on the seabed, on the beach, and in the cliffs. The marine environment of the Gaza Strip contains about 201 fish species which are distributed at a depth between 20 and 200 m. The majority of the species are bony fishes 163 species consisting 81%of the fish population; moreover, the presence of cartilaginous fishes such as sharks, rays, and other forms is 19%of the observed fish fauna. The fish distribute in different types of habitats; the most important habitat for bony fishes in the Gaza Strip is the rocky substrate, while the majority of cartilaginous fishes use the soft bottoms, muddy, and sandy substrates (MEnA, 2001).

The current situation in the water sector of the Gaza Strip has been characterized by various parties as a humanitarian crisis. The primary source of freshwater is the underlying groundwater that is grossly contaminated, and at present yields, almost no flow of acceptable quality for domestic use (PWA, 2011). At its present rate of deterioration, over 95%of the underlying portion of the coastal aquifer on which the Gaza Strip relies on for its water needs is contaminated with unacceptable high levels of either nitrate (NO_3) or chloride (Cl), posing significant health risks to Gaza's residents (PWA, 2014). Desalination of water through reverse osmosis has become the most realistic option to meet the rapidly growing water demand in the Gaza Strip (Assaf, 2001; Ghabayen et al., 2004).

III. OVERVIEW OF DEIR AL-BALAH SEAWATER DESALINATION PLANT

In response to the worsening water crisis in Gaza Strip, the prepared Comparative Study of Options for an Additional Supply of Water for the Gaza Strip (CSO-G) by the Palestinian Water Authority (PAW) highlights that desalination of seawater can urgently mitigate the deterioration in both the quantity and quality of groundwater and can alleviate the current humanitarian and public health crisis in Gaza by

improving the quality and increasing the quantity of the water available for domestic use (PWA, 2011).

Motivated by the critical situation posed in Gaza Strip, the expansion of the existing seawater desalination plant of Deir Al-Balahwas highly advised to alleviate water supply issues and improve the quality of life in Gaza Strip. Currently, the existing capacity of Deir Al-Balahdesalination plant is 2,600 m^3/day of freshwater, and the proposed desalination capacity will be expanded to reach 6,000 m^3/day(PWA, 2011; UN, 2014). The seawater desalination plant of Deir Al-Balah is located in the governorate of Deir Al-Balah at the seashore of Mediterranean as shown in Fig.1.about 850 m to the east from the main sea street, at an elevation of 3 m above mean sea level (MSL). Major land use categories of the coastal area in Deir Al-Balah include residential, industrial and commercial. Parts of the beach are used for fishing and recreational purposes.The land surface features in the coastal zone can be described as flat with an average slope of 1:100; elevations vary from sea level up to 4 m above MSL. The coastal zone is covered by finer sediments (i.e. sand and silt). However, the coastal profile does not only consist of sand, but also of erosion-resistant formations of rock and kurkar, which protrude in parts of the seabed, the beach and in sea cliffs (MEnA, 2001). The nearest residential areas to the desalination plant site are Deir Al-Balah refugee camp and the city center, located approximately 1.5 km north and north east from the plant site, respectively. The community uses the beach for recreation; the beachfront area to the west of the desalination plant site is open and is used for fishing related activities. Currently, Deir Al-Balah desalination plant desalinates the feedwater from three beach wells located about 30 m from the shoreline, the produced brine from the existing capacity of 2600 m^3/day, approximately reaches 3,624 m^3/day, is disposed onshore via surface open channel (Fig.2a.). However, due to the plant's expansion, the expected quantity of brine that will be discharged from the plant in its full operation capacity is about 9,840 m^3/day (PWA, 2011; UN, 2014). Hence, the PWA(2016) suggests to replace the existing brine disposal system by an offshore multiport diffuser extends into the sea (Fig.2b.).



(a)



(b)

Fig.2. Brine disposal systems, (a) Existing; (b) Expansion

IV. METHODOLOGY AND ANALYSIS OF DATA

In achieving the purposes of ESIAforDeir Al-Balah seawater desalination plant, this research appliesCornell Mixing Zone Expert System CORMIX v.9.0 which computes the plume characteristics in the mixing zone within which the fluid motion, turbulent field and saline dispersion are dominated by the discharge properties such as the mass flux and buoyancy flux of outfall jet (Jones et al., 2007). The hydrodynamic flow classification schemes in the CORMIX system use the length scale concepts, as a measure of the influence of each potential mixing process due to momentum and buoyancy fluxes of the discharge relation to boundary interactions, in order to predict steady state mixing zone characteristics and plume dynamics such as free jets, shoreline attached jets, wall jets and upstream intruding plumes (Doneker and Jerika, 2007). The model of CORMIX was run to demonstrate the efficiency of the suggested designof the brine disposal system by PWA, to visualize the diffusion of brine plume into the environment of marine.

On the other hand, in order to gain a comprehensive social study about the society's nature and behavior in the vicinity of the desalination plant and to survey the population's acceptance about the provided water services from desalination plant and other water utilities, the research utilizes well-structured questionnairesthat were distributed on people in the region of plant. The collected data by these questionnaireswere processed, audited, analyzed and visualized into statistical figures.

V. RESULTS AND DISCUSSION

The results of ESIA are presented by integrating the results of EIA and SIA as follow:

5.1 Environmental Impact Assessment (EIA)

As environmental controls become more costly to implement and the penalties of judgment errors

become more severe, environmental quality management requires more efficient management tools based on greater knowledge of the environmental phenomena to be managed (Jirka, and Akar, 1991). Numerical modelling became a good tool tocharacterize the environmental impacts of brine onmarine and predict its behavior and dispersionintothe sea, considering effluent properties, discharge system features and ambient conditions (Palomar et al., 2012a, b). Ocean outfalls are classified according to their location, their mixing features, and their effluent characteristics. Onshore surface discharges have traditionally been installed due to their low costs, and the brine outfall from the existing desalination plant is onshore. However, such discharges should be analyzed carefully and generally be avoided due to their limited mixing characteristics, high visibility, their need for coastal zone construction, and thus generally larger impacts. Therefore, it is recommended to apply more modern efficient mixing devices, which overcome the limitations of traditional surface onshore discharges. These include single or multiport submerged diffuser systems, which have a flexible location and are capable of creating good mixing rates (Bleninger and Jirka, 2010).

In response to the sensitivity of Gaza's coastal zone, it is recommended to apply an efficient brine disposal system to mitigate the environmental negative impacts that may result from the discharging activities of brine into marine environment. In EIA of this study, and in order to characterize the coastal and marine environment at the beach of DeirAl-Balah in the front of the desalination plant, the discharged brine through the supposed design of the disposal system by PWA (2016), shown in Fig.3., was configurated using CorSpy and modelled by CORMIX model.

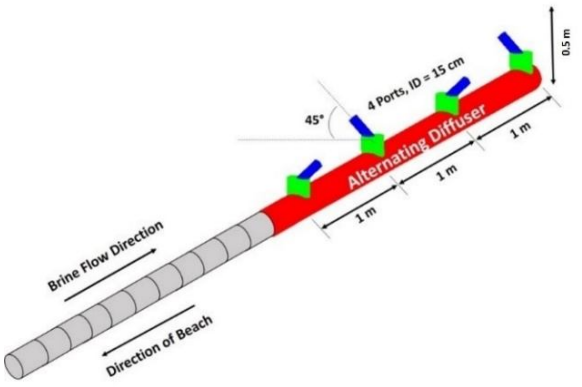


Fig.3.CorSpy view of brine diffuser(PWA, 2016)

The illustrated configuration in Fig.3. is an alternating diffuser system (a fanned-out nozzle diffuser ports design) which imparts no net horizontal momentum flux, the diffuser was suggested by the PWA (2016)to carry the amount of 9,840 m^3/day, for the maximum daily flow of brine. The salinity of the discharged brine via this diffuser reaches 82,500mg/l and it is proposed to extend the diffuser to an offshore distance of 65 m at a seawater depth of 2.2 m MSL. The normal salinity of seawater is about 38,200 mg/l (IOLR, 2016). However, due to the discharge of brine, the excess salinity above the salinity of seawater may reach to 44,300 mg/l (PWA, 2016).

The main parameter that could enhance or inhabit the mixing and diluting process of brine is the velocity of seawater current. Reasonably, the outfall design does not necessarily rely only on remote episodes of very high current speeds. It is also economical as it does not only follow minimum current speed ≃ 0, which is a stagnant and rarely occurring case (Maalouf et al., 2014). Typically, in the coast of Eastern Mediterranean, the observed mean currents are directed northward, parallel to the shoreline, and the mean current velocities are 0.05–0.10 m/s (Brenner, 2003). The general circulation, due mainly to the geostrophic current and shelf waves, depicts the well-known anticlockwise circulation around the whole Levantine basin of Eastern Mediterranean (Brenner, 2003; Menna et al., 2012).

Hence, in this study a current velocity of 0.05 m/s was run as a conservative current speed to illustrate the worst mixing case.Fig.4. demonstrate the simulation result for the discharged brine from Dier Al-Balah seawater desalination plant. The modelling study was prepared on the worst case that forms the maximum expected concentration characteristics of the brine and most limited mixing conditions.

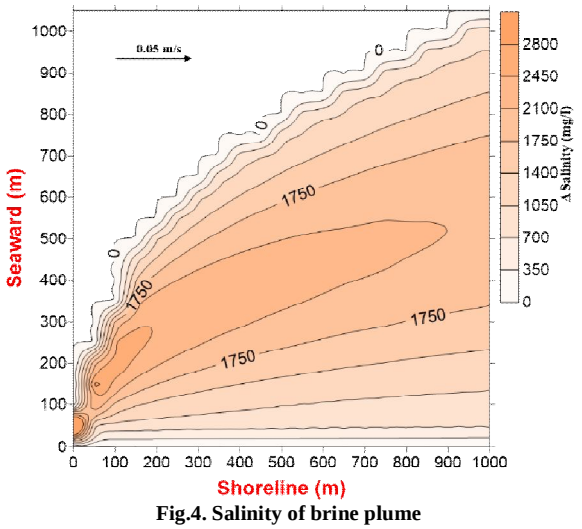


Fig.4. Salinity of brine plume

There are many potential regulations related to mixing zones, but there are no specific regulations on mixing zones particular to brine discharges in Palestine, nor any specific standards that could be directly applied from other countries or plants. Recently, based on studying different alternatives for brine dispersion standard, the PWA recommended

best practice regulations for the disposal of liquid waste based on the UNEP Sea Water Desalination in the Mediterranean: Assessment and Guidelines (2003)–Model Permit and Ambient Standards, was considered appropriate to the brine dispersion modeling and to establish potential permit levels. In this regard, UNEP regulations for the practices of liquid waste discharging into the marine environment characterize the mixing zone as a circle with a diameter of 100 m centered at the disposal point where the excess in ambient salinity at the circle perimeter should not exceed 10% (less than 4 ppt) of the normal ambient salinity. The simulation result of Fig.4. showsthat in the worst dilution pattern at the lowest current speed of 0.05 m/s, the excess salinity at the edge of mixing zone is 2930 mg/l, which is about 7.67% above ambient and according to UNEP regulation it is less than 10% of the ambient (3,820 mg/l). Results show high salinity concentrations within 20 m diameter and gradually decreasing toward the edge of mixing zone. Excess salinity of less than 5%above the ambient has dispersed beyond 1,000 m downstream.

5.2 Social Impact Assessment (SIA)

The social effects of any project on the public arean integral part of ESIA polices. The public consultation and participation facilitate adequate public inputs for identifying issues, evaluating their significance and for deciding measures to avoid or mitigate impacts. Baseline conditions are the starting point to monitor over time the changes to a community due to the introduction of a new project. The baseline conditions are a snapshot in time representing the pr-project conditions in the community. In general, the expanded desalination plant of Deir Al-Balah affects the population of Gaza Strip in whole, however, the main affected populations are the residents of Deir Al-Balah governorate.

5.2.1 Land Use

The area of the seawater desalination plant is an opened area with very limited vegetation cover and bordered with a main costal road connecting Gaza with Rafah. Within this area, recreation facilities have been established at beach. Popular activities including swimming, fishing and walking are practiced in this area. The areas of built-up and mixed agriculture record the highest percentages, more than 50%, from the total area of Gaza Strip, while the area of water resources is the lowest of about 0.24%.Table.1. demonstrates the areas and percentages of land use and land cover (LULC) in the Gaza Strip.

Land Use Category	Area (km^2)	Area (%)
Built-up areas	91.51	24.87
Citrus orchards	36.45	9.90
Greenhouses	8.14	2.21
Horticulture	17.74	4.82
Mixed agriculture	113.30	30.79
Natural vegetation	16.01	4.35
Olives	48.13	13.08
Sand	35.39	9.62
Water	0.87	0.24
Total Area of Gaza Strip	367.54	99.88

Table.1.Land Use in the Gaza Strip (IUG, 2014)

The area around the seawater desalination plant of Deir Al-Balah contains built-up areas in the northern part, while the eastern areas are agricultural areas as well Fig.5. visualize the LULC along the Gaza Strip.

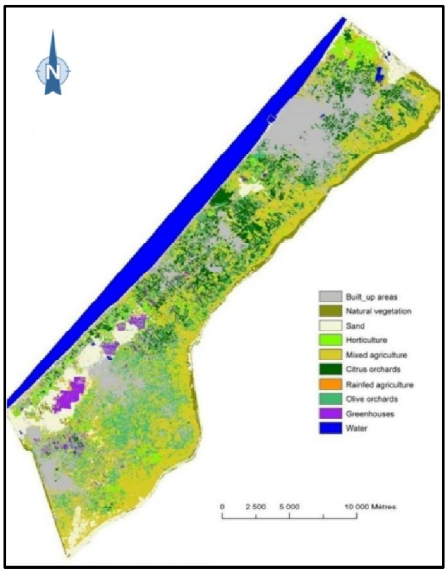


Fig.5. Land use and Land Cover in Gaza Strip (IUG, 2014)

The site of the desalination plant is characterized by agricultural lands with low urban density around 7000 inhabitants living in scattered houses. The dominant agricultural lands in mixed agricultural lands.

5.2.2 Economic Issues

Generally, unemployment in the Gaza Striphas been persistently high. The estimated average unemployment rate in the Gaza Stripbetween the labor forceis approximately up to 41%,Table.2.shows unemployment rate in Palestine for the year of 2015. However, the unemployment rate in Deir Al-Balah was the highest in the Gaza Strip with a 48% which is highest rate in Palestine (PCBS, 2015).

Governorate	Unemployment rate (%)		
	Total	Female	Male
North Gaza	41.7	59.5	37.7
Gaza	36.5	59.3	31.0
Deir Al-Balah	48.0	58.9	44.3
Khanyounis	42.5	58.2	37.8
Rafah	41.6	63.1	34.5
Average for Gaza	41.0	59.6	35.9
Average for Palestine	25.9	39.2	22.5

Table.2.Unemployment rate in Palestine (PCBS, 2015)

The average monthly household expenditure in the Palestinian Territories is 945.4 Jordanian Dinar (JD) in 2011 (729.3 JD = 1,041.85 USD) in the Gaza Strip to an average 6.6 members-family. In addition, the poverty rate amongst the Palestinians according to the patterns of consumption reached 25.8% (38.8% in the Gaza Strip) whereas 12.9% in the Palestinian Territories (21.1% in the Gaza Strip) experience extreme poverty(PCBS, 2017).

The economic variations in the Gaza Strip reflect tragic scenarios in poverty, unemployment rates and income levels. Therefore, it is fair to assume that people will tend to look for the least expensive services to the commodities of their life such as clean water. However, paying water bill for the municipality might not be always possible in light of the prevalence of extreme poverty which might lead to rearranging payment priorities and neglect paying the bills.

5.2.3 Population and Demographical Indicators

By the mid of 2017, the PCBS had estimated the total permanent residents in Gaza Strip by 1,943,398 inhabitants. Demographic profile is shown in Table.3.

Indicators		Statistics
Total population		1,943,398
Population by Residence	Urban Population (%)	82.8%
	Rural Population (%)	1.1%
	Camp Population (%)	16.1%
Population by sex	Male Population (%)	50.8%
	Female Population (%)	49.2%
Birth rate (%)		35.8%
Death rate (%)		3.3%
Growth rate (%)		3.3%
Density of population (inhabitants/km2)		5070
Sex ratio (%)		103.4 %
Dependency ratio (%)		82.7%
Life Expectancy at Birth (Males)		71.5
Life Expectancy at Birth (Females)		74.4
Average Household Size		5.7
Population by Age Group (%)		
0-14		42.6 %
15-29		29.5 %
Over 60		3.9 %

Table.3. Population and demographical data in the Gaza Strip (PCBS 2016, 2017)

Gaza residents comprises of 39% of the total Palestinians in the West Bank and Gaza Strip. The male to female ratio is 51% to 49%. The natural population growth rate in 2017 was 3.4%. Specially, the characteristics of the population of Deir Al-Balah governoratehas the same nature as Gaza Strip in whole. By the mid of 2016, the population of Deir Al-Balahgovernorate was estimated by 273,381inhabitants of which about 63% are urban population, 1% are rural, and 36% live in the refugee camps.

5.2.4 Community Health

A baseline Study on Water Quality and Public Health in the Gaza Strip was conducted in 2015 by the Gaza-Program Coordination Unit (G-PCU) at the PWA, to explore the health impacts attributed to the existing poor quality of water in the Gaza Strip (PWA, 2015a). The study highlights a recorded increase in nitrate concentration, which may cause Methemoglobinemiain infants. The study also concluded that high nitrate level in water is associated with the breakout of parasitic infestations in the years of 2011 and 2012. Most of the project area, including the refugee camps in Deir Al-Balah, is recording high Nitrate concentrations in the municipal supplied water of more than 200 mg/1 (higher than the less stringent drinking water quality standard of PWA).

However, some areas are characterized by Nitrate concentrations less than 50 mg/L (within the limit of the WHO Drinking Water Guidelines). This variation per locality could be explained by specific points of leakages from the sewerage network (PWA, 2015a).

The majority of hepatitis A virus (HAV) infection still takes place in early childhood, where it is asymptomatic, self-limiting and leaves life-long immunity. Palestine as one of developing countries is still endemic for acute hepatitis A. In the year of 2014, there was a decrease of reported number of cases compared to the previous two years. During 2014, a total of 860 cases were reported with an incidence of 48.8 per 100.000 population while during 2013, a total of 1248 cases (73.3 per 100.000 population) were reported and 1010 cases (61.4 per 100.000 population) were reported in the year 2012. This decrease could be explained by the underreporting during the war on Gaza during this year (MOH, 2014). The highest incidence rate per 100.000 population of reported cases in the year 2014 was reported in North governorate (67.4), followed by Khanyounis governorate (63). In Gaza and Deir Al-Balah governorates, the incidence rate was 42.5 and 40.3 respectively and in Rafah governorate the incidence rate was 25.3 as illustrated in Fig.6. This geographical distribution could be explained by the variation of bad infrastructure in some governorates and bad personal hygiene.

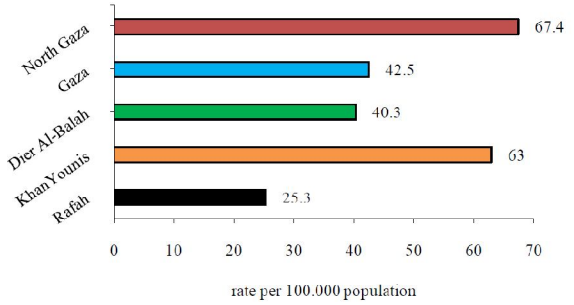


Fig.6.Geographical distribution of Acute Hepatitis A incidence rate per 100.000 population in Gaza Strip (MOH, 2014)

There has also been a reported increase in the incidence of diarrhea during the period between 2009 and 2013 (PWA, 2015b). The rate was 4,017.1 per 100.000 in 2009, which increased to 6,909.1 per100.000 in 2012. Data per governorate shows that Deir Al-Balah (in 2009, 2010 and 2011) elicited the highest incidence rates of diarrhea compared to other communities, such as Gaza city. Bloody diarrhea is a potentially critical condition in which there is blood mixed with loose watery stools. Under this disease all cases with bloody diarrhea are included regardless the cause which could be bacterial infection or parasitic infestation.

As shown in Fig.7., during the year 2014 a total of 7112 cases of bloody diarrhea were reported with an incidence rate of 404 per 100.000 population representing a clear decrease compared to the year 2013 where a total of 8555 cases were reported with an incidence of 503 per 100.000.

From the year 2006 to 2010, there were a continuous decrease of reported cases (MOH, 2014). Geographically, the highest incidence (847 per 100.000) of reported cases was in Deir Al-Balah governorate followed by North governorate with an incidence of 527 per 100.000 population. In Khanyounis and Rafah governorates, the incidence was 495 and 259 per 100.000 while in Gaza governorate it was 148 per 100.000 population (MOH, 2014).

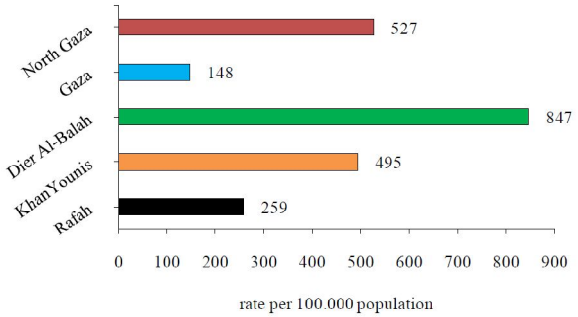


Fig.7. Geographical distribution of the incidence per 10000 population of Bloody Diarrhea in Gaza Strip (MOH, 2014)

5.2.5 Social Survey

The provided social survey by this study demonstrates the responses of the living people in the vicinity of Deir Al-Balah seawater desalination plant to the distributed questionnaires between August and December of 2016.

The results of social survey presented on the community level to ensure the social engagement of relevant inhabitants in the ESIA process.Local community's engagement was ensured using well-structured questionnaires. Around 200 questionnaires were distributed to the residents around the project areas in Deir Al-Balah. The questionnaire contains four parts which are: general questions about the household, domestic water quality at present time, drinking water, impacts of the current desalination plants, residents' social acceptance of the expanding of Deir Al-Balah seawater desalination plant. The results of the questionnaire are as follows:

- **Family Size**

Demonstrated the average members of family in the Gaza Strip, Fig.8. shows that about 35% of the served people have a family size between 6 to 7 members.

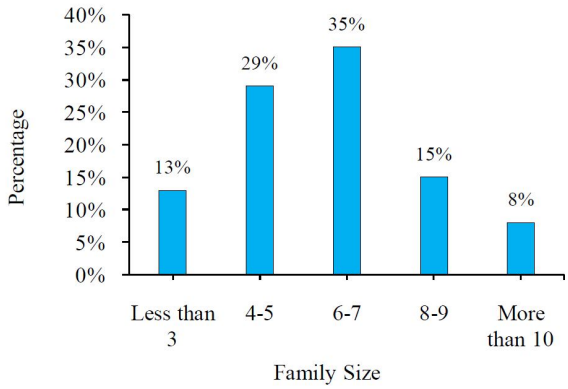


Fig.8. Family size among the local communities participated in the questionnaire

- **Age Distribution of Participants**

The questionnaires were distributed to all age groups youth and old persons living in two to three kilometers from the project areas of Deir Al-Balah seawater desalination sites. Social survey targeted men and women above 16 years old. As demonstrated in Fig.9. around 40% of the participants are above 46 years old while 60% of them are young and below 45 years old. The gender distribution had been taken into consideration, however, around 62% of participants are males while 38% of them are females which reflects the traditional culture of limited women participation in public activities.

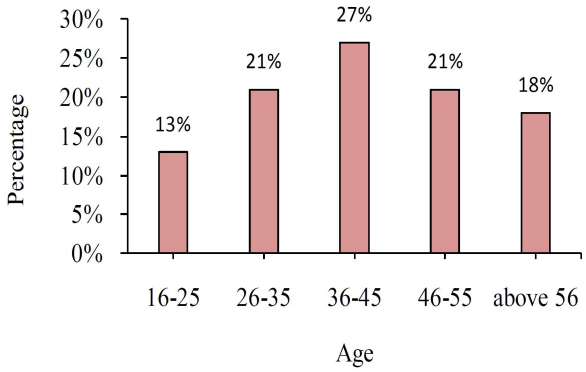


Fig. 9. Age groups among the local communities participated in the questionnaire

- **Employment Rates**

Around 67% of the local communities participated in the questionnaire, Fig.10., revealed that they were not employed in any sectors while around 24% of them were working in service sector and very limited

number working in agriculture, fishing and trade sectors.

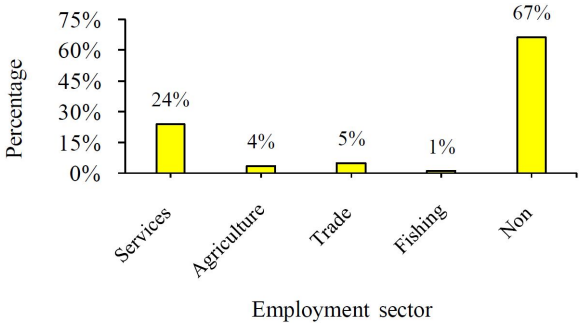


Fig.10. Employment sectors of the local communities participated in the questionnaire

However, as shown in Fig.11., most of them described their living conditions as good or moderate and only 30% of them having bad living conditions.

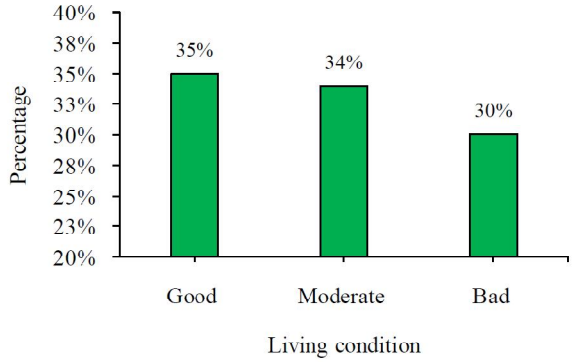


Fig.11.Living conditions of the local communities participated in the questionnaire

- **Source and Quality of Domestic Water**

Most of the interviewed residents inDeir Al-Balah get domestic water from Municipality as service provider while 5% are supplied by CMWU (Costal Municipalities Water Utility) and 7% having their own water wellsFig.12.figures these results.

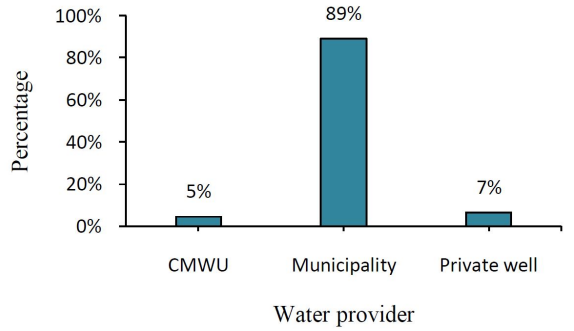


Fig. 12 Domestic water providers

However, Fig.13. highlights that the majority of residents described the quality of water at their households by “very bad” only 3% satisfied of the water quality mostly they are having their own water well. Currently, CMWU is the only service provider in Deir Al-Balah. The residents had little information on the service providers since they used to have the municipality as the only service provider for the last five decades. Such a result reflects a general misunderstanding of the nature and mission of CMWU as a semi-governmental institution which uses the collected fees to sustain and improve water supply in quantitative and qualitative terms.

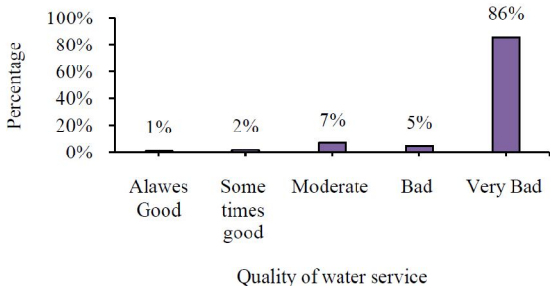


Fig. 13Quality of water services

- **Quantity and Payment of Domestic Water**

Most of the residents (58%),Fig.14., are not satisfied from the received water quantities from municipal networks. Only 9% are satisfied from the water quantities.

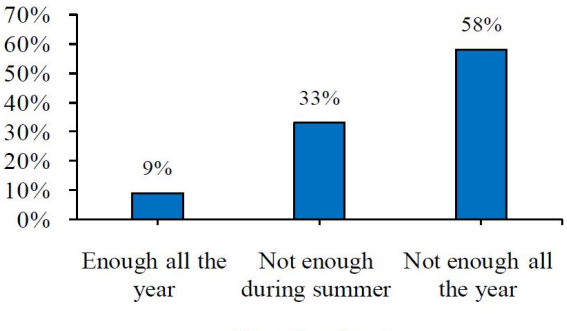


Fig.14. People satisfaction from water quantities

Similarly, as shown in Fig.15., 61% of the resident are not paying the water bills and only 24% are paying the water bills on regular base. Based on the presented results and the opinions of the surveyed people the unfair distribution of water and the unacceptable quality and quality of the supplied water from the services bodies pay the people to escape from paying the water bills. Besides that, the used tariff system does not take into consideration the bad economic situations of the people and their low incomes.

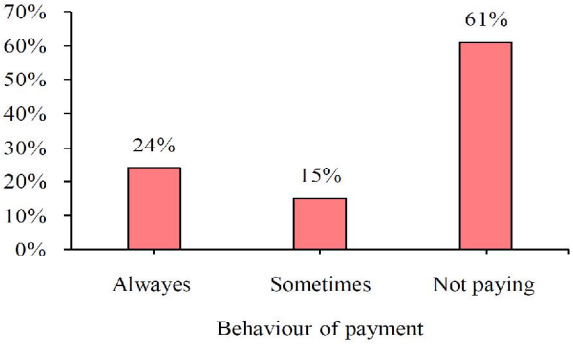


Fig.15.Rate of water bills payment

- **Drinking Water**

Almost all residents are purchasing desalinated (purified) water for drinking purposes. As shown in Fig.16., most of them are depending on vendors (water tankers or shops) to purchase the drinking water.

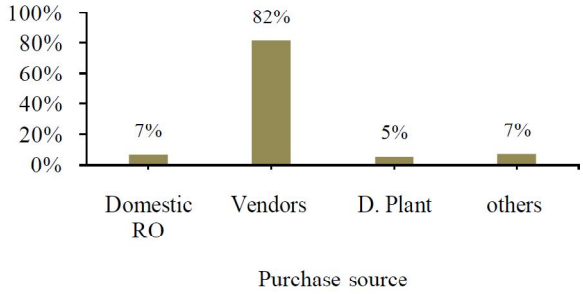


Fig.16. Purchase source of drinking water

Most of the families (Fig.17.) are purchasing one to two cubic meters monthly of water for drinking purposes while 38% are purchasing three to four cubic meters of drinking water.

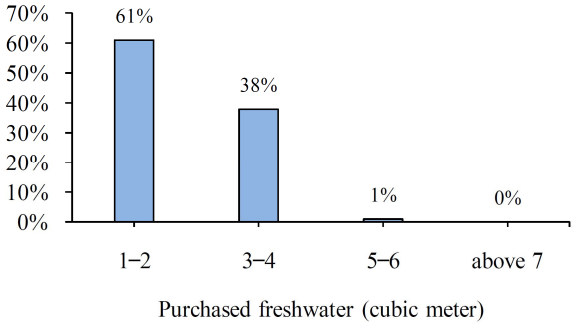


Fig.17. Monthly purchased of freshwater

Most of them (57%)are paying more than 8.5 USD monthly as demonstrated in Fig.18.

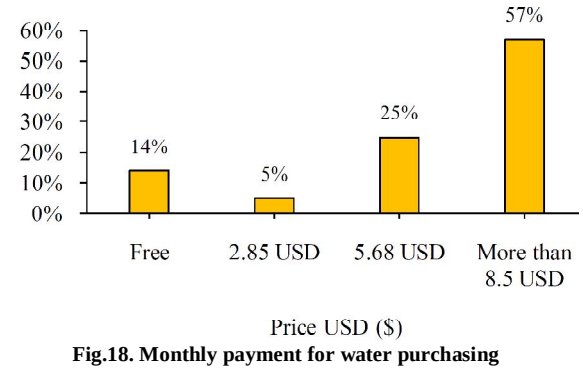


Fig.18. Monthly payment for water purchasing

- **Community Perception of Expansion Activities of Deir Al-Balah Desalination Plant**

Large percentage of the local communities (58%) did not learn about expanding ofDeir Al-Balah seawater desalination plant while 43% have some ideas about it. However most of them are supporting the establishment of such facility and there are considerable percentage they did not decide on this issue as referred in Fig.19.

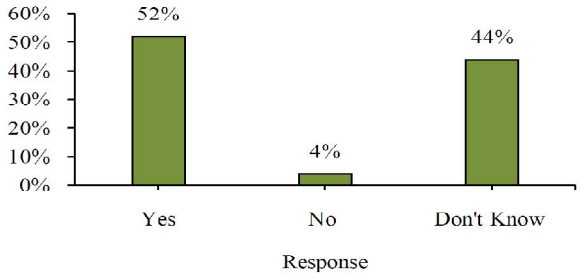


Fig.19. Percentage of people supporting the plant expanding

- **Positive and Negative Impacts of Deir Al-Balah Seawater Desalination Plant**

The majority of the residents reviled that theexpansionactivities for the seawater desalination plant of Deir Al-Balah would have positive impacts from the views of enhancing water quality and quantity and hence most of them support the construction of these types of projects that could improve the sustainability of water services. However, only 5% confirmed that the plant would have negative impacts as a result of the operation process, in addition there are significant percentage (26%) do not know if there are positive impacts or not Figure.20. illustrates graphically the responses of people to the expansion process of the seawater desalination plant.

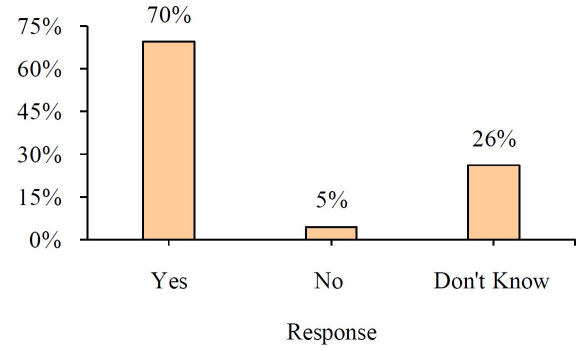


Fig.20. Positive impacts of Deir Al-Balah desalination plant

- **Service Provider and Willingness to Pay**

The vast majority of the residents are preferring the municipality to be the main water service provider for the products of Deir Al-Balah desalination plant as shown in Fig.21.

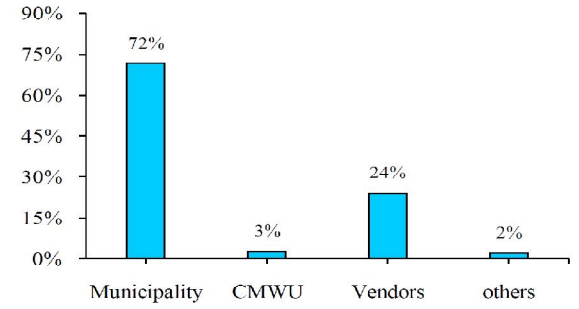


Fig. 21 Water services providers

However, Fig.22. shows that about 54% are willing to pay for the water fees based on the prices of the cubic meter. Also, there is significant percentage (42%) that are not willing to pay because of their economic situations that they are not afford to pay.

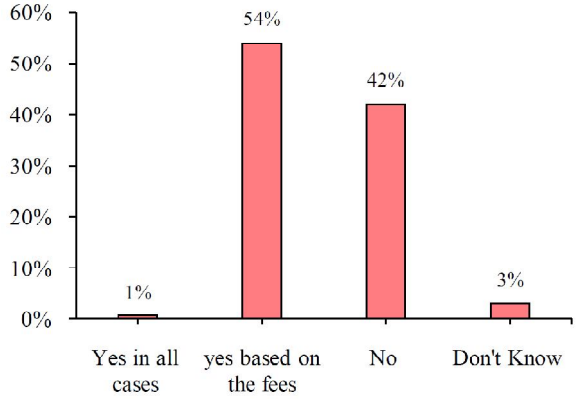


Fig. 22 Willingness to pay for water services

In this regard, due to the regression in the local economic and in order to encourage the consumers to pay for the water service, it is highly suggested to provide a well-structured tariff system that should take into consideration the economic situations and the ability of citizens to pay.

CONCLUSIONS

Seawater desalination plants can significantly contribute in reducing the deficit in the freshwater needs. However, the construction and operation of these plants affects the environmental and society around the plant. Hence, studying the ESIA of the desalination plants is a critical step in order to alleviate their consequences mainly during the operation phase. From the environmental view the main negative impact of the seawater desalination plants is characterized by the challenges of brine discharge into the marine environment. So, optimizing a brine disposal system is an urgent mitigation measure to minimize the negative impact on the environment. In parallel to the EIA, a SIA of the desalination plant should be taken into consideration to survey the acceptance of society in the plant's neighborhood to the existence of such these plants and to investigate how much could the desalination plant contribute in enhancing the quality of people's life.

This study provides an integrated ESIA study for the seawater desalination plant of Deir Al-Balah. The findings of EIA revealed that the suggested marine outfallis very efficient in minimizing the negative effects of brine disposal during operation process in the worst ambient conditions. In the SIA, the study demonstrates that the society in the vicinity of the desalination plant is going to be enhanced and new employment opportunities could be available for the labor force and the quality and quantity of freshwater will be improved. Based on that most of the surveyed people paid acceptance for the expanding operations for the seawater desalination plant of Deir Al-Balah.

REFERENCES

[1] M. Abualtayef,A. Abu Foul, S. Ghabayen, A. Abd Rabou, A. Seif, andO. Mata, "Mitigation measures for Gaza coastal erosion", J Coast Dev,vol.16, no.2, pp.135-146, 2013.

[2] S.A. Assaf, "Existing and the future planned desalination facilities in the Gaza strip of Palestine and their socio-economic and environmental impact", Desalination, vol. 138, pp.17-28,2001.

[3] T. Bleninger, GH. Jirka, "Environmental planning, prediction and management of brine discharges from desalination plants", Middle East Desalination Research Center (MEDRC), Muscat, 2010.

[4] I. Bremere, M. Kennedy, A. Stikker, and J. Schippers, "How water scarcity will affect the growth in the desalination market in the coming 25 years", Desalination, vol.138, pp.7-15, 2001.

[5] S. Brenner, "High-resolution nested model simulations of the climatological", Circulation in the southeastern Mediterranean Sea. AnnGeophys, vol. 21, pp.267-280, 2003.

[6] T. Bleninger, GH. Jirka, "Environmental planning, prediction and management of brine discharges from desalination plants", Middle East Desalination Research Center (MEDRC), Muscat, 2010.

[7] CMWU," Summary about water and wastewater situation in Gaza strip", annual report on water status in the Gaza strip. Coastal municipalities water utility, 2011.

[8] CMWU," Environmental and social impact assessment (ESIA) & environmental and social management plan (ESMP) for Gaza water supply and sewage systems improvement project (WSSSIP) phase 1 and additional financing (AF)", Coastal municipalities water utility, 2012.

[9] R.L. Doneker and G.H. Jirka, "CORMIX user manual: a hydrodynamic mixing zone model and decision support system for pollutant discharges into surface waters", MixZon Inc., Portland, 2007. (Available at http://www.cormix.info).

[10] S. Ghabayen, M. McKee, and M.Kemblowski," Characterization of uncertainties in the operation andeconomics of the proposed seawater desalination plant in the Gaza strip", Desalination, vol.161, pp.191-201, 2004.

[11] K.S. Jacobson, D.M. Drew, and Z. He, "Efficient salt removal in a continuously operated up-flow microbial desalination cell with an air cathode", Bioresour Technol, vol.102, no.1, pp. 376-380, 2011.

[12] G.H. Jirka, and P.J. Akar, "Hydrodynamic classification of submerged multiport diffuser discharges", J Hydraul Eng, vol.117, pp.1113-1128, 1991.

[13] G.R. Jones, J.D. Nash, R.L. Doneker, and G.H. Jirka," Buoyant surface discharges into water bodies. I: flow classification and prediction methodology", J Hydraul Eng, vol. 133, pp. 1010-1020, 2007.

[14] IUG, "Climate Induced Changes on the Hydrology of Mediterranean Basins (CLIMB)", FP-7- 7th Framework Programme Collaborative Research Project, EU, Islamic University of Gaza, 2014.

[15] S. Maalouf, D. Rosso, and W. Yeh, "Optimal planning and design of seawater RO brine outfalls under environmental uncertainty", Desalination, vol.333, pp.134-145, 2014.

[16] B. Ladewing, and B. Asquith," Desalination concentrate management", Springer, Australia, 2012.

[17] S. Lattemann, and T. Höpner, "Environmental impact and impact assessment of seawater desalination", Desalination,vol. 220, pp. 1–15, 2008.

[18] L. Mehta, "Whose scarcity? Whose property? The case of water in western India", Land Use Policy, vol. 24, pp.654-663, 2006.
[19] MEnA, "Gaza coastal and marine environmental protection and management action plan", Ministry of Environmental Affairs, Jerusalem, 2001.
[20] M. Menna, P. Poulain, G. Zodiatis, and I. Gertman," On the surface circulation of the Levantine sub-basin derived from Lagrangian drifters and satellite altimetry data", Deep-Sea Res I, vol. 65, pp.46–58, 2012.
[21] R. Miri, and A. Chouikhi, "Ecotoxicological marine impacts from seawater desalination plants", Desalination vol.182, pp.403-410, 2005.
[22] MOH, "Annual Epidemiological Report Gaza Strip'", 2014. http://www.moh.gov.ps/portal/wp-content/uploads/Annual-Epidemiological-Report-2014.pdf
[23] J. Morillo , J. Usero, D. Rosado, H. El Bakour, A. Riaza, and F. Bernaola, "Comparative study of brine management technologies for desalination plants", Desalination, vol. 336, pp. 32-49, 2014.
[24] H.J. Oh, T.M. Hwang, and S. Lee, "A simplified simulation of RO systems for seawater desalination", Desalination, vol. 238, pp.128-139, 2009.
[25] P. Palomar, J.L. Lara, I.J. Losada, M. Rodrigo, and A. Alvarez A,"Near field brine discharge modelling part 1: analysis of commercial tools", Desalination, vol. 290, pp.14-27, 2012a.
[26] P. Palomar, J.L. Lara, and I.J. Losada, "Near field brine discharge modeling part 2: validation of commercial tools", Desalination, vol. 290, pp. 28-42, 2012b.
[27] PCBS, "Estimated population in the Palestinian territory mid-year by governorate", 1997–2017. IOP Publishing Physics Web.http://www.pcbs.gov.ps Accessed 25 June 2017.
[28] A. Perlin, and E. Kit,"Alongshore sediment transport on Mediterranean coast of Israel", J Waterw Port Coast Ocean Eng, vol. 125, no. 2, pp. 81-83, 1999.
[29] E. Portillo, G. Louzara, M. Ruiz de la Rosa, J. Quesada, J.C. Gonzalez, F. Roque, M. Antequera, and H. Mendoza, "Venturi diffusers as enhancing devices for the dilution process in desalination plant brine discharges", Desalin Water Treat, vol. 51, pp. 525-542, 2013.
[30] PWA, "The comparative study of options for an additional supply of water for the Gaza strip (CSO-G)", the updated final report. Palestinian Water Authority, 2011.
[31] PWA, "Gaza strip: no clean drinking water, no enough energy, and threatened future", Palestinian Water Authority, 2014.
[32] PWA, "Baseline Study on Water Quality & Public Health in the Gaza Strip", Gaza Programme Coordination Unit (G-PCU), Palestinian Water Authority, 2015a.
[33] PWA, "Gaza strip: desalination facility project: necessity, politics and energy", Palestinian Water Authority, 2015b.
[34] PWA, Personal Meeting on May 31, 2016.
[35] UN,"Office of The United Nations Special Coordinator for The Middle East Peace Process Report to Ad Hoc Liaison Committee," United Nations, 2014.
[36] J.L. Sánchez-Lizaso, J. Romero, J. Ruiz, E. Gacia, J.L Buceta, O. Invers, Y.F. Torquemada, J. Mas, A. Ruiz-Mateo, M. Manzanera, "Salinity tolerance of the Mediterranean seagrass Posidonia oceanica: recommendations to minimize the impact of brine discharges from desalination plants",Desalination, vol. 221, pp. 602-607, 2008.
[37] UNEP, "Seawater desalination in the Mediterranean: assessment and guidelines-model permit and ambient standards", The United Nations Environment Programme, 2003.
[38] C.J. Vörösmarty, P.B. McIntyre, M.O. Gessner, D. Dudgeon, A. Prusevich, P. Green,S. Glidden, S.E.Bunn, C.A. Sullivan, C. Reidy Liermann, and P.M. Davies, "Global threats to human water security and river biodiversity", Nature 467:555–561,2010.
[39] B. Zhang, and Z. He, "Improving water desalination by hydraulically coupling an osmoticmicrobial fuel cell with amicrobial desalination cell", J Membr Sci,vol. 441, pp. 18-24, 2013.

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