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Development of a quantitative approach for Environmental Impact Assessment of a desalination plan: Shavei-Zion case study

Research Thesis in Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Environmental Engineering

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Abstract

Desalination is a technology that involves several processes that remove salts and minerals from the water and produce potable drinking water. The total annual production of desalinated water in Israel increases constantly. Seawater desalination plant is planned to be constructed at the Western Galilee in 2018, near Shavei-Zion. By the year 2020, the plant is expected to increase its water supply, so it may require the construction of a small power plant on-site. Desalination plants are, in most cases, associated with high energy consumption, potential damage to marine life as a result of brine discharge to the marine environment, and use of land along the coast.

An Environmental Impact Assessment (EIA) is a procedure conducted in order to evaluate potential effects that are likely to arise as a result of a major project or action. Different methods for EIA are applied for different projects. Yet, in general, the methods applied today have several disadvantages. First, current EIA methods are mainly qualitative rather than quantitative, creating an assessment which is based on qualitative rather than quantitative data. Second, decision makers often lack the necessary knowledge required to achieve the best environmental decision, since they are exposed to unclear indices and inconclusive information. Presenting the EIA results in a quantitative way could help dealing with the problem.

The main goal of this work is to develop a new and better method for assessing the impacts of desalination plants on the environment. This research will focus on the two major environmental effects of desalination activities: air pollution and brine discharge to the marine environment. The marine ecology impact assessment method is based on three main ecosystem parameters: primary production, species diversity and decomposition. For each parameter a degree of impact scale was designed. The estimation of the cost resulted from the effect on air pollution and public health in this work followed a fixed pathway adopted from the European Commission project, the ExternE project, and was improved, using the Impact Pathway Approach (IPA), to enable applying it in other areas. The method is illustrated for assessing the impact of on-site and off-site power production for the desalination plant, and accounts for either local or national air pollution related health effects. We demonstrated the method for estimating the effects of $PM_{2.5}$ emissions due to the facility power requirements and cardiopulmonary mortality in Nahariya and Akko.

The results of the above methods were demonstrated for the proposed Shavei Zion desalination plant. We found that the degree of ecological impact on the three parameters

that were studied is expected to be minimal based on Palmachim desalination plant monitoring data. Regarding air pollution and public health impact assessment, at the national scale, describing all health outcome resulted from the increased PM2.5 concentration (with health related monetary value of 1,896,800 NIS), and the local scale, describing mortality from cardiopulmonary diseases in Akko and Nahariya in people older than 45 as a result of increased PM2.5 concentration (with health related monetary values in the range of 74,500-1,585,500 NIS).

Since there are no concrete construction plans for the Shavei-Zion desalination plant at this point, the expected accuracy of the current impact assessment is not high. Nevertheless, important concepts were set on the way for EIA to gain more popularity and possibly broaden their use.

The research did not suggest an integration between these two assessments. Two possible paths for integration are suggested, and the idea of examine the benefits and weaknesses of the integration in every impact assessment study.

Abbreviations

EIA	Environmental Impact Assessment
IPA	Impact Pathway Approach
EIS	Environmental Impact Statement
MSF	Multi Stage Distillation
ED	Electro dialysis
RO	Reverse Osmosis
SWRO	Sea Water Reverse Osmosis
PM	Particulate Matter
EBD	Burden of Disease
DALY	Disability Adjusted Life Years
YYL	Years of Life Lost
YLD	Years Lived with Disability
GDP	Gross Domestic Product
MV	Monetary Value
C-R	Concentration Response
IF	Impact Fracture
RR	Relative Risk1. Introduction

1.1 Desalination

Many areas worldwide suffer from water shortage, in particular semi-arid and arid regions. The water shortage results from droughts as well as from growing water demand and population growth. One of the popular technological solutions is desalination. Desalination is a technology that involves several processes that remove salts and minerals from the water and produce potable drinking water (Danoun, 2007). Desalination of sea and brackish water is very common around the world. According to the International Desalination Association (2013), the "hot spots" of desalination are the Arabian Gulf, the Mediterranean Sea, the Red Sea, California, China and Australia. Top ten countries by desalination capacity are presented in figure 1.

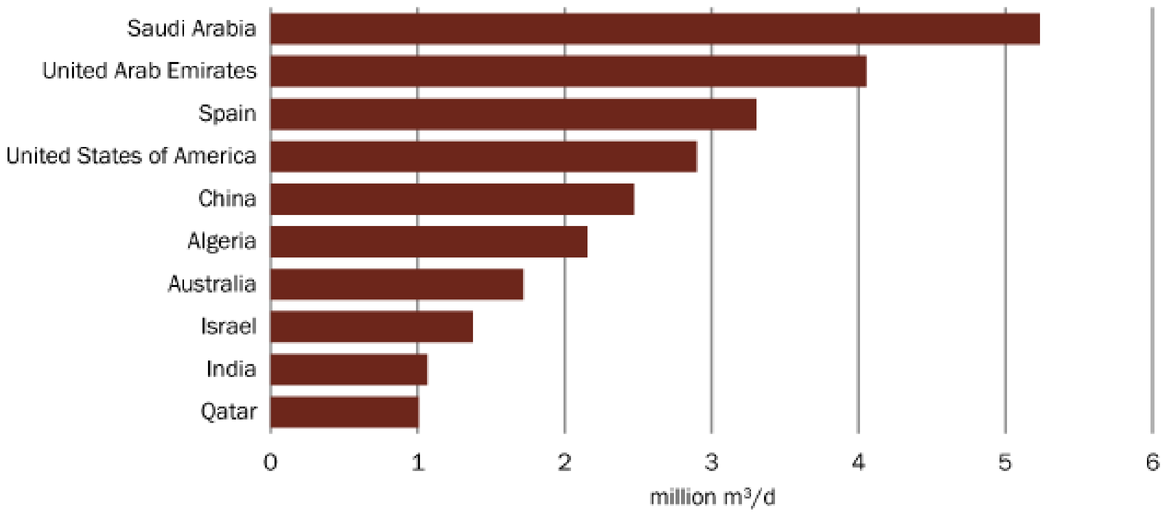


Figure 1. Top 10 countries by total installed desalination capacity as of 2003. Source: Water Desalination Report; www.desalination.com.

The common desalination technologies are divided into two main categories (MAP, 2003):

Thermal processes- based on the hydrological water cycle, the salt water are heated, producing water vapor that is condensed to form freshwater. The most common technology of this category is Multi Stage Distillation (MSF).

Membrane processes- mimics the naturally occurring processes in the body: dialysis and osmosis. In these processes, membranes play a role in separating the salts from the water. The most common technologies of this category are:

1. Electrodialysis (ED) - driven by electrical voltage that moves salts selectively through the membrane, thus creating fresh water.

2. Reverse osmosis (RO) - separation of water from solutes (the dissolved material) by pressurizing the solution as it flows through the membrane. The pressure is used to overcome the osmotic pressure. The RO mechanism is described at figure 2.

Other common desalination technologies are freezing processes, membrane distillation and solar humidification.

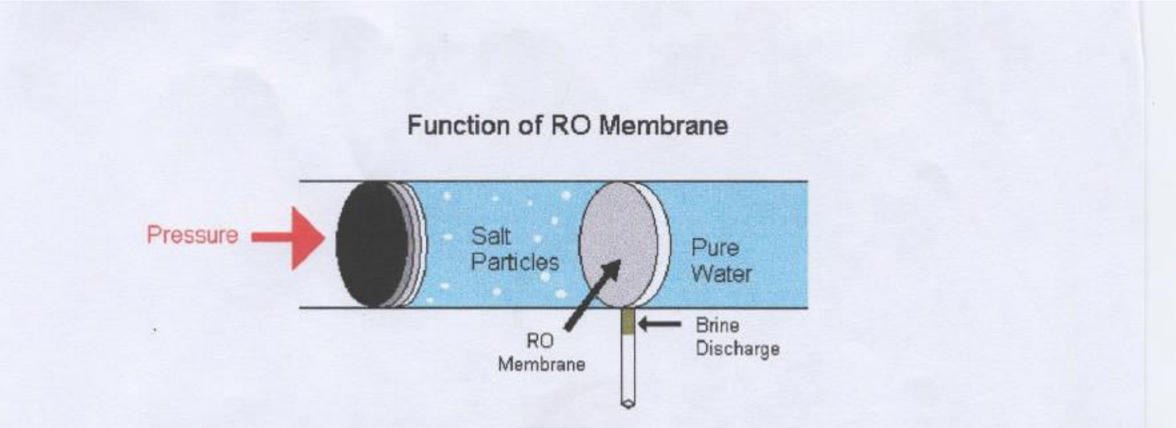


Figure 2.The function of RO Membrane (Mediterranean Action Plan, 2003).

1.1.1Desalination in Israel

Over the past decades, several multi-year droughts, as well as an increase in water consumption and population growth, have created water shortage in Israel. As a result of this shortage, water managers and policy makers decided to develop a large-scale desalination projects in Israel. A series of government decisions have set the requirement for desalination of seawater as part of the national water balance. According to the current national planning program for desalination (TAMA 34 / B / 2 / 2), the total annual production of desalinated water will reach 1.75 billion cubic meters (BCM/year) by 2040,in order to meet the predicted 2.7 BCM/year water consumption requirement (Tenne, 2012). Currently, there are four seawater desalination plants along the Israeli shoreline in Ashkelon, Palmachim, Hadera, and Soreq, producing 500 MCM/year altogether. Another plant, in Ashdod, is expected to start producing another 100 MCM/year of desalinated water in 2014. These plants are all operated with Sea Water Reverse Osmosis (SWRO) technology (Water Authority, 2013). As part of the national planning program for desalination (TAMA 34 / B / 2 / 3), another seawater desalination plant is planned at the Western Galilee, near Shavei-Zion. This plant (to be built in 2018) is planned to provide 50 MCM/year for water to the growing population of Haifa and the Western Galilee area. By the year 2020, the plant is expected to increase its water supply to 100 MCM/year (Water Authority, 2013). At this time, the Shavei-Zion desalination plant may require the construction of a small on-site power plant (TAMA 34 / B / 2 / 3).

Desalination plants are, in most cases, associated with three major environmental effects (Höpner and Windelberg, 1997;Lattemann and Höpner, 2008;Christie and Bonnélye, 2009; Einav et al., 2003;Einav and Lokiec, 2003;Becker et al., 2012):

1. High energy consumption that leads to air pollution and greenhouse gas emissions - 3.75 kWh of electricity is required to produce 1 m^3 of desalinated water (Semiat, 2008). When this energy demand is multiplied by the current 500 MCM/year desalinated water production the total electricity requirement amounts to 1,875GWh, about 20% of the annual electricity consumption of the industrial sector in Israel in 2011 (The Israel Electric Corp., 2013). This high electricity demand results in increased air pollutant emissions (SO_2, NO_X, PM, CO, CO_2, etc.). The possible deterioration of air quality as a result of these emissions may have numerous effects, including global warming, damage to crops and buildings, acidity and eutrophication, morbidity and mortality (Europian Commission, 2003).
2. Potential damage to marine life as a result of brine discharge to the marine environment. The effluent of a SWRO desalination plant is characterized by high loads of suspended solids that contain biological, mineral and organic matter, high salt concentration (generally 1.3-2.5 times higher than seawater; UNEP/MED, 2002; Mauguin and Corsin, 2005), an acidic pH (about 5.5 – the normal seawater pH is close to 8; Mauguin and Corsin, 2005), and chemicals (i.e., coagulants, anti scalants, pH adjustors) (Kress & Galil, 2008).

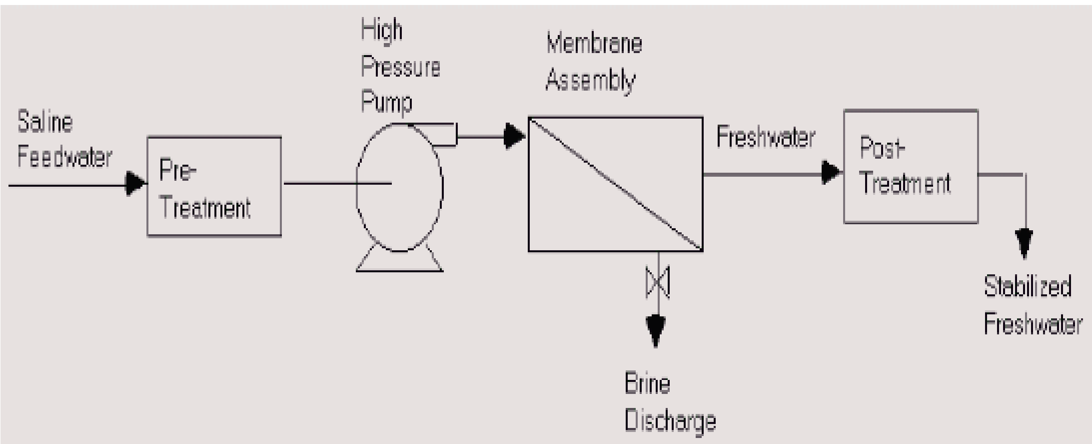


Figure 3. Simple diagram of a desalination plant from the seawater feeding to the clean water and brine discharge (Danoun, 2007).

Changes in salinity in the marine environment may influence (Neuparth et al., 2002a):

- Species development, propagation activity and individual growth
- Survival of larval stages and shortening/lengthening of the generation period
- Population density –increasing/decreasing the population growth period
- Breeding of species and reproductive traits.

The effects of desalination plants' brine discharge were examined by a number of methods, including biological monitoring, laboratory experiments and field experiments. Ruso et al.(2007) examined the effect of brine discharge over soft bottom communities along the Alicante coast for a two-year period. Close to the discharge, they found a substitution of up to 98% of a community that has been characterized by the presence of Polychaeta, Crustacea and Mollusca by a community that was characterized by nematodes. Sánchez-Lizaso et al. (2008) examined the effects of hyper saline discharges on the sea grass *P. oceanic* and found significant effects on the seagrass structure and vitality at salinities of 39.1 and 38.4 psu, respectively. According to Danoun (2007), changes in water salinity can benefit certain organisms with high salinity tolerance, such as shellfish, but have an adverse effect on other species with almost no salinity tolerance.

Whereas most work to these days focused on damage to marine life at the species and the community levels (Dupavillon and Gillanders, 2009; Kress and Galil, 2008; Neuparth et al., 2002; Raventos et al., 2006; Ruso et al., 2007;Sandoval-Gil et al., 2012), some studies looked at the damage to the marine environment at the ecosystem level (Brink et al., 1991; Latterman et al., 2008; Halpern et al., 2012), referring to ecological parameters such as production and decomposition.

3. Use of land along the coast - the Israel national plan from 2004 for establishing of desalination plants (TAMA 34 / B / 2 / 2) set 8 sites along the Israeli coastline for desalination plants. As the Israeli population and the demand for water is expected to increase over the years, additional desalination plants will be required. The direct consequence will be exploitation of the scarce coastal resources and preventing public access to these resources(Becker et al., 2012).

Additional environmental effects are noise and impacts on the costal aquifer (Einav et al., 2003). High pressure pumps and energy recovery systems produce a noise level over 90 dbs. Therefore, they must be located far from populated areas and equipped with appropriate acoustic technology in order to reduce noise level to a minimum (5 dB above background noise). Pipe leaking over permeable areas can cause a serious danger of salting the aquifer waters. These salt water are pumped and used as part of the water consumption and can contain poisonous substances that may cause a serious damage to human health and the environment. To minimize the possible impact of such occurrences on aquifer water, proper sealing techniques must be in use (Sadhwani et al., 2005).

1.2 Impact assessments

1.2.1 Environmental Impact Assessment

An Environmental Impact Assessment (EIA) is a procedure that is conducted in order to evaluate potential effects that are likely to arise as a result of a major project or action. The procedure is assigned to assist decision makers in considering certain strategies and action plans involving a project or an action (Jay et al., 2007). The origin of the EIA as a legislative procedure is in the National Environmental Policy Act (NEPA) in the United States in 1969 (Canter, 1977). According to the Environmental Protection Agency (2014), some projects must conduct an EIA while others may not. Projects that are obligated to do EIA are those with a feasibility to damage the environment, such as construction of thermal and nuclear power stations, extraction of petroleum and gas, and storage of chemical products. Industrial plans, like desalination plants, may be required by the authorities to conduct an EIA, based on their infrastructure, processes and material fluxes. Several EIAs of desalination projects have been done to date (e.g. Hoepner, 1999; Sadhwani et al., 2005; Danoun, 2007; Lattemann et al., 2008). Yet, it is generally agreed that the impact of desalination plants on the environment still lacks fundamental principles that could make the impact assessment easier to conduct and to communicate. In particular, Lattemann et al. (2008) suggested ten basic steps for an EIA of desalination projects:

1. Screening and deciding if an EIA is required for the proposed project
2. Scoping to determine the EIA content and extent
3. Identifying administrative aspects that are relevant for the EIA of the project
4. Describing the processes and technical design of the project
5. Describing the environmental baseline of the project site

6. Describing and evaluating the potential impacts of the desalination plant on the environment
7. Suggesting mitigation options for the negative aspects
8. Providing a summary of the major findings and operational conclusions
9. Preparing a monitoring plan during the construction and operation phases
10. Reviewing the EIA process for decision-making purposes.

The Mediterranean Action Plan (2003) suggests that Mediterranean countries should apply an appropriate procedure for EIA of desalination projects, emphasizing the disposal of brine discharge. Moreover, the report offers a basis for a discussion aiming at identifying a common management approach. Nonetheless, different methods for EIA are applied in different countries (Crabtree and Hann, 2010).

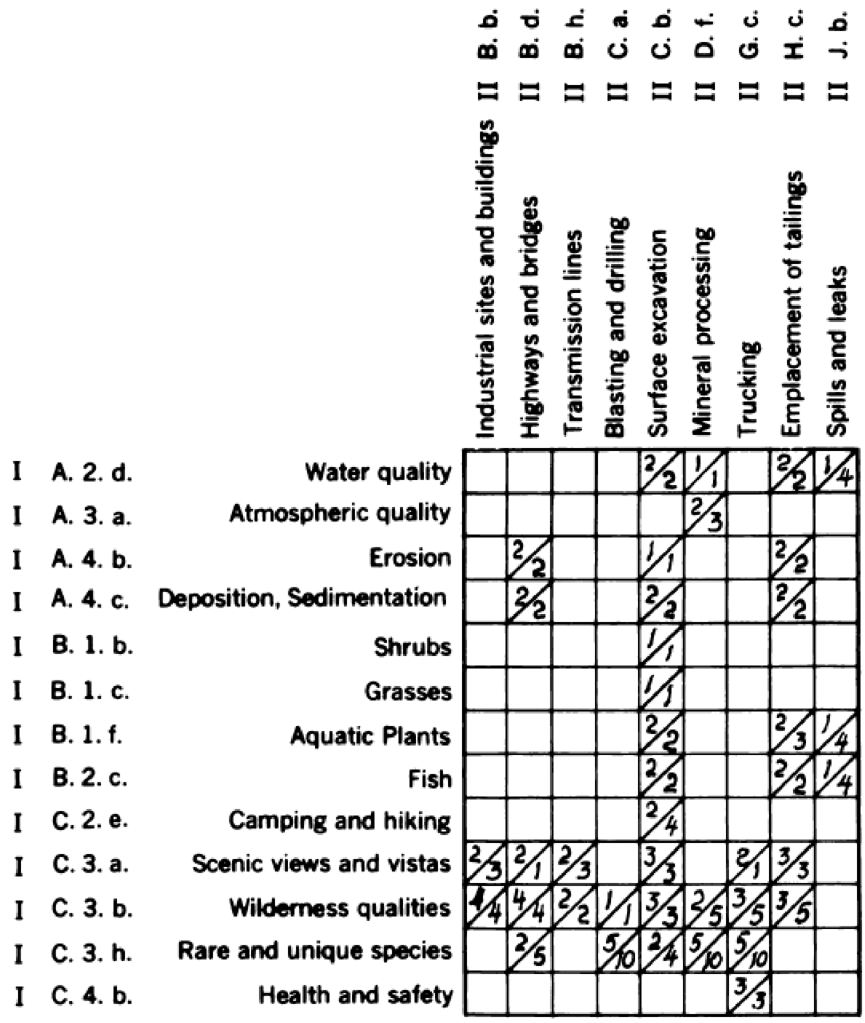
In general the EIA methods that are applied today have several disadvantages. First, they are mainly qualitative rather than quantitative, creating decision-making which is based on qualitative rather than quantitative indices. Second, the quantitative indices are mostly unclear and inconclusive, which pose difficulties for decision makers and the public understanding the expected environmental impacts. Presenting the EIA results in a clear quantitative rather than qualitative way could help in this aspect.

1.2.2 Marine ecology impact assessment

Several studies have been conducted in the field of marine ecology impact assessment, aiming at setting clear guidelines for ecological impact assessment. Halpern et al., (2012) developed a quantitative index to measure the health of marine ecosystems. The index is composed of ten goal aspects that represent the key ecological, social, and economic benefits that a healthy ocean provides: artisanal fishing opportunities, biodiversity, coastal protection, carbon storage, clean waters, food provision, coastal livelihood and economics, natural products, sense of place, tourism and recreation. An index value is calculated for every coastal country's marine ecosystem. Each goal is calculated using different datasets and equations, and in relation to a reference point, status, trend, pressure and resilience factors. The average score of all ten goals is the index value for the country (Ocean Health Index Website, 2014). Höpner and Windelberg (1997) assessed the sensitivity of different coastal sub-ecosystems to desalination plants and created a qualitative scale of the ecosystem sensitivity. Oceanic coasts, rocky or sandy, with coast-parallel currents have the lowest sensitivity whereas mangrove coasts have the highest sensitivity. The United

Nations Environmental Programe (2002) created a similar qualitative matrix of adverse environmental impacts associated with different desalination processes. Disinfectants and eutrophication were categorized as high level impacts; thermal pollution, increased salinity, heavy metals toxicity, air pollution and effect on sediment organisms were categorized as middle level impacts; and pH increase and noise were categorized as low level impacts. All the above methods could not be adopted for the purpose of this research, since they are qualitative assessments of the marine ecosystems whereas this research focuses on quantitative assessment.

Lattemann et al. (2008) used an alternative approach, the "ecological risk assessment" approach, to identify and estimate relationships between stressors due to anthropogenic activity (exposure analysis) and the resulting impacts on the receptors (effects analysis). This approach is based on the analysis of how exposure to stressors occurs and how significant are the associated impacts. The result is a list of stressor-response relationships, also called cause-effect relationships. It is typically summarized in a risk matrix (also called preference or Leopold matrix), where the columns represent the stressors and the rows represent the environmental receptors. The indexes for which rows and columns intersect appear in Figure 4 with numbers that represent the importance and the significance of the impact. The higher the number, the more important and significant is the impact. A clear disadvantage of this approach is the possibility to obtain a matrix that contains a lot of stressor-response relationships, which makes it difficult to analyze and examined each relationship. Moreover, not all the relationships are relevant to all the planning alternative, so there is a need to simplify each alternative matrix and examine the relevance of its terms.



			Industrial sites and buildings II B. b.	Highways and bridges II B. d.	Transmission lines II B. h.	Blasting and drilling II C. a.	Surface excavation II C. b.	Mineral processing II D. f.	Trucking II G. c.	Emplacement of tailings II H. c.	Spills and leaks II J. b.
I	A. 2. d.	Water quality					2/2	1/1		2/2	1/4
I	A. 3. a.	Atmospheric quality						2/3			
I	A. 4. b.	Erosion		2/2			1/1			2/2	
I	A. 4. c.	Deposition, Sedimentation		2/2			2/2			2/2	
I	B. 1. b.	Shrubs					1/1				
I	B. 1. c.	Grasses					1/1				
I	B. 1. f.	Aquatic Plants					2/2			2/3	1/4
I	B. 2. c.	Fish					2/2			2/2	1/4
I	C. 2. e.	Camping and hiking					2/4				
I	C. 3. a.	Scenic views and vistas	2/3	2/1	2/3		3/3		2/1	3/3	
I	C. 3. b.	Wilderness qualities	4/4	4/4	2/2	1/1	3/3	2/5	3/5	3/5	
I	C. 3. h.	Rare and unique species		2/5		5/10	2/4	5/10	5/10		
I	C. 4. b.	Health and safety							3/3		

Figure 4. Leopold matrix. (Source: Leopold, 1971).

Brink et al. (1991) developed a quantitative method, AMOEBA-approach, for describing and assessing ecological parameters of ecosystems. The method accounts for three ecosystem categories: production and yield, species diversity and self-regulation, using reference systems and target species. The reference systems are the same ecosystems in the past or similar ecosystems. The target species must be expressed in terms of numbers, distribution and health. The differences in target species are commonly discussed based on a "radar diagram", with all the distances between the reference and the examined ecosystems added together to a measure called the "ecological Dow Jones index". No distinction is made between the values of different species. Clearly, the smaller the distance from the reference system, the better is the ecosystem condition. The current research used some characteristics of the AMOEBA-approach and improved them by producing a more accurate assessment in terms of numbers instead of distances.

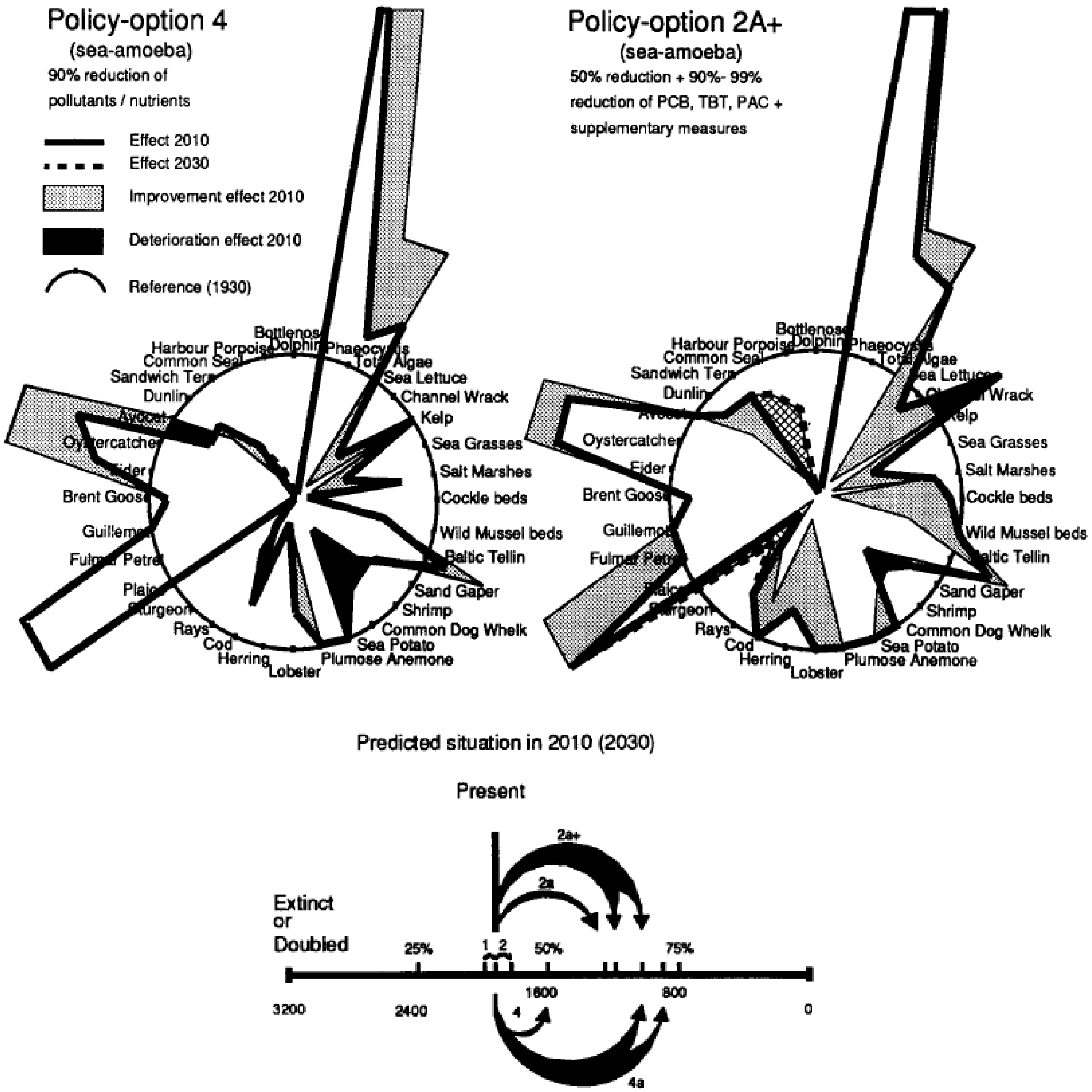


Figure 5. Expected ecological impacts of two alternatives and the "ecological Dow Jones index" according to "Impact-Amoeba" approach (Brink et al., 1991). The smaller the distance from the reference system, the better is the ecosystem condition

1.2.3 Air pollution and health impact assessment

Impact assessment of air pollution and its effect on human health can be evaluated by several different ways. Ostro (2004) presented a method for assessing the Environmental Burden of Disease (EBD) due to exposure to ambient air pollution as part of 26 risk factors analyzed in the World Health Report (WHO, 2002). The pollutants examined were airborne particulate matter (PM), particles with a diameter less than 10 micrometers (PM_{10}) and particles with a diameter less than 2.5 micrometers ($PM_{2.5}$). Particulate pollutants pose a serious health risk, since they can be inhaled and accumulate in the respiratory system (U.S Environmental Protection Agency, 2014). The health outcomes examined in the WHO report were mortality and morbidity as a result of respiratory and cardiovascular disease as well as lung cancer. The associations between these parameters were calculated using concentration-response functions that were derived from the epidemiological literature on long-term and short-term exposures. The expected number of deaths due to air pollution was calculated as the product of the population-wise incidence rates of the given health effects times the relevant exposed population. For example, the Israel Ministry of Environmental Protection (2003) estimated the health risks from exposure to PM, ozone (O_3), sulfur dioxide(SO_2) and nitrogen dioxide (NO_2) in the metropolitan areas of Tel Aviv and Ashdod. The population exposure was based on ambient concentrations and the concentration response functions were those used in North America. The results were presented as the regional death and illness that was attributed to local air pollution exposure.

An alternative approach was suggested by Prüss-Üstün et al. (2003), based on the concept of disability-adjusted life year (DALY). This measure combines the number of years of healthy life lost due to premature mortality and due to disability, and is calculated using regional or national information about a certain risk factor or disease rates in the population. The DALY value must be linked to the distribution of exposure and exposure response relationships in order to get the final DALY value for a risk factor or a disease at the regional or national level.

A different approach was promoted by the External Costs of Energy (ExternE) project, which evaluated the impacts and external costs resulting from production and consumption of energy related activities. The impacts analyzed within this project were human health, building material, yield change of crops, global warming, amenity losses due to noise exposure, and acidity and eutrophication as a result of releases to the environment (Europian Commission, 2003; ExternE, 2014). The results are presented in terms of cost (Euros) per impact parameter per country. The assessments were made using an impact pathway approach. The impact pathway approach follows the pathway of pollutants from source emissions to the increase in ambient concentration, to impact calculated based on concentration response functions, and finally to a monetary value - the cost of a certain impact (Ecosense Web, 2014).The project uses an integrated software online tool, the Ecosense model (http://ecosenseweb.ier.uni-stuttgart.de/), for estimating and calculating different pathway stages of different categories. Technical input data on emission sources in EU countries is entered and output data is obtained regarding the effects on human health, crops, building materials, ecosystems and impacts on climate change. The advantage of this tool is its simplicity, since it serves as a black box that hides the complicated mathematical calculations from the user. However, a number of noticeable disadvantages make this method useful only in specific cases. First, the Ecosense software tool is tailored only to European Union countries. Second, since the models implemented within the software are fixed, they cannot be tuned to other conditions in which its estimates may be less accurate. Third, the software requires very specific input data to obtain its estimates. In case not all the data are available, the tool cannot be used.

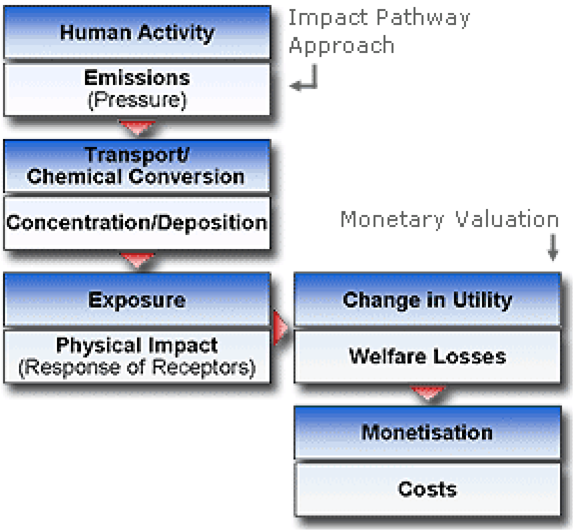


Figure 6. Conceptual scheme of the Impact Pathway Approach. (Source: http://ecosenseweb.ier.uni-stuttgart.de/).

Based on the results of the ExternE project in Europe, Pareto (2008) estimated the external costs of human health in Israel that result from production and consumption of energy. The pollutants examined were PM_{10}, SO_2, NO_X and CO_2. The study used a fixed price per ton emission for every pollutant, based on the prices suggested by the ExternE project. These prices described the external costs related only to health impacts and did not accounted for damages to crops, ecosystems and buildings (unlike the Extern project). On the other hand, the method provides a relatively simple approach for assessing the impacts of desalination plants, although at a low accuracy level, since the model does not account for meteorological differences between European Union countries and Israel. Namely, the adaptation to local (Israeli) conditions is done only by accounting for economic and demographic differences between Israel and European countries.

An approach that provides monetary value for the impact of air pollution from a facility was suggested by Sachs (2002), who suggested monetary value for a healthy life year,

$$MV = \frac{3 * DALY}{pop} * GDP \qquad (1)$$

Namely, according to eq. (1) each healthy life year lost values about three times the annual earnings, to account for the loss of annual earnings, leisure time and market consumption. The poor longevity effect is also taken into account. Assuming that each year of life lost is equal to per capita income, it is possible to multiply it by three and then divide it by the country or region population, to get the percent of gross domestic value of the region or country lost (the currency presented in the result will be the gross domestic value currency). Hence, this approach can be used to estimate the monetary value of the impact of exposure to air pollution both on a national scale (based on the national GDP) and on a local scale (based on the regional/local GDP).

All above methods, except the ExternE and Sachs (2002), are quantitative assessment methods that present a numerical value for the consequences of air pollution in terms of health outcome incidences or years of life lost due to morbidity and mortality. A monetary value for the air pollution impact can improve the above methods by presenting a more effective ("easy to understand") value for the air pollution costs that result from its effects on human health. The ExternE project already presents the outcome in monetary values but as we mentioned above, it is applicable only for European Union countries.

1.2.4 Environmental Impact Statement

An Environmental Impact Statement (EIS) is the legislative application of the Environmental Impact Assessment, submitted to the authorities prior to a construction of a new project or a development decision. The Environmental Impact Statement provides the necessary information to the decision-makers for determining whether to approve a project, change its environmental aspects, or find ways of mitigating its negative environmental impacts (Israel Ministry of Environmental Protection, 2013). Environmental Impact Statement provides a tool for discussing project alternatives and their environmental effects, including the no action alternative (United Nations Environmental Protection Agency, 2013). The environmental aspects described in the EIS involve land, water, air, structures, living organisms, and other environmental aspects (Eccleston, 2000). The EIS format is similar in

most countries and includes:

- Description of the project and of the current situation of the affected environment
- Description of the potential environmental impact
- Different location and design alternatives
- Means of mitigating negative impacts on all environmental aspects.

2. Research Objectives

The main goal of this work was to develop an improved method for assessing the impacts of desalination plants on the environment. The research focused on the two major environmental effects of desalination activities: air pollution and brine discharge to the marine environment.

To achieve this goal, the following sub tasks were defined:

1. Developing a quantitative method of assessing the impacts of desalination plants on air pollution, public health, and marine ecology.
2. Transforming these impacts (in particular air pollution and its effects on public health) to monetary value.
3. Demonstrating the above concept for the planned desalination plant near Shavei Zion.

In terms of public health, the research suggests possible alternatives regarding the local and national impact of the proposed Shavei-Zion desalination plant and its power requirements, and demonstrates the calculation of the estimated costs. Specifically, this research aims at improving the methods currently used for assessing the negative impacts of desalination plants on the environment and on human health by developing a quantitative approach that includes monetary value considerations that can be used by decision makers to achieve better policies. The proposed approach can be used in the future for quantitative impact assessment of desalination plants in Israel.

3. Study area

The study area is a field in the Western Galilee, Israel, where the construction of a new desalination plant is planned according to TAMA 34/B/2/2. The 100 dunam area is an agricultural land close to Shavei-Zion rural community, and is proximate to the two main western Galilee coastal towns of Nahariya ,about 5.5 km north to the proposed plant location, and Akko, about 8 km south to the proposed plant location. Other small rural communities are also situated nearby. The field is located 1.7 km away from the sea, close to a main transportation route (road number 4). The population residing in the study area is about 110,000. The study area is portrayed at figures 7 and 8. The marine study area is part of the continental shelf of Israel and is portrayed at figures 9 and 10 (Bathymetric map of the continental terrace of Israel).

The meteorological conditions along the Israeli shoreline are characterized by long summer and winter and short spring and autumn. The main synoptic pattern in the summer is a Persian trough. This synoptic pattern, together with the land and sea breeze cycle, creates a daily cycle: southeasterly winds during the night that change gradually to westerly winds during the day and evening and then change at once to easterly-southeasterly winds in the late night. The winter is characterized by easterly winds that creates a dry weather, and by lows from the north-west, which bring low temperatures and precipitation. The spring and autumn are characterized by unstable meteorological conditions - sunny and dry to cloudy and stormy (Haim, 2011).

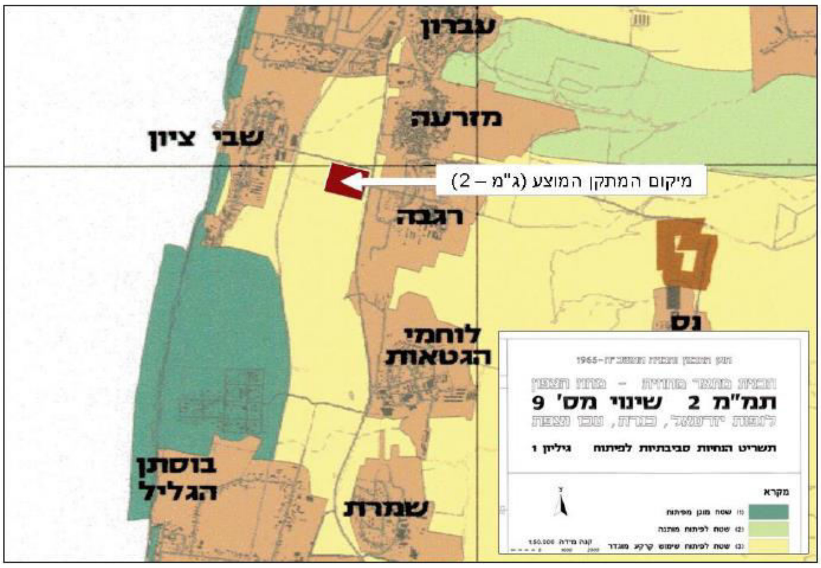


Figure 7. Planned location of the Western Galilee desalination plant at Shavei Zion. (Source: TAMA 34/B/2/2).

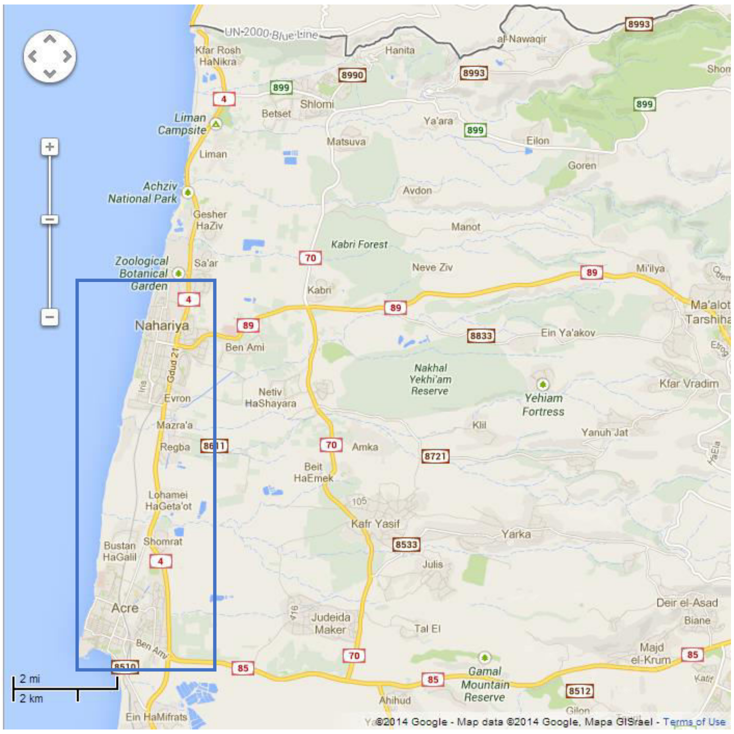


Figure 8. Study area. The blue triangle represent the area examined for the air pollution and public health impact assessment.

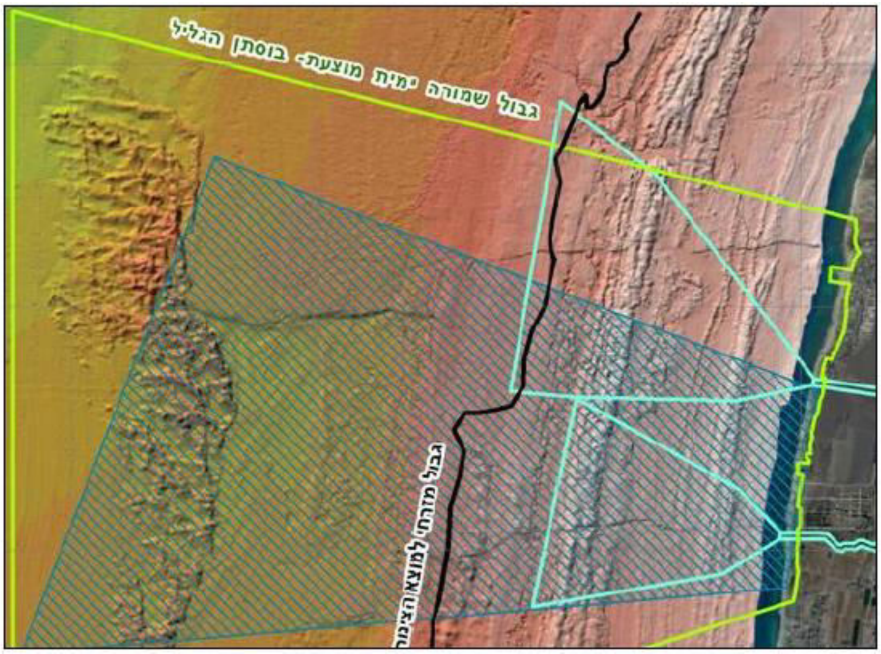


Figure 9. Marine environment study area.

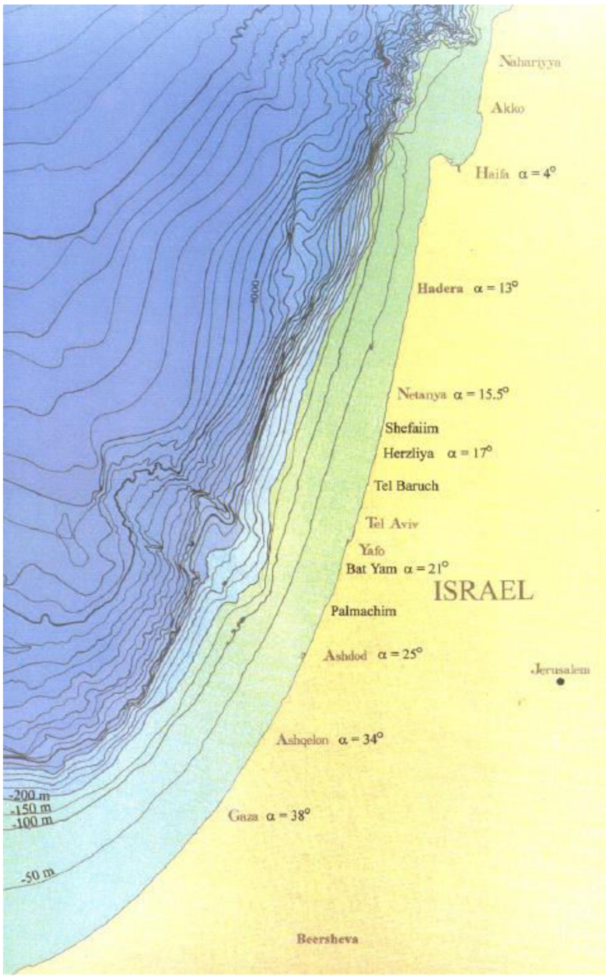


Figure 10. Bathymetric map of the continental terrace of Israel. Source: (Golik et al., 1999).

4. Marine ecology impact assessment

4.1 Database

The marine ecological database was obtained from marine monitoring reports of Palmachim desalination plant (Kress et al., 2005;2009;2010;2011;2012). Palmachim desalination plant was constructed in 2007 and produced 45Mcm per year until 2013. Its capacity was recently increased to 100Mcm per year (Water Authority, 2014). The plant is located in the Palmachim Industrial Park, at a distance of 500 m from the Palmachim beach.

Figure 11.Palmachim desalination plant.

The decision to use the ecological parameters of Palmachim desalination plant as the basis for the EIA of the proposed Shavei Zion desalination plant was for two reasons: (a) the marine environments of the two locations are similar in their abiotic properties like depth (figure 10), and thus in temperature and salinity, (b) the Shavei-Zion desalination plant is planned to have the same capacity as the Palmachim facility (until 2013). Hence, I assume that the degree of impact of the Shavei-Zion and Palmachum desalination plants on the marine ecosystem as a result of change in the abiotic properties would be similar. It is generally accepted that working with real data (e.g. data form existing desalination plant) is expected to provide a better forecast of the ecological impact than when working with theoretical predictions (e.g. model output).

The ecological parameters from Palmachim were obtained from seven monitoring stations located at different distances from the Palmachim brine discharge point (figure 12). The parameters obtained from this database were chlorophyll-a concentrations (μg/l), organic carbon concentrations in the sediment layer (wt %) and number of organisms by species inside the seabed. All the data were obtained at the sea surface level and at the station's specified depth (see Table 1). Additional stations examined different parameters were included in the monitoring program but were not examined in this research. According to the Palmachim desalination plant marine dispersion model, the impact of the brine discharge is discernable within a radius of 500 m from the discharge point.

Table 1. Sampling stations location in the marine environment near the brine discharge of the Palmachim desalination plant.

station	Depth (m)	Relative position relative to the discharge point	Location on global grid	
VM-1	8.6	Discharge point	34°41.640'	31°56.143'
VM-2	10	500 m to the north	34°41.765'	31°56.390'
VM-3	5.4	250 m to the southeast	34°41.767'	31°56.052'
VM-4	8.3	250 m to the south	34°41.547'	31°55.997'
VM-5	9.4	Control point- 3 km to the northeast	34°42.321'	31°57.547'
VM-6	10.9	Suction point- 400 m to the west	34°41.459'	31°56.128'
VM-9	5.5	750 m to the northeast	34°42.000'	31°56.365'

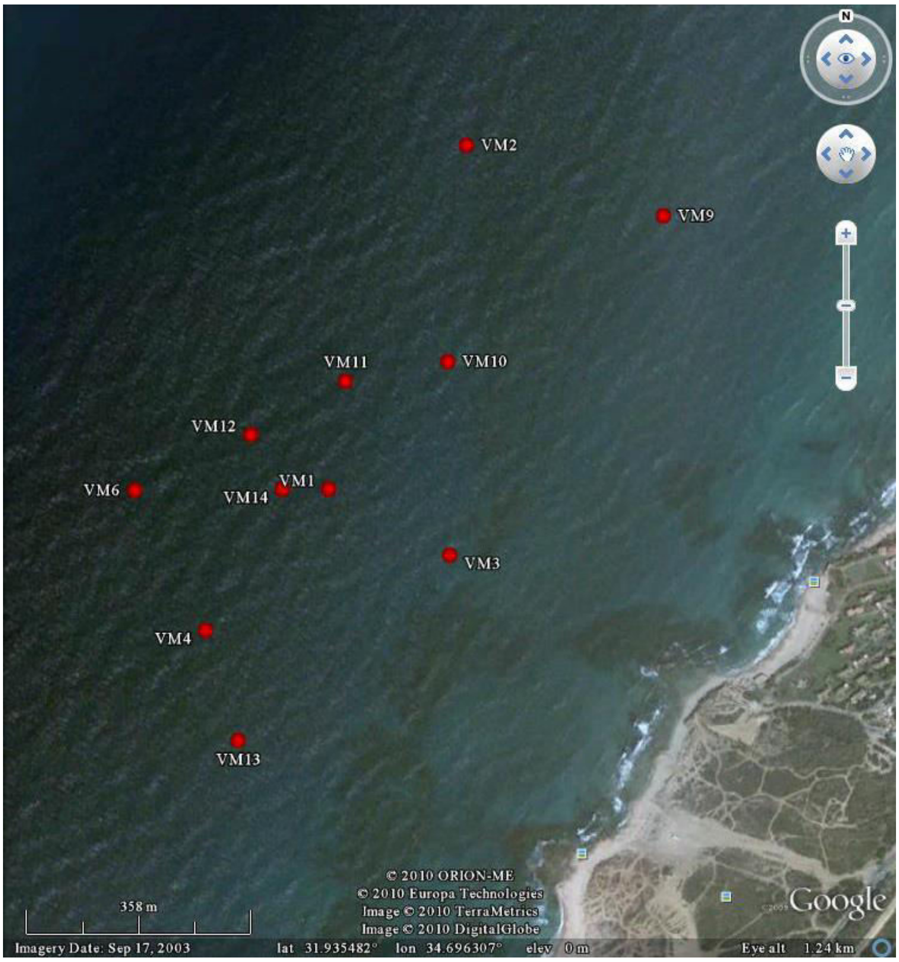


Figure 12.Location of the VM1-VM4, VM6 and VM9 Palmachim marine monitoring stations (Kress et al., 2009).

4.2 Marine ecology impact assessment method

The current research presents a new methodology for marine ecology impact assessment based on three main ecosystem parameters:

1. primary production,
2. Decomposition,
3. Species diversity.

These three parameters are good indicators of ecosystem function (Brink et al., 1991). I assume that the degree of change in these three parameters reflects the impact of a given project on the marine ecosystem as a whole. In order to carry out this method, data on all three parameters are required before- and after the construction of the desalination plant.

4.2.1 Primary production

Primary production is the base level of the food web and slight changes to the system can lead to significant impact on the ecosystem as a whole. Primary production impact assessment is carried out using chlorophyll-a concentration data from the Palmachim marine area before and after the construction of the Palmachim desalination plant in 2007. The impact on primary production is defined as the change in the chlorophyll-a concentration. In order to reveal these changes, the normalized difference of chlorophyll-a concentrations was calculated:

$$\frac{Chl(t_1)-Chl(t_0)}{Chl(t_0)} \qquad (2)$$

Where Chl is the chlorophyll-a concentration, t_0 is pre-construction, and t_1 is post construction of the desalination plant. The calculation was carried out for each of the stations in two depths (layers) and for four years after the construction (2008, 2009, 2010, and 2011) relative to data before the construction (2004) separately.

An increase and decrease in the primary production does not have a symmetric effect. Thus, the scale for degree of impact was defined separately for an increase and decrease in primary production. A decrease in primary production reflects a greater damage to the marine environment than an increase since it reflects in lack of necessary energy for the whole ecosystem. The levels were set arbitrarily.

Once the proportion difference is calculated, the largest change among all the stations and time intervals was defined as the impact of the desalination plant on the primary production. The degree of impact scale of primary production is presented in Table 2.

Table 2. Primary production scale for degree of impact.

Impact level	A decrease in production	An increase in production
1-minimum impact	up to 5%	up to 50%
2- moderate impact	5%-20%	50%-200%
3- heavy impact	21%-50%	200%-500%
4-severeimpact	51%-80%	500%-1000%
5- complete alteration of the ecosystem	81%-100%	>1000%

4.2.2 Decomposition

Since decomposition is the final level of the food chain, and its products usually sink to the sediment layer or drifted by marine currents, changes in decomposition are less significant to the impact on the whole ecosystem than primary production and species diversity. Moreover, whereas primary production reflects the recycle materials of the whole water column, decomposition reflects the recycled materials of the sediment layer only. Decomposition is examined using the weight percentage of organic carbon in the sediment layer. As decomposition rate is changing, the amount of organic carbon inside the sediment is changing at the opposite direction - an increase in organic carbon indicates a decrease in biodegradation, and vice versa. The normalized difference is calculated for each station before and after the construction of the desalination plant in 2007:

$$\frac{OC(t_1) - OC(t_0)}{OC(t_0)} \tag{4}$$

where OC is the concentration of organic carbon in the sediment, t_0 is pre-construction, and t_1 is post construction of the desalination plant. The calculation has been done separately for the years 2008, 2009, 2010, and 2011 relative to 2004. The impact of decomposition is defined as the change in organic carbon concentrations in the sediment layer. Unlike primary production, where negative impact of the desalination plant on the environment is represented as a lower value of the indices, a negative impact on decomposition is represented by a higher value of the index, as a result of the opposite direction effect explained earlier. The impact on decomposition is defined as the largest change of the organic carbon concentration in the sediment layer from its baseline value (e.g. among all the time intervals) in each station. The degree of impact scale of decomposition is presented in Table 3.

Table 3. Scale of the impact of decomposition changes on the marine environment.

1-minimum damage	Up to 50%
2- moderate damage	51%-200%
3-severe damage	above 200%

4.2.3 Species diversity

The impact of the desalination plant on species diversity is assessed using species richness, the number of species in each sample and analyzed using the Jaccard Coefficient of Community Similarity (CCj). This index was developed by Jaccard (1912) and the reason it was chosen was its ability to calculate the similarity of a community composition between two locations. It is calculated as:

$$CCj = \frac{c}{s} \quad (3)$$

where *c* is the number of species common to both communities and *s* is the total number of species present in the two communities. When *CCj*=0 there are no common species in the two communities (they are completely different). When *CCj*=1 all the species are found in both communities (they have exactly the same set of species). However, we used the Jaccard value differently. Namely, instead of comparing species composition between two different stations, I compared species composition of a single station in two different time points: before and after the desalination plant started to work. The calculation has been done for each station separately in order to reveal all possible trends of the parameter as a function of both space and time. High Jaccard values indicate high similarity in community composition between the two periods, suggesting high stability of species diversity and, thus, low impact. The lowest Jaccard value that has been calculated in each location and time interval was defined as the impact on species diversity, since the lowest value indicates the largest impact on the ecosystem. The degree of impact scale of species diversity is presented in Table 4.

Table 4. Scale used for the degree of impact based on species diversity.

Impact level	Jaccard value
1-minimumimpact	0.81-1
2- moderate impact	0.51-0.8
3- heavy impact	0.21-0.5
4-severe impact	0.05-0.2
5- complete alteration of the ecosystem	0-0.05

4.2.4 Statistical analyses

Naturally, biological parameters fluctuate over time (Groom et al., 2005; Becker et al., 2011). Hence, small changes of these three parameters may be part of these fluctuations. In order to separate these natural variations from the true impact of the desalination plant on the ecosystems statistical testing is required. Ideally, we would like to have measurements from the site for several years before constructing the desalination plant, in order to characterize the natural fluctuation of these parameters. In this case, we only had a single measurement before the construction (2004) and four measurements after the construction (2008-11) for every stations However, we could still compare the fluctuations in parameter values between stations located near discharge and stations located far from it. We used the four different values obtained per station per index, representing the available data in the four years after the construction of the desalination plant. We assumed that if the discharge had a strong impact on the ecosystem, these parameters would show a stronger and directional change in stations near the discharge, compared to stations further away. The very small sample required using a non-parametric test for small samples - the Friedman test. Friedman test can detect differences among treatments by comparing the average values of multiple attempts of the same treatments. I used it to detect differences across multi-year sampling for every station. The repeating attempts are the four values for each of seven station at the years 2008-2011 (28 samples total). A sizeable impact is defined if the differences between stations located nearby the discharge point and stations far from it are statistically significant. According to the Palmachim desalination plant marine dispersion model (personal communication with M. Sladkevich, August15, 2012), the impact of the brine discharge is discernable within a radius of 500 m from the discharge point. We therefore compared stations located less than 500 m from the discharge point (1, 3, 4, and

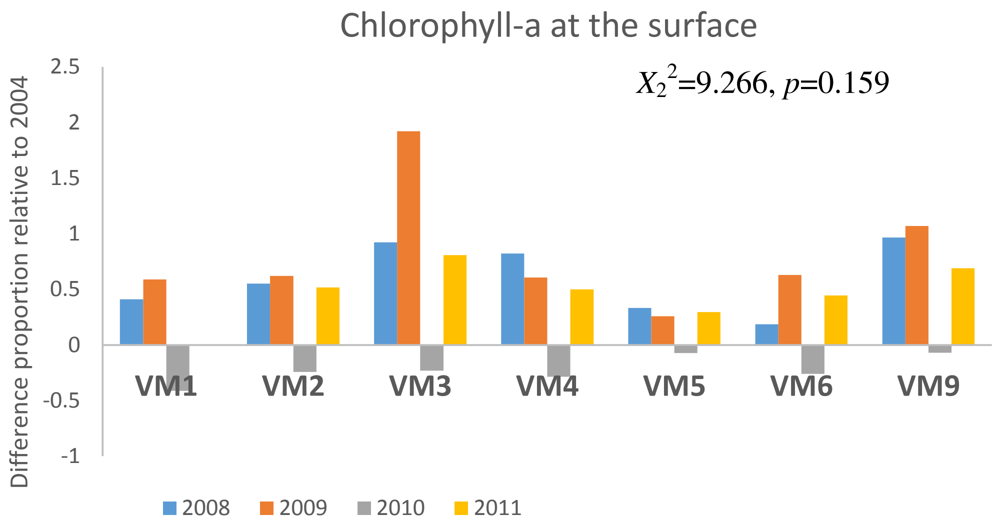
6) to stations located more than 500 m from it (2, 5, and 9). If the differences are not statistically significant, then the impact of the desalination plant, as reflected by the parameter examined, is defined as a minimum impact.

4.3 Marine ecology impact assessment results

4.3.1Primary production

Changes in Chlorophyll-a in each of the marine monitoring stations (Table 1) in the four years are presented in Figure 13. The differences of surface level Chlorophyll-a concentrations in 2008, 2009 and 2011 relative to baseline (year 2004) at all the stations are positive, which represents an increase in primary production. All stations in 2010 revealed negative differences, meaning a decrease in primary production relative to baseline. Since this decrease is apparent in only one year, it is more likely to assume that the cause of this decrease is natural fluctuation of primary production rather than an anthropogenic impact of the desalination plant.

The differences of Chlorophyll-a in the deep water is negative for all time intervals in stations 1 and 6 (discharge and suction points, see Table 1). Moreover, in 2010 all the stations showed negative differences. Stations 2, 4 and 5 (Table 1, Figure 13) show mixed negative and positive differences in 2008, 2009 and 2011. Also, there is no apparent difference between stations 1 and 6 (discharge and suction points, respectively) and all the other stations in both the surface and the deep measurements. The largest decrease in concentration of Chlorophyll-a (57.7%) was in station 1 (discharge point) at the deep measurement point in the year 2010 (relative to baseline). The Friedman test did not reveal statistical significance, meaning that no sampling site was significantly different across time than other sampling sites, thus the hypothesis that sites near the discharge point would be affected from the brine received no support. Hence, the impact of the Palmachim desalination plant on primary production is considered to be minimal.



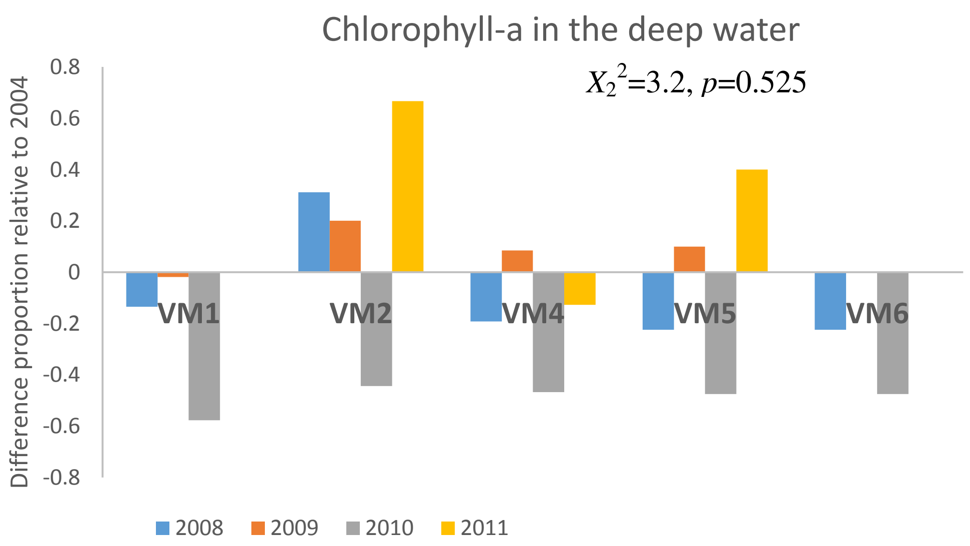


Figure 13. Differences of Chlorophyll-a concentrations at the sea surface and in the deep water.

4.3.2 Decomposition

The difference of organic carbon concentrations in the sediment layer at each station and for the four time intervals is presented in Figure14. The discharge point (station 1) experienced the highest organic carbon concentrations in the years 2008, 2010 and 2011 (relative to 2004). This can indicate a decrease in biodegradation near the discharge point. In 2009, the highest increase in organic carbon concentrations is in the suction point (station 6). The suction point has a potential for affecting decomposition in the sediment layer, since the intake system is usually placed on the ocean floor.

Stations 1, 3 and 5 show consistent increase in the organic carbon in the sediment, suggesting decrease in biodegradation. Stations 2, 4, 6 and 9 also show mostly increase in the organic carbon concentrations. Yet, these stations could have been influenced by natural processes that caused this mixed pattern (increase and decrease in organic carbon/decomposition in the sediment).

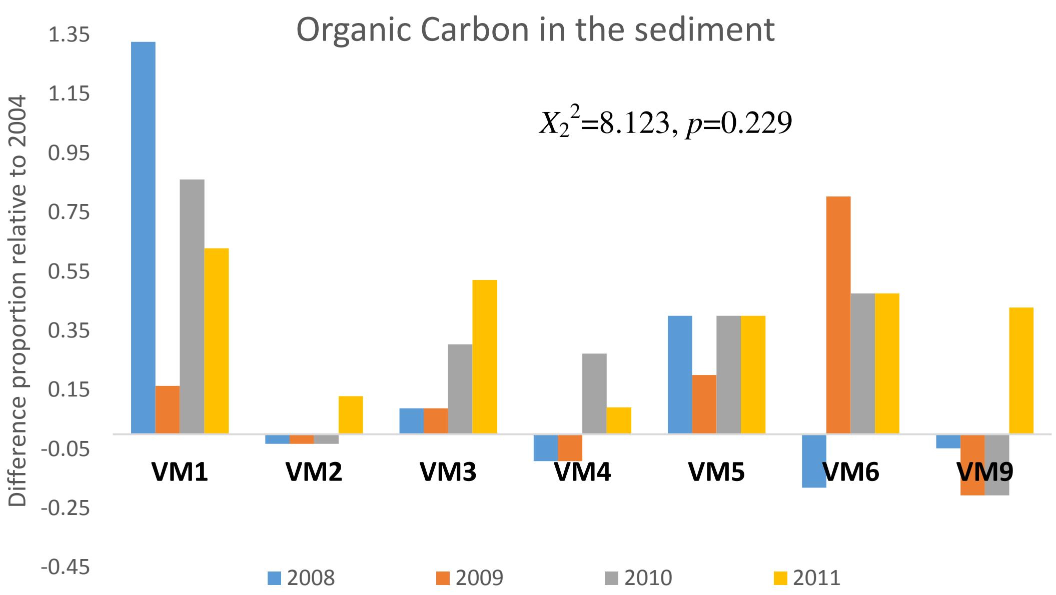


Figure 14. Differences of organic carbon (wt %) in the sediment layer.

The highest increase in organic carbon (decrease in biodegradation) relative to 2004 is seen in station 1 (the discharge point) in 2008. The Friedman test did not reveal statistical significance for these results, hence decomposition changes as a result of the operation of the Palmachim desalination plant are probably negligible and the impact of the plant seems to be minimal.

4.3.3 Species diversity

Species richness at all stations and years examined are presented in Figure 15. All stations were monitored during all years examined. Station or year without a value represents zero species found. Species richness was relatively low in 2004 and 2008 in all stations, higher in 2009 and 2010, and lower again in 2011. There is no apparent trend of differences between stations 1 and 6 (discharge and suction points, respectively) and the other stations.

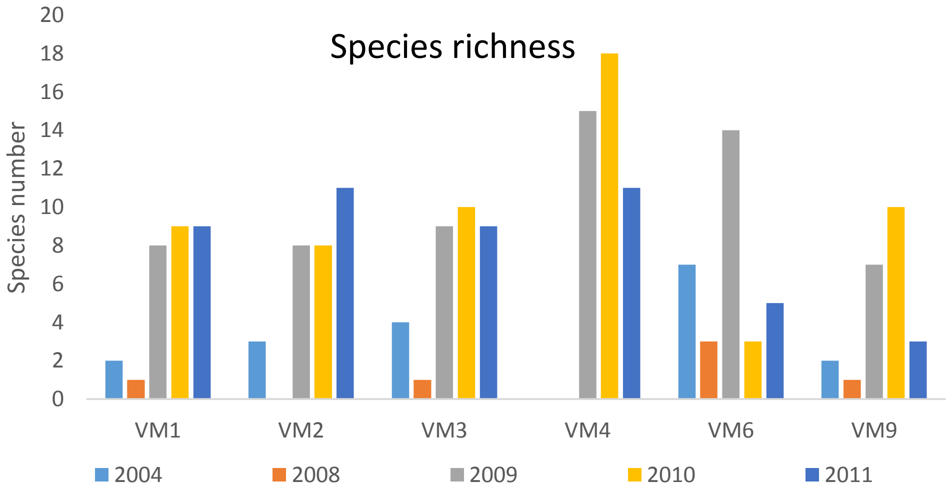


Figure 15. Species richness at all stations. The location of the stations relative to the discharge point is summarized in Table 1.

Jaccard indices were calculated for all stations and time intervals using presence-absence data of fauna species in the Palmachim marine area. The taxa collected were Polychaeta (רב זיפיות), Crustacea (סרטנאים) and Mollusca (רכיכות). The results are presented in Table 5. High Jaccard values represent similarity of the fauna in the two years, thus stability of the species diversity parameter in all the stations for all the time intervals was found.

The Jaccard values for 2008 are higher at all the stations than in the other years, which may reflect decreasing influence on the fauna species as time passes. Station 1 (discharge point) and stations 3, 4 and 6 (see Table 1 and Figure 16) experienced consistent decrease in the Jaccard values as the time pass from baseline. This can indicate a decrease in the stability of species diversity as time passes, or a continual steady change in species composition across time.

Table 5. Jaccard values of for all stations and years relative to 2004 baseline.

Station\year	2008	2009	2010	2011
1	0.71	0.27	0.17	0.15
2	1	0.1	0.23	0.26
3	0.5	0.32	0.18	0.19
4	1	0.27	0.24	0.21
5	0.75	0.2	0.17	0.2
6	0.57	0.3	0.18	0.14
9	0.67	0	0.23	0.38

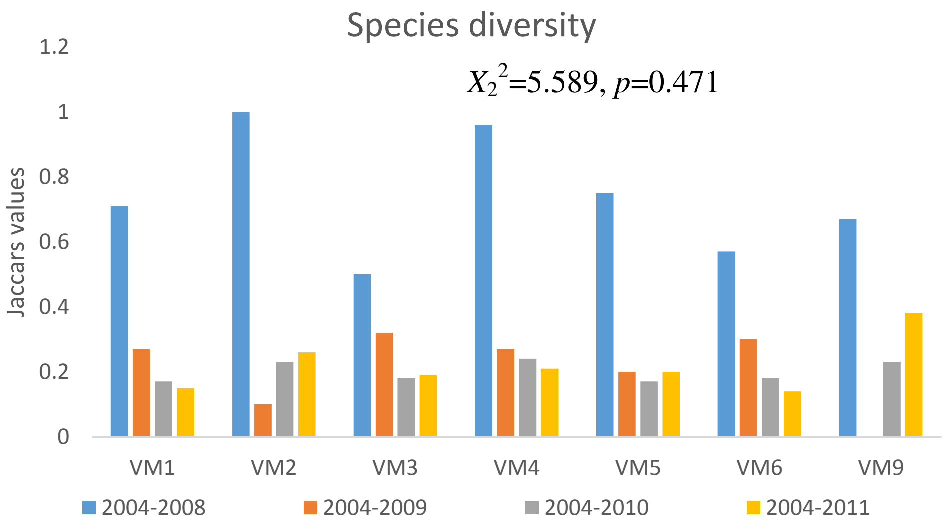


Figure 16. Jaccard index values for all stations and time intervals.

The lowest Jaccard value is 0.17, found in station 1over the time interval 2004-2010. The Friedman test showed no statistical insignificance for the variations of the species diversity parameter among the years, suggesting a minimal damage/impact.

4.4 Ecological impact assessment conclusion and discussion

This work presents a new, quantitative method of assessing the potential ecological impact of desalination plants on the marine ecosystem. Previous studies (e.g. Ruso et al., 2007; Sánchez-Lizaso et al., 2008; Dupavillon and Gillanders, 2009; (Ruso et al., 2007a)(Ruso et al., 2007a)(Ruso et al., 2007a)Sandoval-Gil et al., 2012) examined single species or community under the effect of brine discharge or increased salinity, all found a definite impact expressed as low photosynthesis rates, low vitality rates and substitution of species in a community.

Whereas previous studies suggested a definite impact of desalination plants on the marine environment this research suggest a minimal potential effect of the planned Shavei-Zion desalination plant on the marine environment, based on Palmachim desalination plant monitoring data. These results are consistent with Raventos et al., 2006 that examined the effect of desalination plant on macro benthic communities in the Mediterranean. The results were explained by high natural fluctuations and high dilution rates.

The new approach of looking at the impact from an ecosystem point of view can be one reason for the different result. Since the final assessment is composed of three parameters, a change in one parameter has smaller impact on the whole assessment, unlike a species or community impact assessment. Our surprising result can also result from the data available for this research, which were collected in 7 marine monitoring stations during the years 2004 (before) and. 2008, 2009, 2010 and 2011 (after the construction of the Palmachim desalination plant). More accurate result can obtain by a statistical analysis that is based on more data. Data should be collected for a number of years before the construction of the desalination plant, as well as after. A possible database to provide this data is the Shafdan program monitoring data. Another possible explanation for the minimal impact of the plant we report can be the high variability of the data, which could mask true effects due to low signal-to-noise ratio, and the lack of a sensitivity analysis for the impact assessment scales. Since the sensitivity scales was set by us according to our point of view, there is a need to check its accuracy level according to other ecologist's points of view. The sensitivity analysis can be performed by at least three or four ecologists. Each one should set three different impact assessment scales- one for every parameter. Than the ecological data collected for each parameter should be examined according to all scales, the differences results according to the different scales should be discussed by all ecologists participates, and the most accurate scale for each one of three parameters should be collected.

In this work we chose to represent all species together and not according to their taxa for two reasons. First, according to the research methodology the species diversity parameter, as well as the two other parameters, is describing the marine environment from an ecosystem point of view. In intention to implement this approach I presented one exclusive result for each parameter, including all data collected and examined for the parameter. Second, given the fact that monitoring plans for desalination plants do not collect data regarding all the species in an ecosystem, but only representative species, it is important to implement the methodology to flexible data bases, instead of fixative, like previous studies.

The research methodology we present in this work relies on the similarity between Palmachim and the Shavei-Zion marine ecosystems. The comparison of ecological parameters between these two areas is possible assuming that changes in similar abiotic characteristics of an ecosystem (e.g. depth, temperature, salinity) will lead to similar changes of the ecosystem parameters examined (primary production, species diversity and decomposition). However, this approach may not necessarily fit other locations. For example, an impact assessment of a similar desalination plant (50 MCM/year) in the San Francisco area, California, will probably not be able to rely on this study, since the marine ecosystem of the areas are very different. The San Francisco borders the Pacific Ocean, which features different biotic and abiotic characteristics. However, since the shoreline of Israel is generally similar in its abiotic characteristics (Figure 9), results of this work can probably apply also for other future desalination plants with the same capacity that may possibly be built along the Israeli Mediterranean shore. In contrast, studies that examine the impact of desalination plants in other areas need to either examine the abiotic characteristics of the study area in comparison to Palmachim area, or to rely on a close area or similar ecological database. Impact assessment studies of existent desalination plants, for which monitoring program exists, can follow the research methodology presented here and apply it on the relevant monitoring data.

The research did not provide monetary value for the ecological impact assessment of desalination plants. The reason was our inability to quantify the marine ecosystem as a whole, and since not all of its components have a monetary value. For example, the benthic organisms living in the sediment layer has no importance to humans although they are very important in keeping the marine ecosystem balanced - mostly because they feed on the whole water column "left overs".

However, there are impact assessment methods that do provide monetary values, such as the "ecosystem services" method. The latter measures the contributions of nature to human welfare, using units that describe the conventional goods and services found in GDP and other national accounts (Boyd and Banzhaf, 2007). Since this method cannot quantify the marine ecosystem as a whole I did not used it for the current research.

5. Air pollution and public health impact assessment

5.1 Air pollution and health database

Emissions and fuel type breakdown of the Israel Electricity Corporation for the years 2009-2012 were obtained from the Israel Electricity Corporation. Meteorological data for constructing the Shavei-Zion windrose were obtained from the Israel Meteorological Service. All the data required for DALY values and monetary value calculations, including standard life expectancy, number of deaths and gross domestic product, were obtained from the Central Bureau of Statistics.

5.2 Air pollution and public health impact assessment methods

In this research we adopted the European Commission approach for assessing the External Costs of Energy projects (ExternE), which quantified the external costs related to energy production and consumption in European Union countries using the Impact Pathway Approach (IPA). Following the ExternE project, we developed a method for estimating the costs related to energy production and consumption in Israel, specifically focusing on human health. In general, the estimation of the cost related to energy production and consumption in Israel follows a fixed pathway (Figure 6) whose preferred methods should be determined by the user's preference and needs, as well as by data availability. We improved the IPA approach by referring to on-site power production vs. off-site power production. There are currently two ways for desalination plant to supply its energy requirements: (a) on-site power production by a small power plant (usually gas turbine) that provides all the energy required for all desalination process. The impact of pollutants originated from such a power plant was defined as local scale impact. (b) The alternative option is off-site power production, where the desalination plant receives all its energy demands from the national electricity grid, and the impact assessment assumes that pollutants are emitted from all the power plants in Israel and thus affects all the country's population. This option provides a national scale impact assessment, as described in Figure 17.

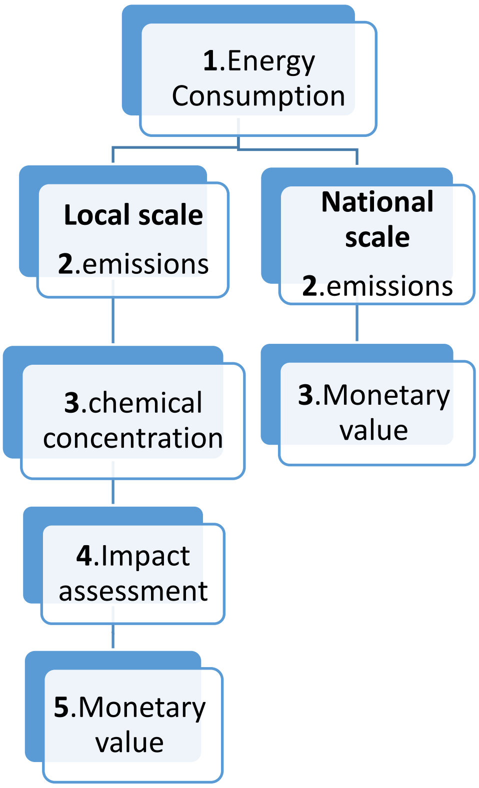


Figure 17.The research methodology for air pollution and public health impact assessment according to IPA approach.

5.2.1 Energy consumption and emissions

Desalination plant energy consumption and emissions can be estimated using data from an existing facility or estimated based on future design. For the latter, emissions can be estimated based on rough energy consumption, using similar existing facilities. For an existing desalination plant, energy consumption and pollutant emissions can be obtain from technical reports, measurements, or process modeling. It is noteworthy that emissions from future power consumption should be estimated based on predictions of future fuel consumption (i.e. load, demand, etc.) and type (i.e. the future fuel basket that will be used to produce electricity by the IEC in case it is not produced locally on the site).

5.2.2 Ambient concentration:

The contribution of the emissions to ambient concentrations can be estimated in several ways. The simplest, yet crudest option is to use a box model. Such models assume that the air shed (around the desalination plant) can be assumed a well-mixed one compartment environment such that the pollutants emitted into it disperse and attain a homogeneous concentration. In practice, however, this model is very limited and can be used only as a preliminary screening tool.

Dispersion models are mathematical models that simulate the processes involved in dispersion of pollutants in the atmosphere. All models require input data on the exact (probabilistic) meteorological conditions (wind direction and speed both aloft and at the ground, atmospheric stability, boundary layer height, ambient air temperature profile, etc.), land use data (topography, site layout, etc.) and emission parameters (source location, strength, height, flux rate, exit temperature, etc.). Some dispersion models require further input data, such as cloud cover and solar radiation. The computation demands of such models depend on the model complexity and spatiotemporal resolution and may require considerable resources. Commonly used models are either Gaussian models or more complexes models such as AEROMOD and CALPUFF.

Estimation of the share of different emission sources/sectors to the observed air quality in an area can be done based on observations/measurements data (e.g. Yuval et al., 2007; Haim, 2011). As such, it is only valid for estimating the shares of existing emission sources. Only an existing emission sources with an existing data collected for them can be examined. Normally, using few assumptions, a set of equations can be developed and solved either as an optimization problem (residual minimization) or in an iterative manner. For example, Yuval et al. (2007) had rich observational database enabling the estimation of the shares of ambient NOx that could be attributed to emissions from industry. Implementing this method to study the contribution of emissions from the desalination power plant would require assuming that: (a) the desalination plant and traffic are the only sources of NOx in the study area, (b) the ratio between the mean number of molecules of NOx and SO_2that are emitted from the desalination plant during weekdays is identical to the ratio during weekends and holidays. The difference between weekdays and holidays are mostly the amount of traffic and the industries working at lower rates. In general, the data used in such studies are obtained from air pollution monitoring databases or from relatively short campaign of intensive sampling, and must be representative over long time periods. This method, too, is not useful for assessing the impact of future designed facilities, since it require real data and cannot rely on assessments.

Another method for estimating the share of pollutants originating from the desalination power plant may follow Haim (2011). Based on this study the share of air pollution contributed by the desalination plant requires the following assumptions: (a) dispersion of SO_2 and of NO_x is identical such that the molar ratio of SO_2/NO_x in the plume emitted from the desalination power plant and arriving at each nearby monitoring station should remain the same as in the stack. (b) Only stations that are downwind of the desalination plant on any time point (i.e. with the wind blowing from the desalination plant to the monitoring station) should be considered. These assumptions are translated into a set of equations from which it may be possible to calculate the share of the desalination plant in the total nitrogen oxides measured at nearby monitoring stations:

$$NO_X share = \frac{NO_{Xplume}}{NO_{Xmonitoring}} \quad (5)$$

Yet, this method is also applicable only for estimating the contribution of an existing emission source to observed levels.

5.2.3 Impact assessment

There are several possible methods for assessing the air quality impact of desalination plants, with each method estimating the impact using different parameters, such as health endpoints or years of life lost (DALY) due to morbidity and/or mortality. The method of choice is related to the impact assessment requirements and to data availability.

A common method for linking air pollution to health effects is by using concentration-response (C-R) functions, derived from the epidemiological literature. Generally, the method calculates the association between air quality and health indices while accounting for census data on the population at risk, It, thus, generates estimates of the expected incidence changes of specific outcomes in the population per a unit change of the air pollutants (EPA, 1999). The health endpoint considered includes overall or disease/condition specific morbidity, hospital admission, mortality, etc., in particular cardiovascular disease and lung cancer. To estimate the risk of exposure to a certain air pollutant we used a PM C-R function that accounts for long-term exposure to ambient PM levels and mortality as a result of cardiopulmonary diseases (heart diseases and pneumonia) (Ostro, 2004; Pope, 2000). After calculating the estimated effect on different endpoints and accounting for standard life expectancy, the user can use the DALY (Disability Adjusted Life Years) concept. for calculating the incidence and disease burden that is attributes to a given risk factor (Miraglia et al., 2005; WHO, 2002; Liu et al., 2012; Mathers et al., 2001).

The DALY is the sum of years of life lost (YLL) due to premature mortality, and of years of life lived with disability (YLD) (Murray andLopez, 1996). Specifically, the disease burden (in terms of DALY) can be attributed to a local or national-wise exposure, depending on the user's needs and data availability.

The calculation of DALY is as follows:

$$\mathrm{DALY} = \mathrm{YLL} + \mathrm{YLD} \quad (6)$$

$$\mathrm{YLL} = \frac{\mathrm{N}}{\mathrm{r}} * (1 - \mathrm{e}^{-\mathrm{rL}}) \quad (7)$$

where: N is the number of deaths, L is the standard life expectancy at age of death, and r is the discount rate (r=0.03). The discount rate reflects the social preference of a healthy year now over one in the future. Namely, the value of a healthy future year is decreased by (Prüss-Üstün et al., 2003). Similarly,

$$\mathrm{YLD} = \mathrm{I} * \mathrm{DW} * \mathrm{L} \quad (8)$$

where I is the number of new cases, DW is the disability weight, and L is the average duration of disability (in years). Disability weights reflect the health state valuation for different diseases and their values can be found in Murray and Lopez (1996).

A second method of assessing the impact of desalination plants on air pollution is by using the relative risk (RR) and impact fraction (IF) concept. RR functions, such as equation 13, describe the relative risk for a certain health endpoint given an exposure to a pollutant concentration. It is different from the C-R functions since it calculates the relative risk of morbidity and mortality for a given pollutant concentration relative to a threshold concentration, while C-R functions calculates an absolute incidence number of a health endpoint. Once the RR is calculated, the IF associated with a given health endpoint in the exposed population is calculated as

$$\mathrm{IF} = \frac{\mathrm{RR}-1}{\mathrm{RR}} \quad (9)$$

where IF represents the proportion of health end point cases that can be related to the change in the pollutant concentration. The health endpoint can be expressed as the absolute incidence, or the proportion of the DALYs calculated for the health end point relative to the DALY of all the health endpoints.

5.2.4 Monetary valuation

Given the predicted health impact, monetary valuation can be done in two different ways. Pareto (2008) presented possible yet simple and not accurate approach to transform the health impact assessments into monetary value. Pareto approach is based on the ExternE project results, translating it to Israeli currency values by using economic and anthropologic parameters. Another approach is based on Sachs (2002). This method translates DALY values to currency values using equation 1. Given the desalination plant air pollution and health impact assessment in DALY values, the area or country population (in relation to the on-site or off-site approaches, respectively), and the national GDP, it is possible to calculate the monetary value of the impact of the plant. While the Pareto method is useful for preliminary assessment, the Sachs method provides more accurate values. Thus, I used the latter for demonstrating the method.

5.3 Air pollution and public health impact assessment results

According to the research methodology, the impact assessment and monetary value of the air pollution due to expected emissions from the planned Shavei-Zion desalination plant was calculated using both the local scale approach and the national scale approach. The specific at each stage were chosen based on data availability. The pollutant examined was $PM_{2.5}$, since it has been associated with numerous adverse health effects, in particular cardiopulmonary disease. Moreover, since the planned Shavei-Zion desalination plant does not have currently a detailed program regarding in-site power plant construction, its energy demands were estimated following Semiat (2008) as 3.75 kwh/m^3.

5.3.1 National scale impact assessment

5.3.1.1 Emissions

Emissions for the local scale impact assessment were estimated based on fuel type segmentation and consumption in 2009-2011, assuming few alternatives of fuels that will be used in the future. The fuel type segmentation data was obtained from the Israel Electricity Corporation. Since the emission data were presented in terms of PM_{10} and the concentration-response function was available for $PM_{2.5}$, a conversion had been done. Namely, the PM_{10} emissions were transformed into $PM_{2.5}$ emissions according to:

$$[PM_{2.5}]_A = \sum F_i * E * P * [PM_{10}]_i * r \qquad (10)$$

where $[PM_{2.5}]_A$ is the estimated $PM_{2.5}$annual emission from the Shavei-Zion desalination plant (ton/year), F_i is the fuel type share at the national level (coal 0.38, gas 0.5, mazut 0.02 and diesel 0.1), E is the estimated energy consumption per 1 m^3 of desalinated water (3.75 kwh/m^3), P is the annual production of desalinated water (50,000,000 m^3/year), $[PM_{10}]_i$ is the average fuel-type specific PM_{10} annual emission (gr/kwh): coal 0.7, gas 0.016, mazut 0.1 and diesel 0.12, and r is the $PM_{10}/PM_{2.5}$average ratio at the power plant facility stack (0.47; Zereini and Wiseman, 2010). Hence, the estimated annual $PM_{2.5}$ emission from the Shavei-Zion desalination plant, based on non-local electricity production, is 25.38 ton/year.

5.3.1.2 Monetary value

Pareto (2008) set fixed prices per ton of emission for various pollutants based on the prices presented at the ExternE project. The prices represent the impact of electricity consumption on the public health. The Israeli Ministry of Environmental Protection updates these prices every year and presents them to the public. As of 1.1.2014, the updated prices (per ton) are presented in Table 6.

Table 6. External cost prices due to industry, electricity production and transportation updated for 2014. (Source: The Israeli Ministry of Environmental Protection: http://www.sviva.gov.il/subjectsEnv/SvivaAir/Documents/airexternalcost/AirExternalCoast10.2.2014.pdf).

	Electricity		**Industry**		**Transportation**	
	1.1.2014	**1.1.2013**	**1.1.2014**	**1.1.2013**	**1.1.2014**	**1.1.2013**
	per ton (₪)	per ton (₪)	per ton (₪)	per ton (₪)	per ton (₪)	per ton (₪)
SO_2	37,326	34,783	47,895	44,633	---	---
NO_x	21,617	20,144	34,043	31,724	80,978	75,461
$PM_{2.5}$	74,736	69,645	127,972	119,254	156,428	145,772
PM_{10}	53,277	49,648	82,781	77,142	101,631	94,707
VOC	---	---	17,830	16,615	23,023	21,454
CO	---	---	---	---	1,119	1,042
CO_2	110	103	110	103	110	103

Based on Table 16, $PM_{2.5}$ that will originate from the Shavei-Zion desalination plant is expected to result in health outcomes which economic value is estimated at 1,896,800 ₪ (according to the national impact assessments).

5.3.2 Local scale impact assessment

5.3.2.1 Emissions

Emissions from the planned desalination plant, assuming local power production, were estimated based on the assumption that a small on-site power production facility will be constructed. Based on current trends following the finding of large gas reservoirs in the Mediterranean, we assume that the facility will operate solely on gas. Examples of gas-fired power plants built recently are Hagit (near Ramot Menashe) and Gezer (near the city of Ramla).

The emissions from such a facility are estimated as follows:

$$[PM_{2.5}]_A(\frac{gr}{sec}) = E(\frac{kwh}{m^3}) * P(\frac{m^3}{y}) * [PM_{10}](\frac{gr}{kwh}) * r * \frac{1}{31{,}536{,}000}(\frac{y}{sec}) \quad (11)$$

where $[PM_{2.5}]_A$ is the estimated annual $PM_{2.5}$ emission from the Shavei-Zion desalination plant (gr/s), E is the estimated energy consumption (3.75 kwh/m^3; (Semiat, 2008), P is the annual planned production of the desalinated water (50,000,000 m^3/year), $[PM_{10}]$ is the average annual PM_{10} emission from gas turbines (gr/kwh) (דין וחשבון סביבתי*;* 2009; 2010; 2011), and R is the $PM_{10}/PM_{2.5}$ average ratio at the power plant stack (0.47; Zereiniand Wiseman, 2010). Hence, the annual estimated $PM_{2.5}$ emission from the Shavei-Zion desalination plant according to the local power production scenario is 0.045 gr/s.

5.3.2.2 Ambient concentrations

Since the desalination plant is not fully planned at this stage, it was not possible to use any of the methods described earlier to calculate ambient concentrations that result from the related emissions. In fact, this situation is common when performing EIA for planned facility. In such cases of the very early design stages, based on a simple Gaussian plume dispersion model and a number of assumptions, it is possible to calculate the range of $PM_{2.5}$ concentrations at the required receptor points (the cities of Akko and Nahariya, the closest large population centers to the planned desalination plant in this work).

First, a windrose for the study region should be created. In the case of the Shavei Zion desalination plant, this was done based on data from the last four years (1/1/2010-1/12/2013) obtained from the Israel Meteorological Service (Figure 18). It is seen that the main wind directions are north-north east towards the city of Nahariya, south-south west and south west towards the city of Akko, and west towards the Mediterranean Sea. The west direction could be neglected, since there is no population in that direction. Next, ambient $PM_{2.5}$ concentrations in Nahariya and Akko were calculated using the standard Gaussian plume dispersion model:

$$C(x,y,z)=\frac{Q}{2\pi u\sigma_y\sigma_z}e^{-\frac{y^2}{2\sigma_y^2}}\left(e^{-\frac{(z+H)^2}{2\sigma_z^2}}+e^{-\frac{(z-H)^2}{2\sigma_z^2}}\right) \qquad (12)$$

where Q is the $PM_{2.5}$ emission rate (0.045 gr/s), U is the average wind speed (5 m/sec in the direction of Nahariya and 1m/sec in the direction of Akko, see Figure 18), x *is* the x-coordinate of the receptor (3 km to Nahariya and 6 km to Akko), y and z are the y and z coordinates of the receptor (0, 0), i.e. the plum's center at ground level, σ_y and σ_z are the plume width standard deviations in the y and z directions, respectively, and H is the effective stack height. The atmospheric stability was taken to be either B, C or D atmospheric stabilities based on the wind speed (1-5 m/s) or assuming the exposure to take place during the day, when people are outside their houses. The effective stack height was taken to be between 40 and 70 m, based on similar small scale gas-firedfacilities.$PM_{2.5}$ concentrations were calculated according to two parameters scenarios- stack height and atmospheric stability, performing a sensitivity analysis type calculation (Figure 19). The minimum and maximum concentrations were assumed to represent the range of possible concentrations (0.0185-0.395 $\mu g/m^3$),

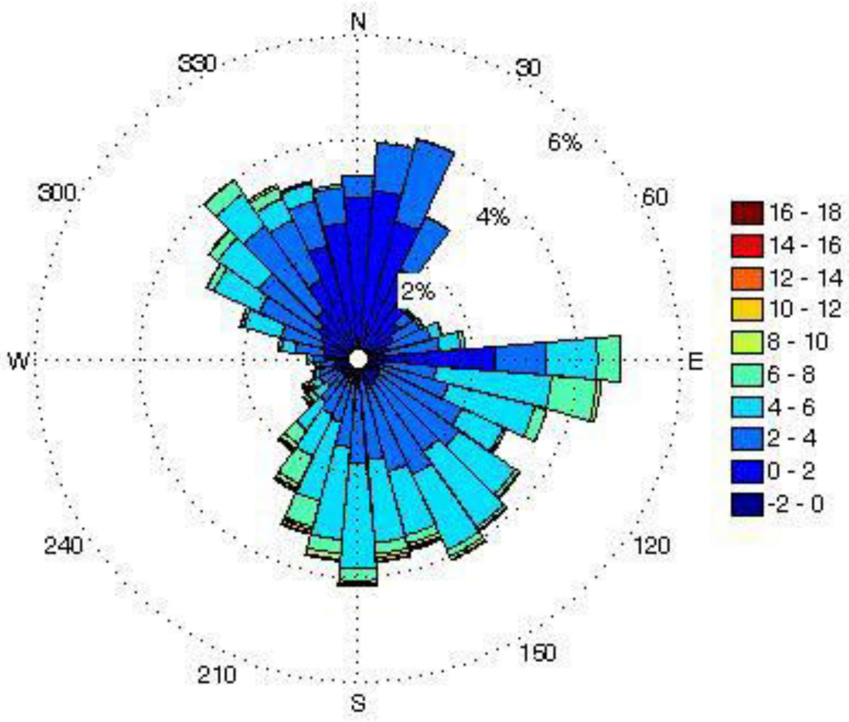


Figure 18. Windrose for the Shavei Zion study area based on the Israel Meteorological Service data from1/1/2010-1/12/2013. Wind speed in meters per second.

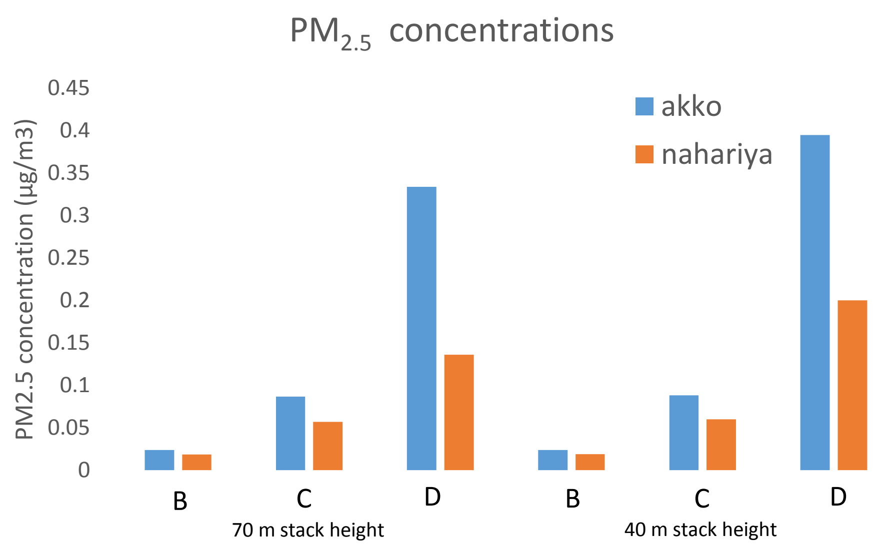


Figure 19. Estimated ambient $PM_{2.5}$concentrations in Nahariya and Akko for the B, C and D atmospheric stabilities and stack height of 40 m or 70 m.

5.3.2.3 Impact assessment: Relative Risk (RR) and Impact Fraction (IF)

The calculation of the RR and IF that result from exposure to ambient $PM_{2.5}$concentrations, attributed to the desalination plant, followed the scheme presented by Ostro (2004) for assessing long-term exposure. For demonstration purposes, the outcome studied was cardiopulmonary mortality, including mortality from heart diseases and pneumonia. This outcome was chosen since it is has been associated with exposure to $PM_{2.5}$(Pope et al., 2002). The relative risk was calculated via

$$\mathrm{RR} = e[\beta * (X - X_0)] \quad (13)$$

where β equals 0.00893 [0.00322, 0.01464] Ostro (2004), X is the $PM_{2.5}$ concentration calculated at the receptor point ($\mu g/m^3$), X_0 is the ambient $PM_{2.5}$ concentration ($\mu g/m^3$), and ΔX (i.e. $X - X_0$) is the $PM_{2.5}$ concentration attributed to the desalination plant. The IF follows the calculation described in equation (4).The IF for cardiopulmonary mortality due to long-term exposure to ambient $PM_{2.5}$ that originate from the desalination facility power plant is estimated to be 0.017% and0.35% for the Nahariya and Akko populations, respectively.

5.3.2.4 DALY

Since the calculated IF referred to cardiopulmonary mortality, I referred only to YYL (Years of Life Lost) instead of the sum of YYL and YLD (Years Lived with Disability). According to Prüss-Üstün et al. (2003), calculating the DALY value of mortality (YYL) and morbidity (YLD) separately, using distinct C-R functions, is a way to value the two health outcomes separately. Here, YYL was calculated using equation (6).All the data required for the calculation of YLL were obtained from the Central Bureau of Statistics. Standard life expectancy at age of death and number of deaths as a result of cardiopulmonary diseases (heart diseases and pneumonia) were obtained for the Akko district population above 45 years of age, obtained from the age group and gender adjusted 2008 census. The relative number of deaths in Akko and Nahariya was obtained by normalizing the deaths by the population at the years 2005-2009. For the purpose of demonstrating a full example of the method, I assumed that the total number of deaths in Nahariya and Akko as a result of cardiopulmonary diseases in people older than 45 will not change dramatically after the construction of the desalination power plant facility.

Finally, the estimated number of deaths in Akko and Nahariya must be multiplied by the impact fraction to assess the direct impact of the facility on public health:

$$YYL_{Attributed} = IF * YYL_{Calculated} \quad (14)$$

The estimated number of years of life lost (YYL) in Akko and Nahariya due to cardiopulmonary diseases in people older than 45, attributed to exposure to $PM_{2.5}$ emitted from the Shavei-Zion desalination plant, is expected to range between 0.26 and 5.61 years.

5.3.2.5 Monetary value

Monetary value of the impact of air pollution attributed to the desalination plant on the public health was calculated according to equation (9), where the attributed YYL was 0.26-5.61 years, the population was the average population of Akko and Nahariya in the years 2005-2009, and the local gross domestic product of Akko and Nahariya in the years 2005-2009 was calculated using the GDP of Israel in 2005-2009 and the ratio between the local population in Akko and Nahariya and the total population of Israel during these years. The local GDP of Akko and Nahariya was simplified for the purpose of demonstrating the method, assuming that the specific GDP for all cities in Israel is the same. The estimated monetary value of the studied health outcomes that are attributed to air pollutants emitted from the desalination plant ($PM_{2.5}$ in this work) in Akko and Nahariya ranges between 74,453and 1,585,395 NIS.

5.4 Air pollution and public health impact assessment discussion and conclusion

Air pollution and public health impact assessment is a common tool for predicting and examining the impact of planned industry projects on the lives of citizens living nearby. To date, the final assessment is usually presented as quantitative values of health indices (e.g. incidence rates, relative risk, etc.). Here we present an approach followed by the ExternE project that provide the predicted impacts in terms of monetary value using various flexible options. The monetary value describes the potential risk in terms of a simpler and more comprehensible metric for the public and decision makers. In this way, the air pollution and public health impact assessment may be more relevant and meaningful to the public and to professionals, and perhaps gain popularity and broaden the use of this tool. A flexible impact assessment method allows the user to choose the components and scale desired for the studied conditions. Much resources can be saved by adjusting the EIA-HIA to the objectives and scope of the assessment.

This work is based on common impact assessment methods, integrating them into one multi-path impact assessment method. This approach allows the user to choose the suitable method of assessment according to accuracy level required and data availability. The approach allows the user to follow the path applicable to the specific conditions at hand, and to choose the proper values that fit best the case studied. Naturally, the impact assessment is more accurate for existing pollutant sources rather than for planned ones. This has to be taken into account while calculating the local impact assessment pathway, presenting the final results as a range of possible values.

Here, we present the impact of the planned desalination plant in Shavei-Zion both at the national scale, describing all the health outcome resulted from the increased PM2.5 concentration (with health related monetary value of 1,896,800 NIS), and the local scale, describing mortality from cardiopulmonary diseases in Akko and Nahariya in people older than 45 as a result of increased PM2.5 concentration (with health related monetary values in the range of 74,500-1,585,500 NIS). A significate public health cost is predicted to air pollution resulted from the desalination plant operation. At the national scale, the cost of exposure to the desalination plant related PM2.5 emissions is relatively high in comparison to other pollutant, but it is relatively small in comparison to other PM2.5 sources, such as industry and transportation (see Table 6).

Since there are no concrete construction plans for the Shavei-Zion desalination plant at this point, the expected accuracy of the current impact assessment is not high. However, it is noteworthy that the two tracks followed for the impact assessment (national and local scales) provide similar monetary values. This similarity suggests that (at least for the example studied) the crude impact assessment we performed following the two distinct research methodologies converges to a common range of monetary values. Since the calculation of impacts based on the national track is relatively simple, it is recommended to always calculate it for comparison purposes.

The pollutant examined for demonstrating the research methodology was $PM_{2.5}$, since it has been associated with numerous adverse health effects, in particular cardiopulmonary disease. A more complete impact assessment will have to take into account other pollutants, such as SO_X, NO_X, CO, etc. The total impact assessment is the sum of all pollutants and health outcomes examined. Clearly, in terms of monetary value summation of all the pollutant specific impacts is possible, which is not always the case when the results are provided in terms of incidence rates or additional (clinical) cases. The latter is particularly important since the effects of different air pollutants are distinct. For example, Small and Kazimi (1995) examined the cost of air pollution from motor vehicles and found that the monetary value resulted from SO_X and particulate matter is 10 times higher than the monetary value that results from VOC or NO_X.

6. Discussion and Conclusions

This research was set up to improve the methods currently used for assessing the impacts of desalination plants on the environment and on human health. We focused on developing a quantitative approach, including monetary value considerations that can be used by decision makers. Distinct impact assessment methods are suggested for the marine environment ecosystem and for air pollution and public health. The methods were demonstrated on the planned Shavei-Zion desalination plant.

As mentioned above, the research had been divided into two different sections. The marine ecology impact assessment section provides a quantitative assessment whereas the air pollution and public health impact assessment section provides monetary valuation. The research does not suggest an integration between these two assessments. A possible integration path is by assessing the ecological impact of desalination plants in monetary values using the ecosystem services method, and then summing all the potential effects of the desalination plant and presenting them as one impact assessment value. However, we did not use this method in the research since the ecosystem services method does not reflect all aspects of the marine ecosystem as a whole, as mentioned in the ecological impact assessment section.

Another possible path for integration can be creating degree of impact scale for the air pollution and public health impact assessment, and then presenting the final assessment in terms of degree of impact. The Impact Fraction value can be used for this path. For the current research the pollutant examined, $PM_{2.5}$, and cardiopulmonary mortality in people older than 45 in Akko and Nahariya, a degree of impact scale can be created using epidemiological data. This scale will describe the severity of the impact on the population in terms of the fracture of the population that was affected. A sensitivity analysis must be performed by the same steps described in the ecological impact assessment section. The final impact assessment value is the weighted average of all parameters described in the research (ecological and public health parameters). There is a need to decide the relative impact of each parameter in advance and perhaps to perform a sensitivity analysis in order to sharper the final result. The main disadvantage of this path is the amount of uncertainties and the lack of attention to the severity of the health impact described.

For conclusion, I think that integration of different impact assessment methods poses a certain which cannot be ignored. Each method refers to a different aspect of the impact of desalination plants and relies on totally different fields of environmental science. Naturally, the two fields discussed in this work are based on totally different concepts and ideas. Integrating them together can result in inaccurate, irrelevant and even wrong results/indices. For every impact assessment study, there is a need to consider if the integration of different methods and fields will improve the final assessment or make interpretation of the results too uncertain for practical use.

Appendix: Lists of species and taxes used for the statistical analysis

Table A1. List of species and organisms number collected in September 2004.

Taxa	Stations	1a	1b	1c	2a	2b	2c	3a	3b	3c	4a	4b	4c	4d	5a	5b	5c	6a	6b	6c	7a	7b	7c	8a	8b	8c	9a	9b	9c
Polychaeta	Capitellidae				2						1		4											1	1	2			
	Cirratulidae	2	5	4	5	5	1	1	1	1	9	4	13	3	1	3	10	12	16	7	1			3	2	1		1	1
	Chaetopteridae									1										1									
	Glyceridae	1	3					2	2	2	3	1	4	1	1			2	2	1				1			2	3	1
	Hesionidae																										3		
	Magelonidae	2	2	2	11	1	6	1	1	3	2			2	1	7	8	7	10	2	2		2	16	10	17		2	1
	Maldanidae					1							6	1		1			1	1		1		1	1			1	
	Nephtyidae	1	3	2	6	1	3	1	1	6	3				2	4	3	4	9	3	2	2	3	7	6	6	4	6	7
	Onuphidae	2	4		4	2	3	2	4	2	2	2	14	1		2	4	2	4	1	2	4	2	1	1				1
	Orbiniidae	6	3	4	3	3	2			3		1	2	3	1	4		1	2		3	20	8	3	2		1	2	2
	Oweniidae										1						1				1		1	3					
	Paraonidae	179	44	177	295	96	172	50	28	117	60	36	149	17	40	46	108	199	222	209			6	49	15	48	1	1	
	Phyllodocidae			1											2														
	Pilargidae	5	7	17	3	7	2	1	3	3	2		4	3	1		2	4		2				3	1	1			
	Sigalionidae				1	2					2									1	2		1			1	1		
	Spionidae	25	13	12	6	8	3	3	7	6	19	7	16	15	7	3	10	8	8	2	8	14	13	26	13	24	3	11	1
	Syllidae											1	9		4	9	41	8	16	5									
Crustacea	Amphipoda																												
	Ampelisca brevicornis			1			2			1				1		1	2		1					1		1			
	Bathyporeia guilliamsoniana																					1							
	Bathyporeia sunnivae		1	1												2	1				2	4	1						1
	Lembos sp.								3																				
	Leucothoe occulta																				1								
	Megaluropus massiliensis			2	1				3	1	3	1	1					3	1	1	4	3	19	1				1	2
	Perioculodes longimanus			4	2		6	3	7	3	9	5	2		2	7	3	10	2	3	4	2	10		2				
	Pontocrates arenarius										3																		
	Urothoe grimaldii			1				1								4		1		1	5	1	8	3	5	6		2	4
	Copepoda		1			1	3	2										1	1	1				1					1
	Cumacea																				1								
	Decapoda																												
	larvae		1	1							3			1						1		1			2				
	Lucifer typus	4															1	1				1	1	1					
	penaeid								2											1				1			1		
	Philocheras monacanthus															1													
	Diogenes pugilator	3		3	1	17	8	7	1	4	2		3	3	1		2	1	1	1			1	2	9	20		1	1
	Ogyrides mjobergi	10		6	13	12	5	7	10	11	13		6	6	5	9	11	9	15	10	15	5	5	12	17	13	8	21	17
	Leptochela pugnax																									1			
	Albunea carabus																		1										
	Leucosia sp.	1		2							1																		
	Brachynotus sexdentatus									1																			

Taxa	Stations	1a	1b	1c	2a	2b	2c	3a	3b	3c	4a	4b	4c	4d	5a	5b	5c	6a	6b	6c	7a	7b	7c	8a	8b	8c	9a	9b	9c
	Stomatopoda																												
	Isopoda							1	1																				
	Tanaidacea			6	1	4	2		3		3		2	1	14	19	32	20	46	13	1			12	2	4	1	20	14
Mollusca	*Acteocina mucronata*			1							1	1				1						1							
	Anadara cfr. Corbuloides											1							1										
	Brachidontes pharaonis																		1			5							
	Chamalea gallina									1																			
	Chrysallida limitum		1																			1							
	Diplodonta subrotundata	1		4					3													1					5		
	Donax semistriatus		1			3		2		1							1		1				2						
	Euspira pulchella						1																						
	Glycymeris glycymeris	1									1																2	2	
	Gregariella petagnae										1																		
	Lithophaga lithophaga																									1		1	
	Loripes lacteus		3												2	18		3	4	3				2	1		2	6	13
	Mactra stultorum						1																4						
	Monoptygma amoena						8	2		4																			
	Mytilus sp.																1												
	Neverita josephina		1									1																	
	Parvicardium ovale			1																									
	Retusa desgenetti			1																									
	Scacchia oblonga																									1			
	Strombus decorus		2				1																						

Taxa	Stations	1a	1b	1c	2a	2b	2c	3a	3b	3c	4a	4b	4c	4d	5a	5b	5c	6a	6b	6c	7a	7b	7c	8a	8b	8c	9a	9b	9c
	Tellina fabula									3													3						
	Tellina sp.	2	4	1							2	1					1	2	1	3	2	4		3	5				1
	Thracia papyracea															1													2
Coelenterata	Actinaria												1																
Pantopoda																	1			1								1	
fish							1											1											

Table A2. List of species and organisms number collected in September 2008.

	Stations	1a	1b	1c	2a	2b	2c	3a	3b	3c	4a	4b	4c	5a	5b	5c	6a	6b	6c	9a	9b	9c
Taxa																						
Polychaeta	*Capitellidae*		14	5	1		2			3		1	2	2	13	5	10	3	3			
	Chaetopteridae			1																		
	Cirratulidae		1	1	4		1			1	7	5		1		1	2	4	4			
	Glyceridae	5	21	15								1		1	1	1	10	2	2			
	Hesionidae		2																			
	Lumbriconereidae									2					1							
	Magelonidae	3	2	2	15	8	30				16	14	6	9	29	12	24	22	11	1	1	
	Maldanidae	1																1				
	Nephtyidae	2	37	25	3	6	7	22	2	9	8	10	13	12	13	8	19	9	9	9	19	17
	Nereidae														1	2						
	Onuphidae		4	5		2	3				1	1	1	1	2		5	5	4			
	Orbiniidae	3		2	5	2	5	16	7	9	6	7	17	11	7	2	8	2	1	9	16	19
	Oweniidae		5	3	1	4	3					1					1				6	1
	Paraonidae	2	4	2	5	3	1				9	5	3	1	9	3	7	10	15	1		1
	Phyllodocidae		2	3		1				1	1	2		1	4					1		2
	Pilargidae	3	236	136											1		10	3	2			
	Poecilochaetidae			1							1			1				1				
	Serpulidae															1						
	Sigalionidae									1			2	1		1			1			
	Spionidae	123	1005	383	32	43	40	2	6	19	109	109	96	52	100	111	123	47	94	12	11	6
	Syllidae	1	1		7	5	8	1		2	12	18	3	3	2	10	3		8	14	48	121
Crustacea	**Amphipoda**																					
	Ampelisca brevicornis						1															
	Ampelisca sarsi														2		2	1	1			
	Ampelisca sp.						3							1		3						
	Bathyporeia guilliamsoniana							5												4	4	7
	Bathyporeia sunnivae							26	2	1										16	11	10
	Megaluropus massiliensis	1						1		1						3				3	3	3
	Perioculodes longimanus longimanus					3	1							1		1						
	Pontocrates arenarius							2		1								1		4	2	
	Urothoe grimaldii	2			9	3	12	16	5	1	7	25	22	7	4	6	5	11	2	34	49	75
	Copepoda																					
	HARPACTICOIDA																					
	Longipedia coronata	4	3	6	11	7	9	12	14	17	11	8	9	6	9	11	34	23	22	3	2	3
	Canuella aff. *furcigera* Sars	1	3	4	5	8	5	2	4	5		2	3	9	6	5	23	13	14	2	4	2
	Canuella aff. *perplexa*	7	9	4	31	41	46	23	34	37	21	44	33	6	5	9	21	30	26	3	4	2
	Canuellina insignis	7	3	4	25	27	33	48	45	55	53	47	42	15	8	9						
	Scottolana bulbosa	2	3	2	5	8	9	4	2	3	6	9	10	19	23	30						
	Canuellidae gen. et sp	13	6	5	3	4	5	7	8	14	16	21	23	17	17	13	15	14	14	1	3	1
	Halectinosoma canaliculatum	1		2	12	15	13	32	17	23	34	38	41	27	32	23	4	4	3	6	3	1
	Halectinosoma diops	8	4	5				1			1	4	6	6	4	3		1				
	Diosaccus truncatus													1	3	4	3	5	5	6	2	1
	CYCLOPOIDA																					
	Tococheres sp.							3	2	5			1	7	4	5	16	21	8	1	3	4
	CALANOIDA	143	107	79	202	167	97	203	159	105	305	231	249	179	208	256	77	45	67	3	5	7
	Bodotria gibba															2						
	Bodotria pulchella													1					1			
	Campylaspis glabra															1						
	Decapoda																					
	Callianassa sp.																					1
	Diogenes pugilator										2							1	6			
	Lucifer sp.					1										1						
	Liocarcinus sp.					1																
	Ogyrides mjobergi	1	2	2	8	2	2			2	2	6	3	3	2	10	3	1	3	3	2	2
	penaeid															1						
	Ostracoda	8	5	12	84	49	92	1	2	4	23	37	32	267	267	246	13	2	5	3	5	2
	Tanaidacea																					
	Apseudes mediterraneus	1					2							4	2	11	2	3	3			
	Tanaissus microthymus				87	68	77	2			22	32	27	71	85	37	25	31	17	1		
	Isopoda	3																				

	Stations	1a	1b	1c	2a	2b	2c	3a	3b	3c	4a	4b	4c	5a	5b	5c	6a	6b	6c	9a	9b	9c
Taxa																						
Mollusca	*Acteocina mucronata*	1					1				1					1						
	Anisocycla striatula									7												
	Bela sp					1	1				1											
	Brachidontes pharaonicus	1		5						25												
	Chamalea gallina																6		1			
	Chrysallida limitum			1																		
	Chrysallida maiae								2	1												
	Diplodonta bogii		98	52										3								
	Donax semistriatus				1	1		2			1				1			2	3			
	Finella lupoide		1	2																		
	Glycymeris glycymeris		3				5						2	1				1				
	Leucotina natalensis														1							
	Lucinella divaricata											1										
	Loripes lucinalis	1			3		1				1					1				1		
	Mactra stultorum	4				5	7	1		3	8	12	11	2	9	12	2			8	3	7
	Modiolula phaseolina		8																			
	Musculus subpictus							1								2			2			
	Mytilus sp																			3	2	
	Nassarius costulatus cuvierii									1												
	Nassarius gibbosulus		2					2	3	5												
	Neverita josephina														1	1						
	Odostomia conoidea																1					
	Retusa desgenettii		105	135																		
	Rhinoclavis kochi		8	16											1							
	Rissoa similis													1	2							
	Strombus decorus	4	37	44			1		1			3	2	2		8	6	1	2		1	
	Tellina nitida	1	1		1	2	9				1	5		2	2	1	2	3	3	1		
	Tellina serrata		4	5										2			1	4				
	Thracia papyracea		5	6	2		5		1		1	2		3	3	11	2	14	13			
Phoronida					1																	
	SUM	**357**	**1751**	**975**	**563**	**487**	**537**	**435**	**316**	**363**	**687**	**701**	**659**	**759**	**884**	**884**	**485**	**341**	**375**	**153**	**209**	**295**

Table A3. List of species and organisms number collected in September 2009.

	Stations	1a	1b	1c	2a	2b	2c	3a	3b	3c	4a	4b	4c	5a	5b	5c	6a	6b	6c	9a	9b	9c	SUM
Taxa																							
Polychaeta	Capitellidae		1	2									1	2		3	2	4					15
	Chaetopteridae				4				1		1	1		4	2		3						16
	Cirratulidae						1						1	1					2				5
	Glyceridae										3		1				1				1	2	8
	Lumbrineridae	1													1	1							3
	Magelonidae	4	1	3	2	2	2			1	2	4	5			2	4	2	6	1	3	1	45
	Maldanidae		1	4	2	2				1	2	1		1	3		15	11	13	1			57
	Nephtyidae	20	21	10	13	16	12	27	23	29	19	24	18	2	10	12	12	12	13	38	54	33	418
	Nereididae		1											1									2
	Onuphidae													1		1					1		3
	Orbiniidae	6	8	4	3	2	4	5	7	4	8	6	4	5	5	4		2	5	5	11	6	104
	Oweniidae				1														1			2	4
	Paraonidae		1			1											1	1	1		1		6
	Pectinariidae	1				1									1	1		1					5
	Phyllodocidae							1	1	1		1						1		5	4	3	17
	Pilargidae	1																1	1				3
	Poecilochaetidae		1																			1	2
	Sigalionidae	1	1	3	1							2		2			3	2	4			1	20
	Spionidae	31	48	70	33	21	45	39	23	1	51	50	41	6	41	38	54	41	29	125	215	149	1151
	Syllidae	2	1	7	5	9	2				10	3	3	1	1				1				45
	Terebellidae																			2			2
Crustacea	**Amphipoda**																						0
	Ampelisca brevicornis	2	3	5	3	4	2				3	4	1	1		2	4	8	3				45
	Ampelisca sarsi																1		1				2
	Ampelisca sp.														4	2							6
	Bathyporeia guilliamsoniana	2	1	1	17	24	11	1	2	6	15	11	14	35	36	32	7	36	11	1	1		264
	Bathyporeia sunnivae	4	25	50	194	111	210	16	34	77	141	112	172	124	143	111	41	115	22	31	68	61	1862
	Caprellidae gen. sp.													1					1				2
	Chairiphotis mediterranea													1									1
	Ericthonius brasiliensis													2					14				16
	Jassa ocia								1														1
	Lembos spiniventris			2	1								3	2	2		3	6	6				25
	Leucothoe incisa													1									1
	Leucothoe sp.												1		3			3		2		1	10
	Megaluropus massiliensis				1																		1
	Perioculodes longimanus longimanus	2	2		4	9	12	1	2		7	4	9	14	20	13	8	35	5	3			150
	Photis longicaudata																		1				1
	Pontocrates arenarius							3	2	1			1	1		1				33	37	16	95
	Urothoe grimaldii	6	3	4	15	4	12	1	11	5	8	21	29	14	19	23	16	18	15	10	17	9	260
	Copepoda																						0
	HARPACTICOIDA																						0
	Alteutha sp. 1													3									3
	Canuella aff. furcigera	3	3	3	4	1	1			1		3				3		4	2				28
	Canuella aff. perplexa	8	2	2	6	11	4	1	5		1	4	2		17	21	22	21	3	2	3		135
	Canuellidae gen. et sp. nov. 1	1			3	3	3					3	2		1	4	3	7	2				32
	Canuellina insignis	62	25	39	25	27	19				44	35	15	1	14	22	1	5	5			1	340
	Diosaccus truncatus													3		1	2		1				7
	Halectinosoma canaliculatum					3	3	1				3	5		1	1	1	5	4	1			28
	Halectinosoma diops													3	7	6							16
	Isocletopsyllus tertius													1									1

	Longipedia coronata				1	3																	4
	Scottolana bulbosa					1						5	5	1	3	1		3					19
	Thompsonula hyaenae	1		1	2	5	1	2	1			2	3	2		1	2	2					25
	CYCLOPOIDA																						0
	Tococheres sp. 1				1		1				1				1			1					5
	CALANOIDA	1	1		3	2	4	1			1	2	1		2	1	2	4	2	1	2	1	31
	Cumacea																						0
	Bodotria gibba				1	1							1								1		4
	Bodotria pulchella																	1					1
	Campylaspis glabra					1					1			1	1			1					5
	Cumopsis goodsir							3	3													1	7
	Pseudocuma longicorne												2	1	1		2	2	1	1			10
	Decapoda																						0
	Diogenes pugilator	2			1	4				1	3	2	1	6	1	1		3	1				26
	Liocarcinus depurator						1	1															2
	Ogyrides mjobergi	1			2				1		1		1	1						1			8
	Upogebia sp.					1																	1
	Trachysalambria palaestinensis																1						1
	Ostracoda	1		1	1	5	3			1		8	3		133	81	16	22	30				305
	Tanaidacea																						
	Apseudopsis mediterraneus	2	2	15	1	3	1							3	18	6	118	65	46				280
	Pseudotanais stiletto	1																					1
	Tanaissus microthymus	8	12	12	106	126	144				89	103	82	22	204	213	76	80	91	1	2		1371
Mollusca	*Arcularia gibbosula*							3	4														7
	Chamalea gallina			1	1							1											3
	Diplodonta bogii														1				1				2
	Donax trunculus		2	1	1		2	1			1							1	1		1		11
	Glycymeris glycymeris				1						5												6
	Lucinella divaricata	3	2	3		1	2				6	4	7	2	16	10	2		2	5	3	2	70
	Mactra stultorum	1																					1
	Musculus subpictus					1							2							1			4
	Neverita josephina		1													1		1					3
	Ringicula cfr. conformis																5	4					9
	Rissoa sp.													1		1		1					3
	Rissoa similis														1								1
	Strombus persicus		1					1	1														3
	Tellina cfr. exigua							1															1
	Tellina fabula					2	1				1												4
	Thracia papyracea						1								1	2	2						6
	Volvulella acuminate																	1					1
Acrania	*Branchiostoma lanceolatum*															1							1
Fish	*Dalophis* sp.		1																				1
SUM		**178**	**171**	**243**	**459**	**407**	**504**	**109**	**122**	**129**	**424**	**419**	**436**	**273**	**714**	**623**	**430**	**533**	**347**	**270**	**425**	**290**	**7506**

Table A4. List of species and organisms number collected in September 2010.

Taxa	Stations	1a	1b	1c	2a	2b	2c	3a	3b	3c	4a	4b	4c	5a	5b	5c	6a	6b	6c	9a	9b	9c	Total
Polychaeta	Capitellidae			1							1			4		2			1			1	**10**
	Cirratulidae						1				4	1		1		1							**8**
	Glyceridae	3	2				2			1	1						1	2			2		**14**
	Hesionidae				1									1	1								**3**
	Lumbrineridae				1																		**1**
	Magelonidae	1			2		3				1	1		1	2	6		1	1	2	1	1	**23**
	Maldanidae		1		3	3					1	1	2	3		6	3	3	1	2		1	**30**
	Nephtyidae	26	29	24	56	24	43	29	22	20	39	41	15	45	53	63	29	34	18	61	62	37	**770**
	Nereididae			1				1	1	2	1					1							**7**
	Onuphidae				3	3	5	5	3	4	3	4	1	6	5	1	2			3	3	6	**57**
	Orbiniidae	1		2			1	3	3	2		1		1	3			1		2	2	4	**26**
	Oweniidae																		1				**1**
	Paraonidae		2	1	9	2	4	2	2	2	14	7	2	11		2	4	3		4	4	2	**77**
	Phyllodocidae						1	1	1	1				1			1			10	1	4	**21**
	Pilargidae		4	1													5	5	3				**18**
	Poecilochaetidae	3	3	2	8	1	7				2	2		8	2	5	6	4	1	5	3	1	**63**
	Serpulidae													1									**1**
	Serpulidae													1									**1**
	Sigalionidae	1	1		1	3	3	2	2	5	2	4	2	2	2	4	4	3	1	3	8	1	**54**
	Spionidae	54	50	75	47	5	27	11	21	7	57	54	33	33	30	84	24	25	18	80	60	25	**820**
	Syllidae		3		4	1	5				3	6	3	4	2	16				1	3		**51**
	Terebellidae										1												**1**
Crustacea	**Amphipoda**																						**0**
	Ampelisca sp.				6	1	3				3		1	3	1	3				1		1	**23**
	Bathyporeia sp.							2	3	2										4	2	2	**15**
	CAPRELLIDAE																						
	Urothoe sp.	2	1	1	12	8	7	5	11	16	12	11	3	10	7	23				9	7	8	**153**
	Specimens not identified									1					1					1			**3**
	Copepoda																						
	HARPACTICOIDA																						
	Canuella aff. *furcigera*										12	7	5	9	15	12							**60**
	Canuella aff. *perplexa*	11	7	8	12	7	14				1		1	78	99	71	5	3	9	12	16	19	**373**
	Canuellidae gen. et sp. nov. 1				3	4	9	2	4	4	2	3	6	11	9	5				3	2	1	**68**
	Canuellina insignis	6	24	34	16	10	23	8	11	13	17	10	13	134	127	104	14	5	7	9	18	15	**618**

Crustacea	*Diosaccus truncatus*				3	1	1	1	6	3												**15**
	Halectinosoma canaliculatum				4	4	2	3	2	4	2	1	2		2	3				2	5	11	**47**
	Halectinosoma diops											1	2										**3**
	Longipedia coronata				1		1				2	2	3	13	17	10							**49**
	Scottolana bulbosa	8	13	17	15	8	12				4	4	2							2		1	**86**
	CYCLOPOIDA																						
	Cyclopina sp.					1								1	3	2							**7**
	Euryte sp.		2	1										4	1	3							**11**
	Oithona sp.																						**0**
	Tococheres sp.	3	1	1	3	3	4	5	4	6	1	3	2	3	5	4				1		2	**51**
	CALANOIDA	4	11	7	2	8	11	7	6		4	5	1	6	7	3		3	8	4	6		**103**
	Cumacea																						
	Pseudocuma longicorne										1												**1**
	Decapoda																						
	Ostracoda		2		91	33	29	22	17			5	4	46	74	75		1		116	132		**647**
	Tanaidacea																						
	Apseudopsis mediterraneus		1		4	2	8				1	3		7	5	3	4	2		4	4		**48**
	Tanaissus microthymus	1	2	1	135	34	67	11	20	26	84	85	21	55	70	135	1	1		223	159	50	**1181**
Mollusca	***Acteocina mucronata***	11	16	10	3	1			1		1	8				2	5	2		5		2	**67**
	Bittium sp.																	2					**2**
	Brachidontes pharaonis											1											**1**
	Chamalea gallina																			1			**1**
	Chrysallida obtusa						2									1							**3**
	Dentalium sp.						1								1								**2**
	Diplodonta bogii	2			2	1	1		1			1					8				1		**17**
	Donax semistriatus																				2		**2**
	Finella pupoides			1																			**1**
	Glycymeris glycymeris					1							1										**2**
	Leucotina natalensis							3		1		1			4					3			**12**
	Loripes lucinalis	1			6	6	4	14	3	5	5	6		3	10	24				11	6	15	**119**
	Mactra stultorum	3	4	2	2			3	2	4		2		2	3	1	1		1	9	6	6	**51**
	Mediolulua phaseolina										2				1								**3**
Mollusca	***Nassarius gibbosulus***								1														**1**
	Rinoclavis kochi													2	95	44							**141**
	Rissoa sp.															1							**1**
	Rissoa guerini				1										1								**2**
	Strombus persicus													2	2	11		1	1				**17**
	Tellina fabula															1							**1**
	Tellina planata											1											**1**
	Thracia papyracea					1						1					1						**3**
	Turbonilla rufa													1									**1**
	Total	**141**	**179**	**190**	**456**	**176**	**301**	**140**	**147**	**129**	**284**	**283**	**125**	**513**	**660**	**732**	**118**	**101**	**71**	**593**	**515**	**216**	**6070**

Table A5. List of species and organisms number collected in September 2011.

Taxa	Stations	1a	1b	1c	2a	2b	2c	3a	3b	3c	4a	4b	4c	5a	5b	5c	6a	6b	6c	9a	9b	9c	11a	11b	11c	12a	12b	12c	15a	15b	15c
Polychaeta	Capitellidae		1		1	1	1				1	2			3	2					1					9	167	115			3
	Chaetopteridae												1													1		1			
	Cirratulidae		1		1		1					3	1		1	1															
	Glyceridae	1	1	1		2	1				1	1	1		1				1	1	1		1		4	2	4	3			
	Hesionidae	1	1	2								5	2			1	1								1		1	1			
	Magelonidae	1	1	4	6	7	4				6	9	4	5	6	3	12	7	5			1	1			3	7	5			
	Maldanidae	1		1	1	1					3	2			1	1	2	1	2	1		1	1				1				
	Nephtyidae	5	10	7	11	5	13	12	8	4	13	7	4	2	5	11	5	3	4	6	15	11	2	6	5	5	15	25	9	8	10
	Nereididae		1			1	1		1			1									1			1	1			2			1
	Onuphidae	4	6		2	3	3	9	2	7	7	2	2		1	2	1			5	6	8	3		4	2	2				
	Orbiniidae	4	1		6	2	5	46	37	23	3	6		1	1	5		1	2	18	17	17	1	4	1	1			2	1	1
	Oweniidae		1														1		1												
	Paraonidae		2		3	1					2	5		3	11	6		5	1	1								1			
	Phyllodocidae				1	1	1			1						1	1									1		1			
	Pilargidae	2		1																				1	2		3	9			
	Poecilochaetidae		1		1	2	2				1				1	1									1		2				
	Sigalionidae	1		1	1	3	2	4	1		3	2					1	1		1							1		1	1	4
	Spionidae	33	35	31	19	27	41	4	1	6	20	60	32	23	61	92	21	18	20	6	4	5	25	64	65	50	125	145	1		2
	Syllidae	3	2		3	3	13					1	1	2	2	10		1		1					2		1				1
	Terebellidae	1												1								1					1	1		1	
Crustacea	**Amphipoda**																														
	Ampelisca sp.		4	3	7	4	1				4	4	1	2	1	6	5	2	5	1						2	4	2			
	Bathyporeia guilliamsoniana				4	5	1	30	16	21	1									20	14	8	2	2	1			1	23	7	16
	Cheiriphotis mediterranea																									4		2			
	Leucothoe sp.				1												1														
	Perioculodes longimanus longimanus							1												1											1
	Urothoe grimaldii	3	3	3	6	4	1	55	24	20	15	12	4	2	7	10	3	2	2	10	2	4	3	6		3	6		13		7
	Copepoda	1								1														1	1						
	HARPACTICOIDA																														
	Canuella aff. *furcigera*										7	4	4	6	9	10															
	Canuella aff. *perplexa*	7	4	5	11	10	7	7	5	4	3	3	2	34	41	30	7	13	6	5	7	4	7	3	4	5	4	7	4	5	5
	Canuellidae gen. et sp. nov. 1							1	3	2	5	8	5	5	3	3															
	Canuellina insignis	3	5	6	12	16	15	5	6	4	7	5	8	29	33	35	10	12	11	3	7	5	2	5	5	6	8	4	3		2
	Halectinosoma canaliculatum	3	4	3	2	2	1	11	9	7	4	3	6	1	1																
	Halectinosoma diops																								1						
	Longipedia coronata	2	2	3	2	1	2	1	2	2	3	4	2	10	11	16							1	1	2	4	6	4			
	Scottolana bulbosa	4	7	5	10	11	7	3	2	3	3	6	3	7	9	5				1		1	2	2	3	3	4	4		2	1
	CYCLOPOIDA																														
	Cyclopina sp.							1	3	2				2		2															
	Euryte sp.													4	2	3															
	Tocoheres sp.	2	4	3	1		1	4	3	3	3	2	4	11	8	12															
	CALANOIDA	12	14	10	9	15	13	9	4	8	3	7	4	7	5	10	5	7	2	9	5	7	4	6	8	23	34	30	7	5	4
	Cumacea																														
	Pseudocuma longicorne						1								1																
	Ostracoda	27		3	55		46	9		5	2		1	18	41	18		1	3			1					8				
	Tanaidacea		1		5	3	46					1																			
Mollusca	***Acteocina mucronata***										2	4	1			1							1	8	17						
	Bittium latreillii													1																	
	Chamalea gallina																														1

Mollusca	*Chrysallida obtusa*						1																				1				
	Chrysallida terebellum						1																								
	Diplodonta bogii		2											1				1	2						2		13	8			
	Donax semistriatus						1																	1							1
	Finella pupoides																											1		1	
	Glycymeris glycymeris																	1													1
	Leucotina natalensis	1																	2		1			1	1			1	1		
	Loripes lucinalis				1	1	2						1									2		1	1						1
	Lucinella divaricata							1	1																						
	Mactra stultorum	3	3	4	4	7	12	3	1	4	2	5	4	1	1	2	2		2	2	5	3				1	3	6			
	Musculus subpictus																													2	2
	Odostomia conoidea								1																						
	Pusillina philippi																										2				
	Rinoclavis kochi																							2							
	Rissoa sp.														1																
	Strombus persicus	1	4	2	2		2						1		6	3	1		3		1		3		2	3	18	12		1	3
	Tellina planata															1															
	Thracia papyracea	2	1		1	3	3					5	1	1	5	3											2	3			
Phoronida																			4												
	SUM	128	122	98	189	141	252	216	130	127	124	179	100	179	279	306	79	76	78	92	87	79	59	115	154	128	443	394	64	34	67

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פיתוח גישה כמותית לבחינת השפעה על הסביבה של מתקן התפלה:

מקרה בוחן שבי ציון

חיבור על מחקר לשם מילוי חלקי של הדרישות לקבלת התואר

מגיסטר למדעים בהנדסה סביבתית

גילי נוי הרפז

הוגש לסנט הטכניון- מכון טכנולוגי לישראל

תשרי תשע"ה חיפה אוקטובר 2014

המחקר נעשה בהנחייתם של פרופ' ח' דוד ברודאי ופרופ' ח' יוחאי כרמל.

אני מודה לטכניון על התמיכה הכספית הנדיבה בהשתלמותי.

תקציר

התפלה היא טכנולוגיה המשלבת מספר תהליכים שבעזרתם ניתן להפריד מלחים ומינרלים ממים ולהפיק מי שתייה. התפלה של מי ים ומים מליחים מאוד נפוצה בכל העולם. התפוקה של מים מותפלים בישראל מתוכננת להגיע ל-1.75 מיליארד מ״ק עד שנת 2040. כחלק מתוכנית מתאר ארצית 2/3/ב/34,מתוכנן לקום עד שנת 2018 מתקן התפלה נוסף באזור הגליל המערבי, ליד שבי ציון. המתקן מתוכנן לספק כ- 50 מיליון מ״ק מים מותפלים לאוכלוסייה ההולכת וגדלה של אזור חיפה והגליל המערבי. עד שנת 2020, המתקן צפוי להגדיל את התפוקה שלו לכ- 100 מיליון מ״ק מים מותפלים בשנה. בתפוקה כזו המתקן ידרוש הקמה של תחנת כוח בקנה מידה קטן על מנת לספק את דרישות האנרגיה שלו.

הערכת השפעה על הסביבה הוא תהליך שנעשה במטרה להעריך את הנזק הפוטנציאלי שיכול להיגרם מפרויקט מתוכנן או קיים. את ההשפעה על הסביבה של מתקני התפלה ניתן לייחס, ברוב המקרים, לצריכת אנרגיה גבוהה, לנזק פוטנציאלי לסביבה הימית כתוצאה משחרור רכז לים ולשימוש בקרקע לאורך החוף, אזור בעל ערך אקולוגי ותיירותי גבוה.

מחקרים שנעשו עד היום בתחום הערכת השפעה על הסביבה של מתקני התפלה ניתן לסווג להערכת ההשפעה על הסביבה הימית ועל זיהום אויר ובריאות הציבור. בתחום הערכת ההשפעה על הסביבה הימית נבדקה בעיקר ההשפעה של התמלחת, תוצר לוואי של תהליך ההתפלה על מינים וחברות באיזור הקרוב לנקודת שחרור הרכז. בנוסף פותחו מספר שיטות להערכה כמותית של ההשפעה על הסביבה. שיטות אילו נותנות הערכה גרפית או סיווג ההשפעה למספר פרמטרים, אך לא השפעה כמותית כוללת ואובייקטיבית.

בתחום הערכת ההשפעה על זיהום האויר ובריאות הציבור נעשו מספר מחקרים לחישוב כמותי של ההשפעה. מחקרים מסוימים חישבו את מספר מקרי המחלה שניתן לייחס לפליטה של חומר מסוים בכמות מסוימת. מחקרים אחרים הציגו את ההשפעה כמספר שנים שאבד כתוצאה ממקרי מחלה ומוות שניתן לייחס לכמות מזהמים שנפלטה ממקור מסוים. כל מחקר התאים את עצמו לתחום ספציפי מבחינת רמת הדיוק הדרושה ודרך ההצגה של הנתונים.

קיימות שיטות שונות להערכת השפעה על הסביבה של פרויקטים שונים מנקודות מבט שונות. לשיטות המיושמות היום יש מספר חסרונות. ראשית, השיטות הנפוצות היום, בעיקר בתחום ההערכה על הסביבה הימית, הן בעיקרן שיטות איכותיות, היוצרות הערכה שהיא בעיקרה איכותית, על פני כמותית. הערכה כזו קשה נורא ליישם כשמדובר בהסקת מסקנות והחלטה על צעדים בפועל. שנית, מקבלי ההחלטות הם בד״כ אנשים שאינם אנשי מקצוע בתחום איכות הסביבה ועל כן הערכה איכותית המורכבת ממושגים מתחום איכות הסביבה לא תספק את הידע הדרוש להם על מנת לקבל החלטה מושכלת ונכונה. הצגת תוצאות מחקרי הערכת השפעה על הסביבה בפרמטרים כמותיים ולא איכותיים יכולה לתרום רבות למקבלי ההחלטות ולציבור הרחב לקבל, להבין וליישם החלטות בדבר פרויקטים בתחום איכות הסביבה.

מטרת העל של המחקר הייתה לפתח שיטה חדשה להערכת השפעה על הסביבה של מתקני התפלה. המחקר עסק בשתי השפעות עיקריות של מתקן התפלה, השפעה על הסביבה הימית והשפעה על זיהום האויר ועל בריאות הציבור. עבור שתי ההשפעות הללו פותחו שיטות חדשות שמציגות את התוצאות כערך כמותי, ואף כספי.

שיטת ההערכה בתחום השפעה על הסביבה הימית מורכבת מנקודת מבט כוללת על המערכת האקולוגית. על מנת לתאר את ההשפעה על כלל המערכת נבחרו שלושה פרמטרים: ייצור ראשוני, מגוון מינים ופירוק ביולוגי. עבור כל פרמטר פותח סולם שמתאר את ההשפעה, מהשפעה מינימלית ועד נזק חמור לאותו פרמטר. שיטה זו הודגמה בעזרת נתוני ניטור של מתקן ההתפלה בפלמחים. מתקן הפעל בשנים שנבדקו באותה תפוקה המתוכננת במתקן בשבי ציון. ההערכה היא כי הפרמטרים הא-ביוטיים (עומק, טמפרטורה, מליחות) בסביבה הימית דומים בשני האזורים ועל כן מידת ההשפעה על המערכת האקולוגית תהיה דומה גם כן.

שיטת ההערכה בתחום השפעה על זיהום אויר ובריאות הציבור בנויה בצעדים קבועים מראש, ומבוססת על פרויקט של האיחוד האירופי, ExternE. שיטה זו שופרה והותאמה למחקרים המבוצעים בישראל ע"י הוספת מספר נתיבים אפשריים של עבודה, כתלות ברמת הדיוק הנדרשת ובנתונים הקיימים. השיטה התייחסה למספר אלטרנטיבות אפשריות באשר לפליטות מתקן ההתפלה, ייצור חשמל בתחנת כוח ייעודית למתקן או אספקה מרשת החשמל הארצית, וכן פליטה בקנה מידה ארצי או בקנה מידה מקומי. השיטה הודגמה באשר למתקן ההתפלה המתוכנן בשבי ציון עבור כל האלטרנטיבות האפשריות. המזהם שנבחר לחישוב הוא $PM_{2.5}$, מאחר והוא מזהם נפוץ המשויך לייצור אנרגיה ובעל השפעה גדולה בעיקר על מחלות לב וריאה, על כן נבדקה ההשפעה על תמותה ממחלות אילו.

נמצא כי ההשפעה הפוטנציאלית על הסביבה הימית באזור שבי ציון, בהתבסס על נתוני מתקן ההתפלה הקים בפלמחים, היא מינימלית עבור כל הפרמטרים שנבדקו. עבור ההשפעה על זיהום האויר ובריאות הציבור, בקנה מידה ארצי ההשפעה של עליית ריכוז PM2.5 על כל ההשפעות הבריאותיות הוערכה בכ-1,896,800 ש"ח. בקנה מידה מקומי ההשפעה של עליית ריכוז PM2.5 על מקרי מוות כתוצאה ממחלות לב ריאה באנשים מעל גיל 45, בעכו ונהריה, הוערכה בין 74,500- 1,585,500 ש"ח.

ההשפעה המינימלית על הסביבה הימית שנקבעה במחקר נוגדת את רוב המחקרים הקיימים כיום הטוענים כי למתקני התפלה השפעה מכרעת על הסביבה הימית. קיימות מספר סיבות בעזרתן ניתן להסביר זאת. הסיבה הראשונה הינה סיבה טכנית. רוב המחקרים כיום בודקים השפעה על מין אחד או חברת מינים. המחקר הזה הסתכל על שלושה פרמטרים יחד כאשר מספר המינים הינו רק אחד הפרמטרים, לכן לשינוי במספר המינים השפעה יחסית נמוכה יותר על ההערכה הכוללת משאר המחקרים, סביר להניח שעובדה זו השפיע על התוצאה הסופית של המחקר. שנית, מאחר ומספר הנתונים בעזרתם נעשה הניתוח הסטטיסטי היה קטן, נאלצתי להשתמש במבחן סטטיסטי לא פרמטרי. במידה והיו קיימים יותר נתונים אפשר היה להשתמש במבחן סטטיסטי מדויק יותר והתוצאה הייתה שונה.

בתחום הערכת ההשפעה על זיהום האוויר ועל בריאות הציבור ההשפעות המחושבות הן בקנה מידה ארצי והן בקנה מידה מקומי הראו השפעה לא מבוטלת בחיי אדם כתוצאה מייצור אנרגיה עבור מתקן ההתפלה המתוכנן בשבי ציון. בנוסף, עבור שתי האלטרנטיבות (יצור חשמל מקומי או שימוש בחשמל מהרשת) ההשפעות המחושבות הראו ערכים דומים. כלומר, בעוד שצריכת חשמל מהרשת מלווה בתרומה קטנה יותר לפליטות מזהמי אוויר ולכן לריכוזי מזהמי אוויר נמוכים יותר, השטח המושפע מהעלייה בריכוזים גדול יותר ולכן יותר אנשים יכולים להיות מושפעים, אם כי רמת החומרה הצפויה של ההשפעה זו על בריאות הציבור נמוכה. מאידך, ייצור חשמל מקומי צפוי לגרום לריכוזים גבוהים יותר באזור הסמוך. לכן, למרות שצפויים פחות מקרים ביחס למקרה בו ייצור החשמל הוא ארצי דרגת החומרה של ההשפעה הרפואית צפוייה להיות גבוהה יותר.

מכיוון שלא קיימות תכניות בנייה עבור מתקן ההתפלה המתוכנן בשבי ציון, לא ניתן היה להעריך את ההשפעה של המתקן ברמת דיוק גבוהה. למרות זאת, המחקר עשה צעד משמעותי קדימה לכיוון העלאת הפופולריות ושימוש רחב יותר בכלי של הערכה כמותית של השפעה על הסביבה לא רק לבעלי מקצוע, אלא גם למקבלי ההחלטות ולציבור הרחב.

המחקר לא מציע לאחד בין תוצאות הערכת ההשפעה על הסביבה בשני התחומים שנבדקו. שתי דרכים שונות לאחוד התוצאות מוצגות, וכן הרעיון שיש לבחון את היתרונות והחסרונות של איחוד התוצאות בכל מחקר של השפעה על הסביבה. .