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ENVIRONMENTAL IMPACT ASSESSMENT OF NUCLEAR DESALINATION PLANT AT KANUPP

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A Nuclear Desalination Demonstration Plant (NDDP) of 1600 m^3/d capacity is being installed at Karachi Nuclear Power Plant (KANUPP). A Nuclear Desalination Plant (NDP) can impact the aquatic environment mainly by subjecting the aquatic life to possible temperature increase and salinity changes in the vicinity of the cooling water and brine discharges. Any wastewater effluent, which will be discharged from the NDDP, may have some adverse effects on the marine life and general environment. In order to protect the environment and comply with the requirement of the Pakistan Environmental Protection Agency (PEPA) an Environmental Impact Assessment (EIA) for the discharged effluent from NDDP was carried out. In the present work baseline study was carried out for project location, climate, water resources, and ecology. Checklist has been prepared for identification of possible environmental impacts of the project and marked as insignificant, small, moderate or major impact. Appropriate mitigation measures have been recommended that can be incorporated into the intended program to minimize environmental impacts identified during the assessment. Specific conclusions of the study and recommendations have also been provided in this paper.

Keywords: Nuclear desalination, EIA, Multi-effect distillation

1. Introduction

About seventy percent of the earth is covered with water, however, only 2.5% of that is fresh water. More than 70% of this fresh water is frozen in the icecaps of Antarctica and Greenland. Rest is in the form of soil moisture or in deep inaccessible aquifers or falls at the wrong time and place in monsoons resulting in floods. Only about 0.08% of that water is thus readily available for human consumption and even that is very unevenly distributed [1].

Many countries, including China, India, Mexico, Pakistan and nearly all of the countries of Middle East and North Africa, have literally been heaving a free ride over the past two or three decades by rapidly depleting their water resources [2]. This could have catastrophic results in terms of limiting their ability to produce enough food to feed their populations. Moreover, even as the population of world grows, the limited easily accessible freshwater resources in rivers, lakes and shallow groundwater aquifers are dwindling as a result of over-exploitation and water quality degradation. According to United Nations forecasts, about two thirds of the world´s population will face shortages of clean freshwater by 2025 [3].

1.1 Water Scarcity in Pakistan

The population of Pakistan is over 144 million and is projected to increase to 260 million by 2050. Added to this, the per capita consumption of water in Pakistan is the highest in the region and the 14th highest in the world due to inefficiency of use [2, 4]. Water supply development in Pakistan is also reaching its limits. The Mangla dam may become inoperative in 10 to 15 years time because of silting and no new large dam is being built [2, 3].

Rapid urbanization and high population growth in major cities of Pakistan has led to a deterioration of living conditions. Problems are compounded as almost all fresh water resources are severely polluted due to discharge of untreated industrial and municipal wastes [5]. Investments in drinking water supply, sanitation, wastewater disposal and treatment facilities have not followed the pace of urbanization. As a result rivers, lakes and other freshwater bodies close to cities are polluted and downstream communities are forced to use unsafe water or treat the water at high cost [6, 7].

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Pakistan is among 17 countries listed under “absolute water scarcity” [2]. Water scarcity in the near future will be the single greatest threat to human health, the environment and the food supply. Pakistan is entering a period of severe water shortage, which may create chaos in water distribution and its use. Pakistan has a sizeable seacoast extending from Karachi to Iranian border, this belt extends up to 1046 kilometers of this 930 km is from Karachi to Gwader city in the province of Baluchistan. The annual rainfall in this belt is at an average only 15 centimeters. Fresh water is a major priority in sustainable development. Therefore fresh water availability is a major factor for the development of the coastal belt of Pakistan [8].

1.2 Water Supply and Demand in Karachi

The mega city Karachi has limited water resources for domestic as well as for industrial uses. The main water resources for the city are the Kinjeer Lake, where water comes from the Indus River and the Hub River where a dam has been built to capture rainwater. The city receives 435 MGD of drinking water form river Indus and other sources. However, the net demand for the year 2001 has been 594 MGD thus there is a gap of 159 MGD in demand and supply. As per the data provided by the Karachi Water & Sewerage Board (KW&SB) the demand of water in the city increases by 6% annually which is approximately 100 Million Gallon per Day (MGD) every three years. KW&SB calculates the water demand on the basis of 54 gallon per capita per day consumption. Better water conservation, water management, pollution control and water reclamation are all part of the solution to projected water stress. The present scenario necessitates the exploration of new sources of fresh water, including the desalination of seawater [8].

1.3 Seawater Desalination

Desalination technologies have been well established since the mid-20th century and widely deployed in the Middle East and North Africa. The contracted capacity of desalination plants was 20 Million m^3/d worldwide as of 1995 and has since been increasing by an annual average of 1 Million m^3/d [9]. Desalination processes currently being utilized for fresh water production in the world can generally be classified into two categories namely; membrane and distillation processes [10]. Commercial seawater desalination processes that are proven and reliable for large-scale freshwater production are multi-stage flash (MSF) and multi-effect distillation (MED) for evaporative desalination and reverse osmosis (RO) for membrane desalination. Vapor compression (VC) plants based on thermal and mechanical vapor compression are also employed for small and medium capacity ranges. These processes have their inherent advantages and disadvantages.

Most desalination today uses fossil fuels, and thus contributes to increased levels of greenhouse gases. Due to the inadequacy of natural energy sources in Pakistan coupled with the environmental pollution concerns, there is a strong case for adopting an environmentally clean technology for power supply. Therefore, nuclear desalination seems to be a better solution to produce sweet water from Arabian Sea. Joint production of power and water has been studied in assistance with International Atomic Energy Agency (IAEA) in various parts of world. Studies showing that utilizing nuclear energy for the production of power and water is an economical option. It is possible to obtain potable water at the cost of 0.5US$/$m^3$ and electricity upto 4 cents/kWhr [8].

1.4 Nuclear Desalination

Nuclear desalination is the production of potable water from seawater in a facility in which a nuclear reactor is used as the source of energy (electrical and/or thermal) for the desalination process. The facility may be dedicated solely to the production of potable water, or may be used for the generation of electricity and the production of potable water, in which case only a portion of the total energy output of the reactor is used for water production. In either case, the notion of nuclear desalination is taken to mean an integrated facility in which both the reactor and the desalination system are located on a common site and energy is produced on-site for use in the desalination system. It also involves at least some degree of common or shared facilities, services, staff, operating strategies, outage planning, and possibly controls facilities and seawater intake and outfall structures. Nuclear power plants have relatively lower thermal efficiency, as compared to conventional power plants. Hence, of the same electrical energy output, the nuclear power plant will have larger amounts of waste heat for dumping in oceans and rivers. It is this waste heat that can be effectively utilized for producing water through thermal desalination.

Furthermore, nuclear desalination option has economic advantage, minimum environmental and public health impacts, and provides the saving in the remaining fossil fuel. Fortunately, both nuclear and desalination technologies are mature and proven by experience, and are commercially available from a variety of suppliers.

1.5 Role of PAEC and IAEA in Nuclear Desalination

As early as the 1960s, the International Atomic Energy Agency (IAEA) and individual countries carried out several technical and economic feasibility studies to investigate the utilization of nuclear energy for seawater desalination. IAEA passed a resolution in 1989 to investigate the scope of nuclear desalination in collaboration with various member countries. An advising body to director general IAEA was founded in 1997 to provide recommendations and suggestions in the field of nuclear desalination. Assessments of IAEA performed for nuclear desalination studies indicated that nuclear desalination would be technically feasible and economically competitive with fossil and renewable energy in a range of situations.

With the assistance of IAEA a feasibility study was executed to evaluate the potential for a small scale desalination demonstration plant at KANUPP, which can provide the basic information for a potential future large scale plant. PAEC is participating in the Coordinated Research Project (CRP) launched by IAEA in February 2002 titled 'Economic research/assessment of coupling existing 137 MWe KANUPP with a desalination plant'. Presently, installation of a 1600 m^3/day Nuclear Desalination Demonstration Plant (NDDP) coupled to KANUPP is in final stages [11].

2. EIA for NDDP at KANUPP

A desalination plant can impact the aquatic environment mainly by subjecting the aquatic life to possible temperature increase and salinity changes in the vicinity of the cooling water and brine discharges. Any wastewater effluent which will be discharged from the NDDP at KANUPP may have some adverse effects on the marine life and general environment. In order to protect the environment and comply with the requirements of the Pakistan Environmental Protection Agency (PEPA) an Environmental Impact Assessment (EIA) for the discharged effluent from NDDP is imperative. Therefore, present study is carried out to assess the environmental impact (if any) due to the installation and operation of NDDP.

2.1 Methodology

In order to carry out the EIA of NDDP baseline study was carried out for project location, climate, water resources, and ecology. Checklist has been prepared for identification of possible environmental impacts of the project and marked as insignificant, small, moderate or major impact. Appropriate mitigation measures have been recommended that can be incorporated into the intended program to minimize environmental impacts, if any identified during the assessment.

3. Environmental Impact Assessment

The main objective of safety in a Nuclear Desalination Plant (NDP) is to protect individuals, society and the environment from harm by establishing and maintaining in nuclear installations effective defenses against radiological and other conventional hazards. The safety of a nuclear desalination plant depends mainly on the safety of the nuclear reactor and the interface between the nuclear plant and the desalination system. It must be ensured that any load variation of steam consumption in the desalination plant would not cause a hazardous situation in the nuclear plant. There should be suitable provision for monitoring the radioactivity level in the isolation loop and desalination system. In case of a Pressurized Heavy Water Reactor (PHWR), the tritium level in the heating steam and product water must be checked regularly. Adequate safety measures must be introduced to ensure near zero radioactivity release to the product water. Any adverse effect of discharging effluent from desalination plant should be monitored.

3.1 Siting and the Impact of Proximity of Population Centres

Proximity to population centres is an advantage for desalination plants from the point of view of water supply planning, whereas isolation from population centres is often preferable for a nuclear plant. Balancing these two competing factors is an essential element in the overall water and energy supply policy for a country. Where the nuclear desalination system is located in proximity to population centres, this must be taken into account in emergency planning. In addition, the safety aspects at every stage of the nuclear desalination project should be evaluated to assess any adverse environmental impact to the workers and nearby population.

3.2 Discharged Water Considerations

The limits for discharge of radioactivity to the environment are normally specified by national regulatory bodies and are often based on internationally agreed values. Brine discharges, cooling water discharges and product water must be evaluated in this respect. The specification is worked out for each location of the nuclear plant taking into account the food chain of the local population, the site conditions, etc. The annual limit of intake (ALI) values for each radionuclide is determined, and these form the guidelines for assessment of discharge levels from the nuclear desalination plant. Discharge limits for a nuclear plant are normally based on open discharge into the sea, allowing for high levels of dilution before reaching the human population [10].

Finally, care must be taken in the design of the intake and outfall structures for a nuclear desalination plant to ensure that water discharged from the plant cannot be circulated by local water currents back to the location of the intake structure. While this is an important consideration for nuclear power plants, it is particularly important for nuclear desalination plants, as well. Discharge water from the nuclear plant, possibly containing radionuclides, must not be drawn back into the intake structure and subsequently make its way to the desalination plant, leading to the possibility of radioactive materials being carried over into the desalted water.

3.3 NDDP at KANUPP

Nuclear Desalination Demonstration Plant (NDDP) at Karachi Nuclear Power Plant (KANUPP) is being installed having capacity of 1600 m^3/d. The NDDP at KANUPP is based on Multi Effect Distillation (MED) process which has a fairly long history. It is the oldest large scale evaporative process used for the concentration of chemicals and food products, and it was the first process used for producing significant amounts of desalted water from seawater. Thermal energy to the NDDP will be provided through a closed loop re-circulation system. Thermal energy of the extraction steam will be provided to the heat exchanger (re-boiler) for the production of secondary steam [11].

In a nuclear desalination plant it is necessary to prevent transport of radioactivity into the product water. This can be effectively accomplished by suitable design features, which make use of multiple barriers and pressure differentials to block transport of radioactive materials to the desalination plant, and with appropriate monitoring before distribution of the product water. At KANUPP to ensure protection against any radioactivity leakage into the NDDP feed water supply safety feature is provided. An isolation loop (Intermediate Coupling Loop) is provided which is based on Low pressure-High pressure-Low pressure (LHL) strategy. In LHL system isolation loop is kept at high pressure as compared to primary regenerative heater and main feed water loop of NDDP. This provides the safeguard against the entry of any radioactivity from low pressure primary loop to high pressure isolation loop. A pump of 1300 m^3/h capacity will be installed in the pump house, which will supply the seawater to the NDDP.

3.4 Source of Raw Water for the Production of Potable Water

Arabian Sea is located between the Indian and the Arabian Peninsula in the northwest of Indian Ocean. The Arabian Sea is the main source of raw seawater for the production of potable water at NDDP. In addition to this Arabian Sea will act as discharge sink for the effluents generated by NDDP.

Objectives of Environmental Impact Assessment

The present study has been carried out to meet the following objectives:

- **Identification** of various activities associated with the proposed study that may have an impact on environment.
- **Prediction** of the likely impacts on the environment due to intended activity during operation of plant.
- **Analyze** the different activities, which may have significant impact on the environment.
- **Document** the impact of different activities on the environment.
- **Recommendation** of appropriate mitigation measures that can be incorporated into the intended program to minimize environmental

impacts, if any identified during the assessment.

4. Types of Studies

Following two main types of studies are carried out:

- Baseline Studies
- Environmental Impact Identification Studies

4.1 Baseline Studies

4.1.1 Selected Parameters

The baseline study was carried out to get the existing data/informations about the environment. Baseline studies included general location and boundaries, climate, water resources, ecological resources, and general environment.

4.1.2 Data Collection

In order to carryout the base line study data were collected from Meteorological Department, Karachi and through net. This includes relative humidity, temperature, precipitation, and astronomical tide level history. The information about water resources and ecological resources were collected from published reports. The required data for climate of NDDP site was obtained from the meteorological station installed at KANUPP. Some of the required information is presented in Table 1.

4.1.3 Parameters Selected for Analysis

As the seawater will be used as influent to the NDDP for potable water production, the quality of seawater was determined. Physical and chemical analysis of seawater at the intake structure was carried out as a baseline study. The maximum, minimum and average values of selected parameters are depicted in Table 2. Maximum rainfall during last 50 years, temperature, and tidal history and wind direction were examined for the existing environment. Probable characteristics of discharged effluent also examined for any possible adverse environmental impact (Tables 1, 3).

As the effluent from NDDP will be discharged with the present outfall of existing power plant, detailed information about the characteristics of the outfall flow rate, TDS and temperature of effluent was collected and presented in Table 1. Out fall flow rate and temperature was obtained from control room recorder which is continuously monitoring these parameters in routine. TDS was determined in the Chemical Monitoring Laboratory, KINPOE, using Gravimetric method [12].

Table 1. Data collected for baseline study for NDDP.

Parameter	Value
Maximum rainfall during last 50 years	253.3 mm
Lowest astronomical tide	28.4 m
Highest astronomical tide	32.0 m
Mean sea level	30.5 m
Ground level	42.1 m
Minimum temperature	6 °C
Maximum temperature	39 °C
Average temperature of effluent discharged at the existing outfall	37 °C
Average flow rate of effluent discharged at the existing outfall	24,500 m^3/hr
Maximum TDS of effluent discharged at the existing outfall	45,000 ppm
Relative humidity at the site	65 - 90%
Annual average wind velocity	3.3 m/s
Annual prevalent wind direction	North-West to South-East
Average Summer wind direction (Morning)	North-West to South-East
Average Summer wind direction (Evening)	West to East
Prevalent tidal wave current direction	West to East

4.2. Environmental Impact Identification Studies

A checklist was prepared (Table 4) for identification of environmental impacts. The checklist provides significance of different parameters of Environmental Impacts in case of installation of NDDP at the site.

4.2.1 Impact Due to Project Location

The site of the NDDP is located at Karachi Nuclear Power Plant (K-1) which is located adjacent to Paradise Point on the arid Arabian Sea coast, at the end of Jhil/Sonari range, about 30 km to the west of Karachi. The nearest port is situated at Kiamari. The average ground elevation at the site is about 41.8 meters (138 feet) and mean sea level at the site is 30.5 meters (100 feet). The normal range of temperature noted in the area is 6°C to 38°C during winter and summer respectively [13].

Table 2. Characteristics of seawater adjacent to NDDP site.

Parameter	Units	Minimum	Maximum	Mean
Temperature	°C	16	31	27
pH at 20 °C		8.0	8.2	8.1
Turbidity	NTU	--	30	15
Conductivity	mS/cm	--	--	53.6
Chemical Oxygen Demand (COD)	mg/l	1.03	1.05	1.04
Total Hardness as $CaCO_3$	mg/l	6,350	7,580	6,500
Total Dissolved Solids (TDS)	mg/l	38,000	45,000	42,000
Total Solids (TS)	mg/l	--	--	46,200
Calcium as Ca^{2+}	mg/l	400	460	450
Magnesium as Mg^{2+}	mg/l	1,300	1,570	1,450
Sodium as Na^{1+}	mg/l	10,800	12,800	11,800
Potassium as K^{1+}	mg/l	380	480	450
Chloride as Cl^{1-}	mg/l	19,360	23,000	21,000
Sulfate as SO_4^{2-}	mg/l	2,700	3,300	3,000
Oil	mg/l	Nil	Nil	Nil

Table 3. Characteristics of various effluents generated at NDDP.

Parameter	Location				
	Pump House	Final Condenser (Inlet/Outlet)	Hydro Ejector (Inlet/Outlet)	Dump Condenser (Inlet/Outlet)	MED (Inlet/Outlet)
Flow rate (m^3/h)	1100	472/240	26/26	602/602	232/165
Pressure (bar)	4	5.4/1	5.4/1	2/1	4.7/1
Temperature (°C)	27	27/40	27/31	27/40	39/42.3
TDS (ppm)	*45,000	45,000	45,000	45,000	45,000/63,000

*Design value.

As the site is already developed and within the boundary of existing power plant the installation of project would produce no significant effect at the KANUPP site with respect to cutting trees, herbs and weeds. In addition, project has no significant effect on workers, surrounding population, buildings, and existing transport routes. Hence, installation of NDDP has no significant adverse environmental effects due to its location.

4.2.2 Impact During NDDP Operation

NDDP is a small demonstration plant which will produce potable water at a rate of 1600 m^3/d. As the thermal energy will be provided from KANUPP the NDDP will not produce any significant air pollution and also does not produce any green house effect in the environment. Arabian Sea will provide the required raw seawater which is profuse and its characteristics are suitable for the said NDDP. The intake structure is at an elevation of 25.6 meter (84 feet) with respect to mean sea level of 30.5 meter (100 feet) i.e. 16.5 meter (54 feet) below the ground level or 4.9 meter (16 feet) below the mean sea level. From the tidal history one may safely assume that there will not be any interruption in the seawater supply during plant operation. It is found that the inlet conduit always remains submerged in the seawater, even during the historically lowest astronomical tide of 28.4 meter (93.2 feet).

4.2.3. Impact of Discharged Effluents from NDDP

Characteristics such as flow rate, temperature, pressure, and total dissolved solids (TDS) of various effluents generated from NDDP at KANUPP is presented in Table 3. In order to compare characteristics of effluents discharge from

Table 4. Checklist of some aspects of EIA for the NDDP, during construction and operation.

No.	Parameter Affecting The Environment	Damage to Environment	Remarks/ protection measures	Initial environmental examination			
				Insignificant effect	Significant effects		
					Small	Moderate	Major
1	Deployment of construction equipments and material	Disturb the surrounding environment	Proposed site is located within K-1 project boundary, which is already developed, minimum construction will be carried out as compared to be done on a virgin land.	✔			
2	Production of CO_2, CO, NO_x and other gases	Increase the air pollution	As the NDDP plant will receive the energy from local grid/K-1 it will not cause harm to environment in terms of air pollution.	✔			
3	Groundwater pollution due to drilling for feed water wells	Risk of groundwater contamination	NDDP plant will get the raw water from the inlet of K-1, there is no chance of groundwater contamination due to drilling of feed water wells.	✔			
4	Increase in TDS	Damage to environment and aquatic life. Degradation of recreational water quality.	Effluent will be diluted with low TDS streams and final effluent will have TDS well below the NEQS allowable limit. Therefore, in the presence of enough diluting seawater it will not cause any significant effect to environment and aquatic life.	✔			
5	Rise in seawater temperature	Damage to aquatic life.	As the final effluent has temperature of 40 °C which will pass through mixing chamber and 426 feet long drain channel. The temperature of discharged effluent at the outfall will be less than allowable limit of 40°C.	✔			
6	Depletion in DO level	Damage to aquatic life.	COD of discharge effluent is only 0.23 ppm while allowable limit is 150 ppm. Therefore, this much COD value will not depleted DO level of seawater significantly.	✔			
7	Change in pH	Damage to aquatic life.	Effluent does not change the pH of seawater.	✔			
8	Rise in toxic material concentration	Hazard to public & aquatic life	According to the specification of antifoaming and antiscaling agents effluent does not contain any toxic component.	✔			
9	Change in COD	Damage to aquatic life. Eutrophication may occur.	COD of discharge effluent is only 0.23 ppm while allowable limit is 150 ppm. Therefore, effluent will not cause any significant environmental effects.	✔			
10	Rise in Gross α and β activity	Hazard to public & aquatic life	There will be no additional α and β activity in the effluent. Isolation loop provides maximum safety against radioactivity leakage	✔			
11	Rise in tritium level	Hazard to public & aquatic life	There will be no additional tritium activity in the effluent. Isolation loop provides maximum safety against radioactivity leakage	✔			

NDDP with the allowable limits provided by EPA, National Environmental Quality Standards (NEQS) for liquid industrial effluents discharged into a water body are presented in Table 5. It is clear from Table 3 that effluents discharged from Dump Condenser outlet, Hydro Ejector outlet, and Final Condenser outlet has normal seawater TDS values and will not increase the TDS value of seawater if discharged into the Arabian Sea. However, discharged effluent from the MED outlet has TDS value of 63,000 ppm. According to NEQS allowable limit discharged effluent may have TDS exceed up to 3,500 ppm from the TDS value of influent or feed water (45,000 ppm). In order to mitigate the problem a mixing chamber of capacity 7.5 m^3 will be provided at the outlet of NDDP. All four effluents (shown in Table 3) will be mixed in this chamber before discharging into the drain channel. Mass balance calculations performed based on conservation of mass and energy using control volume analysis [14]. Mass balance calculations show that the average flow rate of mixed effluent will be about 1,033 m^3/h and average TDS value will be 47,875 ppm which is below the NEQS allowable limit of 48,500 ppm (Table 5) and it will not cause any significant change in the TDS of seawater in the presence of large amount of diluting seawater.

Table 5. National Environmental quality standards given by EPA for liquid industrial effluents discharged into a water body.

Parameter	Units	Standards / permissible limit
Temperature	°C	<40
pH at 20 °C		6-10
Chemical Oxygen Demand (COD)	mg/l	<150
Total Dissolved Solids (TDS)	mg/l	*3,500
Total Suspended Solids (TSS)	mg/l	1,150
Chloride as Cl^{1-}	mg/l	1,000
Sulfate as $SO4^{2-}$	mg/l	600
Oil & grease	mg/l	10

*The concentration of pollutants in raw water being used will be subtracted from the effluent for calculating the NEQS limits.

Impact of Discharged Effluent Temperature: If the temperature of seawater alters significantly it may disrupt the aquatic life and may disturb the natural ecosystem. Table 3 shows the temperatures of different effluents discharging from different points at NDDP. Temperature of effluents discharging from different outlets varies from 31 to 42.3°C. The NEQS allowable limit for effluent temperature discharge into the sea is 40°C (Table 5). However, mass balance calculations shows that the temperature of the mixed final effluent at the outlet of plant will be about 40.1 °C. As after the mixing chamber final effluent from NDDP will spent enough time in about 53.6 meter (176 feet) long closed and 76.2 meter (250 feet) open drain line leading to outfall into the sea which is expected to reduce the effluent temperature significantly before dumping into the sea. In addition to that, the effluent will be discharged with the effluent being discharged at the outfall originating at existing KANUPP. Flow rate and average temperature of effluent being discharged from KANUPP at the outfall is about 24,500 m^3/hr and 37°C respectively [11]. As the existing flow rate at the outfall is about 23 times more than the expected flow rate of effluent from NDDP. Enough dilution will take place at the discharge outfall with the low temperature KANUPP effluent. In the worst condition when temperature of effluent from NDDP will be 40.1°C the expected final temperature of mixed effluent at the outfall will be 37.1°C. Therefore; the impact of NDDP effluent temperature will not cause any significant effect on the seawater chemistry and aquatic life.

Design of the intake and outfall structures for a NDDP is very important to ensure that effluent discharged from the plant should not be circulated by local water currents back to the location of the intake structure. In addition to that, the distance between them should be sufficiently well to ensure enough dilution of the discharged effluent before reaching the inlet structure. The location of inlet and outfall points along with the tidal wave current direction was evaluated.

The outfall point is protruded into the sea (design based on that the effluent should not recirculate back to the inlet structure) from the seashore and is located in the east of the inlet structure of NDDP. The prevalent direction of wave currents is from west to east in this area during summer (Table 1), which will not allow the discharged effluent to flow towards the inlet structure with tidal wave currents [8]. Hence, the possibility of recirculating the discharged effluent into the inlet of NDDP is insignificant. Furthermore, the separation between the inlet and outfall is about 228.6 meters (750 feet). This separation will ensure in case of any recirculation that the discharged effluent should be diluted before reaching at the inlet structure [11].

Impact of Additives in Discharged Effluent**:** In addition to TDS and temperature, presence of antiscalant (Belgard EV) and antifoaming agent (Belite M8) was considered. These agents will be added in the inlet stream of seawater in MED in a very low concentration (Belgard EV 2.5 ppm and Belite M8 0.1 ppm) which may increase some inorganic/organic constituents in the effluent. Allowable limit of Chemical Oxygen Demand (COD) in the discharge effluent into the sea is 150 ppm [15]. However, addition of 0.1 ppm of Belite will increase COD value up to 0.23 ppm which is negligible value as compared to the allowable limit of 150 ppm [16]. Similar results are reported by many researchers while using these additives in desalination process [17, 18].

Manufacturer of these chemicals ensured that these chemicals do not contain any component which is hazardous in nature. According to the BWA Water Additives the antifoaming agent Belite M8 is a formulated liquid product considered to present no known hazards under normal conditions of use. In addition Belite M8 formulation is approved for use as food additives by the US-FDA [16]. Regarding antiscaling agent Belgard EV, BWA reported the results of acute studies which classed it as non-toxic. Belgard is certified to ANSI/NSF Standard 60 for use in seawater distillation plants producing potable water [15]. Therefore, these chemical additives are harmless to the aquatic life and environment. One may conclude that very low concentration of both additives in the effluents will not cause any significant environmental impact to the seawater chemistry and aquatic life.

5. Conclusions

The Environmental Impact Assessment of the NDDP at KANUPP was performed. Emphasize was given to find any significant impact on the environment due to discharge of effluent from NDDP into the Arabian Sea. Following conclusions were made regarding environmental impact of discharge effluent.

1. NDDP will discharge effluents from four different points during operation. Effluents discharged from Dump Condenser outlet, Hydro Ejector outlet, and Final Condenser outlet has normal seawater TDS values of 45,000 ppm and will not increase the TDS value of seawater if discharged into the Arabian Sea.
2. Effluent from the MED outlet has relatively higher TDS value of 63,000 ppm however, mass balance calculations show that the average TDS value of the final effluent will be 47,875 ppm which is within the NEQS allowable limit of 48,500 ppm.
3. The average temperature of final discharged effluent from mixing chamber will be 40.1°C. This temperature will further be reduced when effluent discharged into the 53.6 meter (176 feet) long closed and 76.2 meter (250 feet) open drain line leading to outfall into the sea. This will further reduce the temperature of final effluent below the NEQS allowable limit of 40°C.
4. The existing flow rate at the outfall is about 23 times more than the expected flow rate of effluent from NDDP. Therefore, enough dilution will take place at the discharge outfall with the low temperature KANUPP effluent. The expected final temperature of mixed effluent at the outfall in the worst case will be 37.1°C. Therefore; the impact of NDDP effluent temperature will not cause any significant effect on the seawater chemistry and aquatic life.
5. The outfall point is protruded into the sea and is located in the east of the inlet structure of NDDP. The prevalent direction of wave current is from west to east in this area, which will not allow the discharged effluent to flow towards the inlet structure with tidal wave currents. Hence, tidal wave current drag the effluent away from the inlet of NDDP and the possibility of recirculating the discharged effluent into the inlet of NDDP is negligible.
6. Presence of antiscalant (Belgard EV) and antifoaming agent (Belite M8) was analyzed and found that addition of small quantity of these agents will increase COD value up to 0.23 ppm which is negligible value as compared to the NEQS allowable limit of 150 ppm.
7. According to the manufacturer these chemicals do not contain any component, which is hazardous in nature. Therefore, these chemical additives are harmless to the aquatic life and environment. One may conclude that very low concentration of both additives in the effluents will not cause any significant environmental impact to the seawater chemistry and aquatic life.
8. In the present study a checklist is provided for the identification and examination of various environmental impacts due to discharge of effluents from NDDP at KANUPP. Checklist revealed that the installation of proposed NDDP does not have any significant environmental effects.

Therefore, analysis of the data obtained and examination of different environmental parameters show that the proposed activity will not cause any significant impact on the public and environment if the activities are undertaken as proposed and described in this report.

7. Recommendations

The routine monitoring of a working plant is a vital part of environmental safety. It is, therefore recommended to monitor the influent and effluent quality parameters (Table 6) on monthly basis to ensure the safety of the environment and quality of product water [15].

Table 6. Environmentally significant effluent quality parameters to be monitored in routine [3, 4].

Parameter	Type of Stream	
	Influent	Effluent
Temperature	X	X
pH at 20 °C	X	X
Turbidity	X	
Conductivity	X	
Chemical Oxygen Demand (COD)	X	X
Total Hardness as $CaCO_3$	X	
Total Dissolved Solids (TDS)	X	X
Total Solids (TS)	X	
Calcium as Ca^{2+}	X	
Sodium as Na^{1+}	X	
Sulfate as SO_4^{2-}	X	
Oil & grease	X	X

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