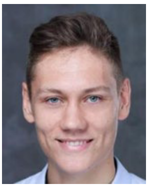
https://doi.org/10.31713/m1313

IMPACT ASSESSMENT OF THE JEBEL ALI POWER AND DESALINATION PLANT ON THE ENVIRONMENT

Jerom DANKERS
BSc., Innovation Sciences at the University of Technology in Eindhoven, Nederlands; AGH University of Science & Technology in Krakow, Poland

Jiaqi LU
BSc., China University of Mining and Technology; AGH University of Science & Technology in Krakow, Poland

Sebastian ROTHER



BSc. Graduate Student in mechanical engineering at the Ruhr-University-Bochum, currently on an exchange to the Faculty of Energy and Fuels of the AGH University of Science & Technology, Poland

Wiktoria SOBCZYK
Professor, DSc, PhD, Eng, Faculty of Energy and Fuels,AGH University of Science & Technology, Poland

Abstract

The research aim of the article is to assess the impact of a large industrial facility on the environment: Jebel Ali Power Plant and Desalination Plant located in the United Arab Emirates.

We use AHP and Leopold Matrix principles and techniques to assess the impact of power plants on the environment. The combination of the two methods AHP and Leopold's Matrix ensures that decision-makers make informed choices towards sustainable solutions.

The analysis shows that the Jebel Ali power plant and desalination plant have little negative impact on the environment. Nevertheless, noticeable impacts on the hydrosphere and atmosphere were observed. The burning of fossil fuels has a direct impact on the atmosphere by emitting harmful substances. Desalination of salt water and returning by-products to the sea also has a direct negative impact on the hydro-

sphere. The combination of both factors also affects the biosphere.The power plant is of great importance in solving the problem of water shortages in the region. The problem is solved by combining power generation and water desalination.

Keywords: risk assessment, AHP Method, Leopold Matrix, Energetics

Introduction

The Jebel Ali Power and Desalination Plant (Fig. 1, 2) has an installed capacity of 8.6 gigawatts. In 2021, the Complex was confirmed by Guinness World Records as the Largest Single-site Natural Gas Power Generation Facility in the World. The Complex has a power generation capacity of 9,547MW. And it can desalinate 2.228 million m³ of seawater per day which corresponds to 490 million imperial gallons [1].

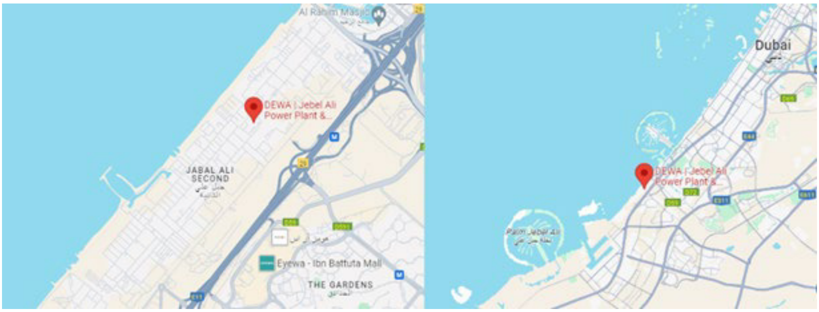


Fig. 1. Location Jebel Ali Power and Desalination Plant (zoomed-in, and out) [2, 3]

Fig. 2. Jebel Ali Power and Desalination Plant [3]

Desalination is becoming increasingly necessary due to drinking water scarcity, but the practice requires electricity, created by power plants that need large amounts of water. There is a mutual benefit for both in combining these two processes together. It's the ideal fit.

The power and desalination plant is located about 40 km southwest of Dubai in the United Arab Emirates. It is right next to the sea, and has direct access to the sea water. Which is necessary for their processes.

The power production process

The primary fuel being used to power the plant is natural gas. In case of shortage of natural gas, the plant can also run on diesel. Electricity is generated through a gas turbine and a steam turbine. First, air is compressed by multi-stage blades, and the compressed air is mixed with natural gas fuel, which is then ignited to produce high temperature and high-pressure gas. The gas pushes the impeller to rotate, and the rotating shaft of the gas turbine is connected to a generator, which outputs power directly from the rotating shaft to the generator to produce electricity.

When the flue gases leave the gas turbine, there is still residual heat that can be utilised. In a heat recovery steam generator, high temperature flue gases heat water in a heat exchanger into water vapour, and the steam flows through a steam turbine. The steam turbine is also connected to a generator, which produces more electricity. The steam turbine is powered entirely by the high temperature flue gas from the tail end of the gas turbine.

The desalination processes

Hot steam can be used to desalinate seawater, in addition to being used to generate further electricity. The main principle of distillation is the removal of salt from water by boiling it.

All distillation apparatus contain hot pipes into which hot steam is fed. Unheated seawater is then sprayed onto the surface of the hot pipes from the top and the seawater cools the hot steam. The hot steam condenses into fresh water inside the pipes and exits at the bottom of the pipes, while the steam from the heated seawater is transferred to the pipes in the next distillation section. The desalinated water is collected from the hot pipes within the distillation section, while the concentrated brine, exits through the bottom of the still (Fig. 3). The vapour from the last section is reintroduced to the first distillation unit through a hot compressor [4].

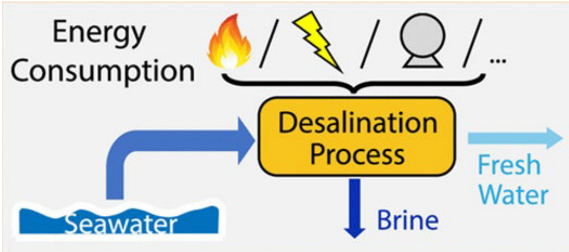


Fig. 3. Desalination process [1]

The research methods

To evaluate and analyse the environmental impact of the subject power station we apply the AHP and Leopold Matrix principles and techniques. The AHP acronym stands for Analytic Hierarchy Process and is a multi-criteria decision making method. It translates the value of the impacts into measurable numeric relations. The main characteristic of the method is the use of pairwise comparisons; in our case we compare the impact on different elements of the environment one by one, pair by pair, in order to create a hierarchy showing the importance of the impact on different elements (biosphere, atmosphere, lithosphere…), giving a reasonable explanation to every comparison [5, 6, 7].The valuations obtained were presented in the form of local weights (importance). The weight with a value close to zero means a small amount of impact. The weight close to 1 indicates a strong impact of the project on a given item. The sum of weights at each level is 1 (100%).

Each number represents a vector corresponding to the priority percentage of every element in the overall scheme: the higher the value of the vector the more important the item is [5].

The Leopold matrix is a framework method that enables us to do the environmental risk assessment of a project, on the basis of criteria related to significance, probability, and duration of the impact. Similarly to the AHP, it belongs to the multi-criteria decision making methodology. It consists of a two-dimensional matrix where individual actions are assessed in relation to the actual environmental features and conditions that could be affected by the project's operations. In this method we use the weights obtained in the AHP as a reference in order to assess the actions that accompany the power station activities and affect each element, so that we are able to create a specific hierarchy of elements affected and specify actions taking place within the scope of the the subject power station of the study [5, 6].

The course of the research

To assess the environmental impact of the Jebel Ali Power and Desalination Plant in the UAE, we use AHP to prioritize factors like air and water quality, land impact, and ecosystem health. Then, the Leopold Matrix can be applied to evaluate the impact of each option on these factors. Combining these methods provides a straightforward and structured approach to understand and compare the environmental consequences of different alternatives for the Jebel Ali project.

In the case of the Jebel Ali Power and Desalination Plant, this method was also used to determine which attributes (lithosphere, hydrosphere, atmosphere, anthroposphere, biosphere and landscape aesthetics) are impacted the most by this power plant. The scores were given based upon the findings and information retrieved from the aerial images of the plant.

The consistency index (C.I.) of the assessment was 0.09, and therefore the results are sufficient and reliable. Filling in the AHP matrix resulted in weight scores for each element. In Table 1 the calculated weight score can be seen. The hydrosphere and atmosphere have the highest weight factor, whereas the lithosphere has the lowest weight factor. The results are as follows: lithosphere 0.03; hydrosphere 0.33; atmosphere 0.33; anthroposphere 0.07; biosphere 0.10; landscape aesthetics 0,15.

Table 1

Weight factors resulting from the AHP analysis

Element	Weight
lithosphere	0,03
hydrosphere	0,33
atmosphere	0,33
anthroposphere	0,07
biosphere	0,10
landscape aesthetics	0,15

For each environmental element a score for each potential output factor of the plant is given. Ranging from 0 (no impact) to 5 (very strong impact). The given score is then multiplied by the corresponding importance factor, and results in a score.

The sum of these scores is then calculated per output factor, but also per environmental element.

In Table 2 importance per environmental element, ordered from highest to low-est sum the Leopold matrix can be seen.

Table 2

Importance per environmental element, ordered from highest to lowest sum

Rank	Environmental Elements	Importance	Sum
1	Hydrosphere	0.33	2.95
2	Atmosphere	0.33	1.97
3	Biosphere	0.10	1.43
4	Landscape aesthetics	0.15	1.04
5	Anthroposphere	0.07	0.87
6	Lithosphere	0.03	0.29
	Sum	*1.00*	*8.56*

Results and Discussion

If we examine the results, we can look at two different things. Firstly, all the contributing factors from the plant (including water in the manufacturing process, infrastructure of the Power Plant, occupation of surface, unpleasant odors, vibration, and noise). We determined that the water in the manufacturing process impacts all the environmental elements the most (score of 3.27), whilst the infrastructure of the Power Plant also has a noticeable impact on the environmental elements (score of 2.95). This makes sense because the plant produces a lot of fresh water whilst using sea water. This has an impact on the sea water because some of the by-products of the process are being released back into the sea. The occupation of surface (score of 1.3) is significant due to it being large and close to a big city, and therefore also has impact. The impact of odors (score of 0.49), vibration (score of 0.32) and noise (score of 0.32) were deemed to be insignificant and were therefore given a lower score.

The impact score per factor from the plant can be seen in Fig. 4 (ordered by value from high to low).

Power Plant (inside the graphics)

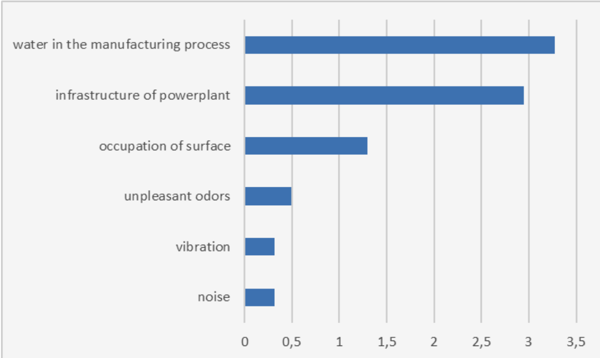


Fig. 4. Impact score per factor as derived from the Leopold matrix

The second thing we can examine is the sum of all impacting factors on the environmental elements. This was done by using the data from Table 2. In this table, we can see that the hydro- and atmosphere are impacted the most by the plant. In Fig. 5 an overview is provided. Due to the processes of the plant, it makes sense that the hydro-(score of 2.95) and atmosphere (score of 1.97) are impacted. The burning of fossil fuels has a direct impact on the atmosphere, and the desalination of salt water, whilst returning the by-product back to the sea also has an immediate impact on the hydrosphere. The combination of these both also has an impact on the biosphere (score of 1.43), and this impact is thereby also noticeable in the figure. The lithosphere (score of 0.29), anthroposphere (score of 0.87) and landscape aesthetics (1.04) are seemingly less impacted by the plant.

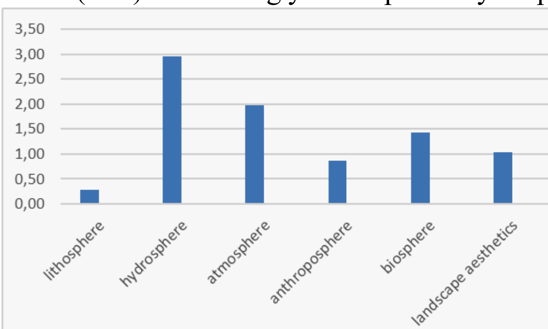


Fig. 5. Sum of impact per and on environmental element, derived from the Leopold matrix

And lastly a wind-rose can be used to visualize the differences in the average given score (ranging between 0, and 5) for each of the factors, as an impact on each of the environmental elements. This wind-rose can be seen in Fig. 6. On average, the biggest impact was on the biosphere (2.5 out of 5). The score of the impact on the anthroposphere was on average (2.17). The average score of the impact on the landscape aesthetics (1.17), lithosphere (1.5), hydrosphere (1.5), and atmosphere (1) are significantly lower than the average score of the impact on the bio- and anthroposphere.

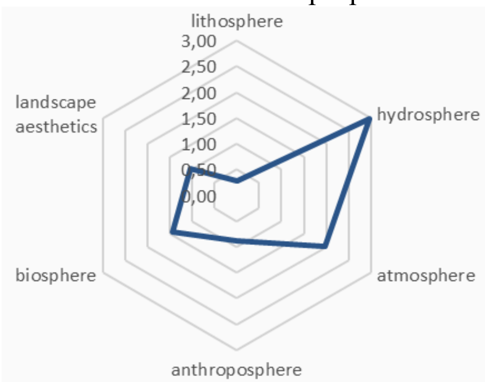


Fig. 6. Average given score (between 0, and 5) per factor, of the impact of the Power Plant on each environmental element

Conclusions

In evaluating the environmental impact of the Jebel Ali Power and Desalination Plant using the AHP and the Leopold Matrix, several key insights came to light. The plant, recognized by Guinness World Records for its scale, plays a vital role in addressing water scarcity through the symbiotic coupling of power generation and desalination [8].

The AHP method facilitated a comprehensive assessment of environmental factors, assigning weights to elements such as lithosphere, hydrosphere, atmosphere, anthroposphere, biosphere, and landscape aesthetics. This structured analysis provided a nuanced understanding of the relative importance of each element, with hydrosphere and atmosphere standing out as the most critical factors.

The Leopold Matrix, employing weights derived from AHP, delved into the plant's impact on specific environmental elements. The results underscored the significant influence on hydrosphere and atmosphere, aligning with expectations given the plant's desalination and power generation processes. Notably, water in the manufacturing process emerged as a primary contributor to environmental impact, emphasizing the interconnectedness of desalination and power production.

Considering factors such as infrastructure, occupation of surface, odors, vibration, and noise, the study revealed that water in the manufacturing process and infrastructure had the most substantial impact, while other factors were deemed relatively insignificant.

In summary, the Jebel Ali Power and Desalination Plant, while essential for addressing water scarcity challenges, imposes notable environmental effects, particularly on the hydrosphere and atmosphere. The integration of AHP and the Leopold Matrix provides a comprehensive framework for decision-makers to weigh the trade-offs and make informed choices toward sustainable energy and water solutions in the UAE.

W Sobczyk https://orcid.org/0000-0003-2082-9644

Author Contributions:

J. Dankers, J. Lu, S. Rother and W. Sobczyk authored the project and designed the study; J. Dankers, J. Lu, S. Rother contributed to the study design and discussed the data; J. Dankers, J. Lu, S. Rother and W. Sobczyk revised the data; J. Dankers, J. Lu, S. Rother and W. Sobczyk wrote the original draft of the paper; all authors contributed to the manuscript final form and approved the version to be submitted.

Conflict of interest statement

The authors declare no conflict of interest.

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