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Research article

Chapter 1: Development of Desalinated Water Safety Plan (WSP) in Developing Countries

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Abstract

Water desalination that widely applied in Gaza Strip (Developing Country), has environmental and health risks. For operation of desalinated plants, Water Safety Plan (WSP) is very important to identify potential risks and available barriers in their systems and support the introduction of a preventive risk management approach to problems that could have an impact on the quantity and quality of water supplied. Eighteen desalination plants were assessed in terms of application of the main stages of WSP. It was found that 40% of the delivery trucks and 20% of the home tanks were infected by microbiological pollutants. WSP was not applied in the Strip where number of actions needed to secure safety of drinking water. The main hazardous events in the desalination water distribution system were at the second and last stages in the system delivery trucks and home tanks. Monitoring and follow up of these desalination plants is very important to pursue the compliance of these desalination plants to conditions and terms of water quality. Close coordination between all parties involved in water issues to confirm the implementation of WSP in Gaza Strip.

Keywords: Water Safety plan (WSP), Desalination plants, Gaza Strip, water framework, water quality

1. Introduction

Water is an important resource for use of mankind. It is essential for agricultural and industrial growth, as well as for supporting growing populations who require a safe drinking water supply. Increasing demand for water is a global problem. Natural resources cannot satisfy the growing demand for low-salinity water with industrial development, together with the increasing worldwide demand for supplies of safe drinking water. In addition, the rapid reduction

of subterranean aquifers and the increasing salinity of these non-renewable sources will continue to exacerbate the international water shortage problems in many areas of the world. This problem can be solved with different solutions like, the economical use of water, reducing distribution losses, and using the recycled water but if there is still a shortfall then desalination of seawater or brackish water may be the option [1]. Desalination techniques are capable of providing the solution, and have already become an acceptable solution for shortages in conventional water resources [2].

The groundwater in Gaza Strip has deteriorated over the past thirty years both in terms of quality and quantity. Gaza Strip suffering from the huge increasing in population which depends mainly on a ground water. During the last years, water quality has deteriorated and became unsuitable for human consumption in most parts of the strip. To face this problem, the citizens and the authority in Gaza Strip use many options; the major of these options is water desalination where the reverse osmosis (RO) technology is applied [3]. For existing desalinated plants, water safety plan (WSP) is very important to identify potential risks and available barriers in their systems and support the introduction of a preventive risk management approach to problems that could have an impact on the quantity and quality of water supplied [4].

In Gaza Strip more than 90% of the population depends on the desalinated water for drinking purpose. There has been dissemination of many small scale brackish water desalination plants in the Gaza Strip (private RO plants) [5]. However, the desalination process in addition the storage of the desalinated water has no monitoring and assessment, so the desalinated fresh water may be contain some pollutants or the concentration of dissolved chemical compounds are not within the standard. Because of that, the need of the monitoring, assessment, and provide safety plan of the desalination systems have extended to obtain water quality according to WHO standard, prevent water borne diseases and to save the public health. This paper aims to develop Water Safety Plan in Gaza Strip by assessment of the water supply system from desalination plants to tap and identification the hazards that may be introduced at each stage (source, distribution and storage).

2. Materials and Methods

2.1 Study Area

Gaza Strip (GS) area is located at the eastern coast of the Mediterranean Sea. It is one of the most densely populated areas in the world with an average density of more than 4300 inhabitants/km2; and it is expected that the population density will exceed 5835 inhabitants/km2 in 2020[6]. GS is administratively divided into five governorates, among which Middle governorate which is the study area as shown in Figure 1. GS is an extreme model on how unstable political environment, disastrous economic situation, decaying environmental conditions and unplanned human activities are combined together to further deteriorate the GW quality [7]. Ongoing deterioration of the water supply of GS poses a major challenge for water planners and sustainable management of the coastal aquifer. The aquifer is presently being overexploited, with total pumping exceeding total recharge. In addition, anthropogenic sources of pollution threaten the water supplies in major urban centers. Many water quality parameters presently exceed (WHO) drinking water standards. The major documented water quality problems are elevated chloride (salinity) and nitrate concentrations in the aquifer [8]

2.2 Data Collection

Data was collected through three types of questionnaire:

- A total of 400 questionnaires were planned to be randomly distributed to persons who consume desalinated water from governmental and privet plants.
- A total of 18 questionnaires, (depend on desalination plant number), were planned and distributed for governmental and privet desalination plants to evaluate the existing situation of the desalination plants in the study area and the extent of WSP application in the study area.
- A total number of 18 questionnaires were planned to be randomly distributed to water vendors who distribute the desalinated water.

- Historical data for chemical quality of water samples from the records of the central public health laboratories (CPHL) of the Palestinian Ministry of Health (MoH) for the outlet of desalination plants.
- Historical data for microbiological quality of water samples from the records of the central public health laboratories (CPHL) of the Palestinian Ministry of Health (MoH) for the outlet of desalination plants.

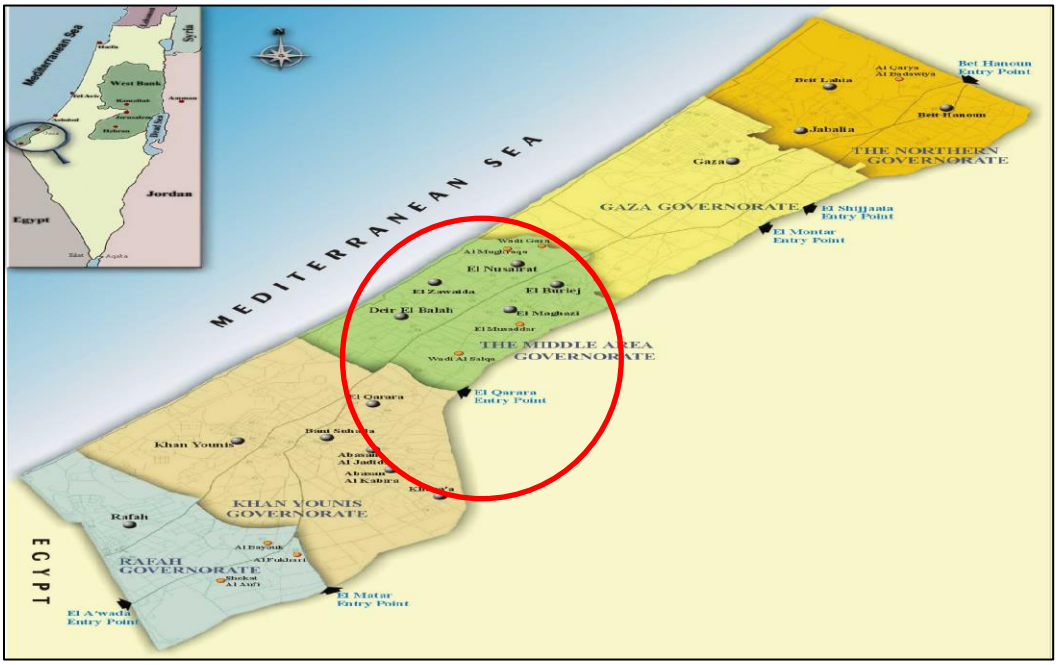

Figure 1: Location map of Gaza Strip

2.3 Water Samples and Laboratory test

- A total of 20 samples were collected for microbiological analysis (Total Coliform and Fecal Coliform) from home tanks in the study area.
- A total of 15 samples were collected for microbiological analysis (Total Coliform and Fecal Coliform) from delivery trucks in the study area.
- These samples were collected during the period from 03 March 2013 to 26 March 2013 and samples were delivered to MoH Laboratory for Total Coliform (TC) analysis. Sampling was performed according to Standard Methods for the Examination of Water and Wastewater 20th edition.

2.4 Data processing and analysis

- Data analysis was conducted within the framework of the study objectives.
- Data was analyzed (Questionnaire analysis, chemical and microbiological analysis results of samples) by using Microsoft Excel and Statistical Program for Social Sciences (SPSS).

3. Results and Discussion

3.1 Evaluation of Desalination Plants

From the results of the questionnaire, it is found that 66% of the workers have secondary school degree. This low level of education required more attention to conduct the training and awareness campaign to the worker in this field to increase the competencies of them. Concerning the control measures issues, it is found that the control measures were not taken into account by the owners and operators of these plants. The control measures which included in the questionnaire were (security and safety equipment such as (stand by generator, automatic shutdown, continues monitoring alarm, dormant fire), stock fencing around the water source, control of waste water effluent, diversion of local storm water flows around the well, use of pesticides nearby agricultural crops, taking approval from MoH to use water treatment chemicals and materials. 89% of the desalination plants do not have an approval form MOH to

use water treatment chemicals, and 80% of these plants do not have safety equipment. Concerning the environmental issues, 78% of the brine discharged in to Municipal sewage.
With regard to monitoring and assessment issues, it is found that there are no periodic visits to the desalination plants by the official authorities represented by Palestinian Water Authority (PWA) and Ministry of Health (MOH). On the other hand, 84% of the desalination plants conduct chemical properties test every six months and 95% of the desalination plants conduct microbiological test in a period of more than one month. Clearly, the monitoring and assessment in the desalination plants is absent and this leads to increase in diseases.
The management procedures such as presence of key personnel if the water has unusual taste or odor or documentation system in the desalination plants. 83% of the desalination plants did not have a contact with key personnel if the water has unusual taste or odor. Also 77% of the desalination plants did not have documentation system in the plant and 83% of the desalination plants did not have treated water in storage or alternative supply options. All of the previous results confirm the necessity of implementation of WSP in desalination sector.

With regard to quality assurance, the desalination plants should have staff from engineers and technical to assure that the plant works as required and examine the water that distributed to consumer's home. This staff should be included in water samples collection by MoH. None of the desalination plants have a staff to examine the water that distributed to consumer's home, also only one plant has a trained staff in the plant involved in water samples collection by MoH. The desalination plants need many supporting programs to improve the efficiency of the desalination sector in Gaza Strip. Examples of the needed support were free water tests by PWA and the concerned municipalities and ministries, free health tests to the workers. Different support methods were mentioned by the owners of these private desalination companies such as: 1) Availability of RO membranes with suitable prices, 2) Reduction in the fees of licensing the desalination companies and water wells, 3) Free water tests, 4) Purchasing the produced water from these companies and distributing it to the governmental institutions, 5) training courses in the field of operation, maintenance and hygienic. The results show that 73% of the workers in desalination plants have not hygienic working knowledge. Also, 83% of the workers in the desalination plants have not training of operation and maintenance.

3.2 Evaluation of Water Distribution System (Delivery trucks)

Clearly that most of the water vendors have secondary school or below. This result shows that the workers in this field have not any knowledge about hygienic or the issues that result in water pollution. Concerning the monitoring system, 78% of them say that there is no regular testing for the contaminants.
Concerning the legal side, 73% of the water vendors have a license to sell the desalinated water. From the previous result, it is clear that wide number of the water vendors have a license to sell water. The concerned authorities can apply some conditions to get the license to sell the desalinated water such as getting some courses in the field of hygienic, cleaning the mobile tank and how to maintain the distribution tube from the pollutants. On the other hand, the cleaning and disinfection process are not regular in the distribution system. This is clear from the results of the interviews with the water vendors, 51.1% of the water vendors clean the mobile tank in a period more than one month. Also, 84 % of the water vendors did not disinfect the tanks. It is important to mention that from the results of the interviews the workers cannot make the disinfection due to the lack in the hygienic knowledge and how to disinfect the tanks, so it should be established special department with qualified staff to conduct the disinfection process. Also, 72.2% of the water vendors do not empty the mobile tank before filling the tank with new desalinated. It is necessary to empty the tank before filling it with new desalinated water to avoid the mix with the old water and decrease the pollution level.

3.3 Situation of Consumer's opinions

Due to the bad quality of the municipal water in Gaza Strip, (74.5%) of the consumers purchased the desalinated water from the desalination plants. This high percentage emphasized that the municipal water in the strip is not suitable for drinking purpose. Regarding the period between filling the home tanks with desalinated water, (42.5%)

of the consumers were filled their tanks every 7-10 days. Also, the majority (83.3%) of the consumers did not empty the tank before filling it with new desalinated water, this behavior did not give an opportunity to clean up the tank and to eliminate the pollutants in the tanks.

Concerning the hygienic knowledge side, the majority (91%) of the consumers did not inform the owners of the desalination plants when they feel that there is problem in the odor or taste in the water. From this result, it is clear that the consumers have not the required knowledge about the water quality and the risks of water pollution on the public health. The concerned authorities are the responsible about this problem. The concerned authorities should establish an information center include specialists in the field of water quality and biology to enable the consumers to contact with the specialists when they have a problem in the desalinated water. On the other hand, 89.6% of the consumers did not have periodic cleaning and disinfection for their tanks. All of the previous results show the insufficiency in the hygienic knowledge among the consumers. Concerning the opinions of the consumers in general about the water crisis, the majority (89.9%) out of the consumers agree that the desalination plants contribute in solving water crisis. On the other hand, (88%) out of the consumers agree that these plants will improve the water services in Gaza Strip.

3.4 Evaluation of Chemical water quality of outlet water from desalination plants

Desalination plants in Gaza strip consist of different filters (sand filter, carbon filter, Antecedents, RO filter). The main filter of the desalination plants is Reverse Osmosis filter. This filter is very effective; the purification degree of it could reach to the 99% of the elements, but this degree controlled by many different factors like (inlet water quality, running time of the filter, inlet water pressure). The most important factor is the inlet water quality that, highly effect on the element removal efficiency and on the desalinated water quality. The quality of some elements in the outlet of the desalination plants in Gaza Strip were studied in case of evaluation of outlet water desalinated quality [9].

3.4.1 Total Dissolved Solids (TDS)

100% of water samples have TDS concentration committed with the maximum limit of WHO standards, but it clear that these desalination plants do not pay attention to the recommended minimum limits. The recommended minimum level of TDS in drinking water 100 mg/l and maximum value of 1000 mg/l [10].66.7% of these samples have TDS concentration less than 100 mg/l, figure (2).

3.4.3 Total Hardness (TH)

The WHO states that the maximum allowable value of total hardness concentration for drinking water is (500 mg/l as $CaCO_3$).100% of the water samples have TH concentration accepted by the WHO standards. The total hardness concentration in water samples is less than 70 mg/l as $CaCO_3$.

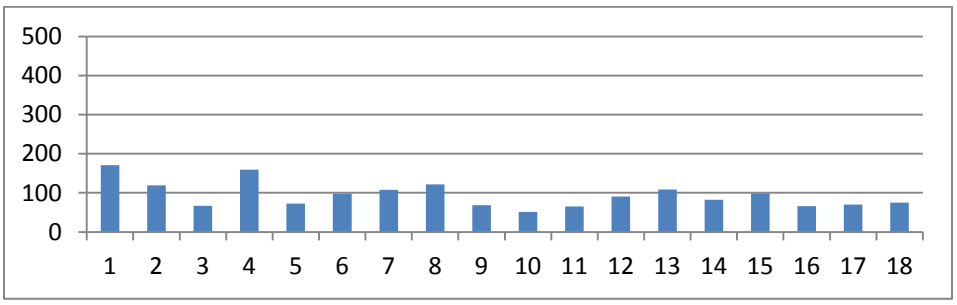

Figure 2: TDS concentration in the outlet water samples

3.4.2 pH value

The pH analytical data in outlet water samples show that (100%) of the samples has pH under both WHO and Palestinian standards (6.5-8.5). Due to the desalination process and the elements removal, the pH value of some desalinated water became under the minimum concentration that recommended by the WHO and Palestinian recommendations. So after desalination, water needs correction to the pH by adding (NaOH), but if this operation not happened the pH of the water will be very low [9]. The data results show that 44% of the samples have pH lower than 6.5 as shown in figure (3).

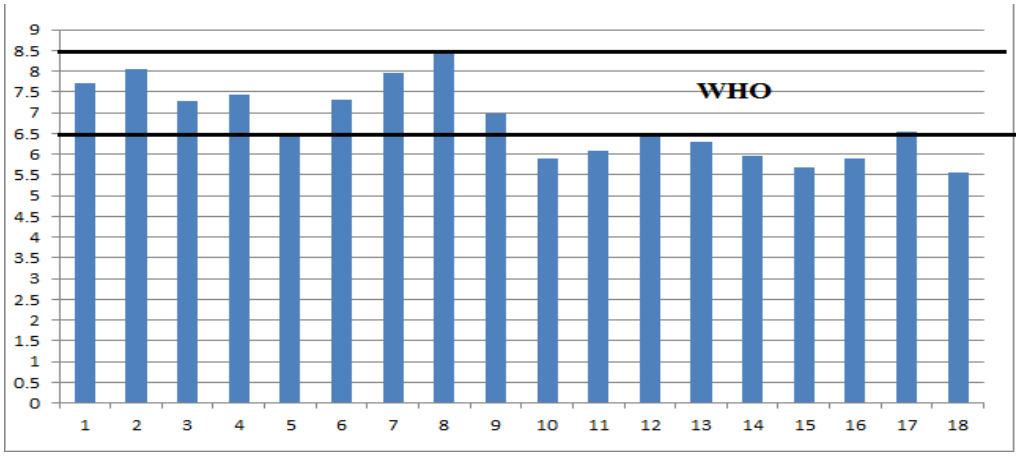

Figure 3: pH value in the outlet water samples

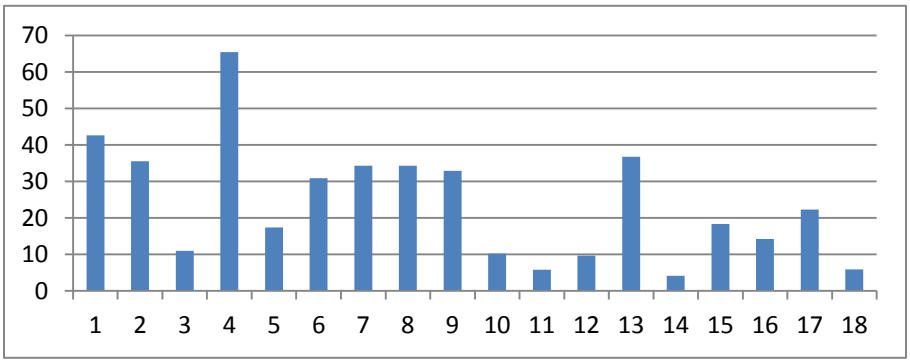

Figure 4: TH value in the outlet water samples

3.4.4 Calcium Concentration (Ca2+)

The analytical data of the outlet water samples show that 100% of the samples have calcium concentration less than the recommendation (100 mg/l). The calcium concentration in water samples ranges from 1 mg/l to 20.9 mg/l as shown in figure (5).

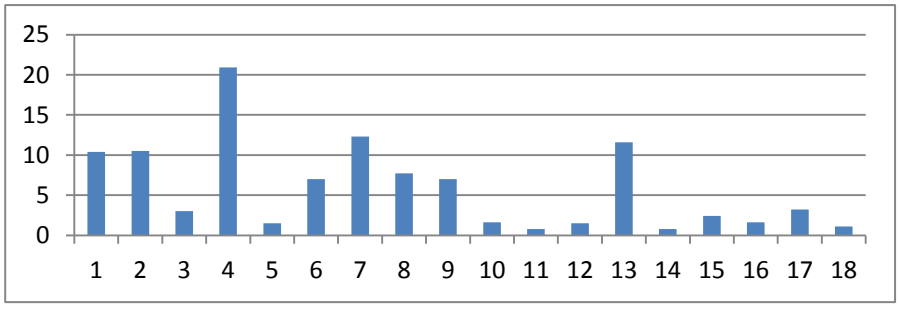

Figure 5: Calcium concentration in the outlet water samples

3.4.5 Magnesium Concentration (Mg2+)

In the outlet samples, magnesium concentration of all the samples is less than 10mg/l as shown in figure.6

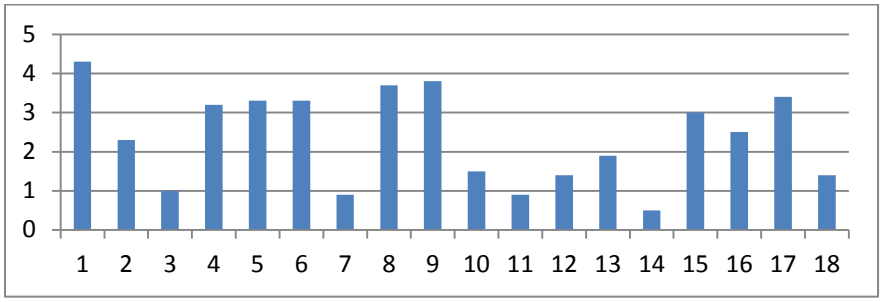

Figure 6: Magnesium concentration in the outlet water samples

3.4.6 Chloride Concentration (Cl^-)

The chloride concentration of all the water samples is under the WHO recommendation standard (250 mg/l). Chloride concentration ranges from 17.3 mg/l to 46.2 mg/l as shown in figure 7.

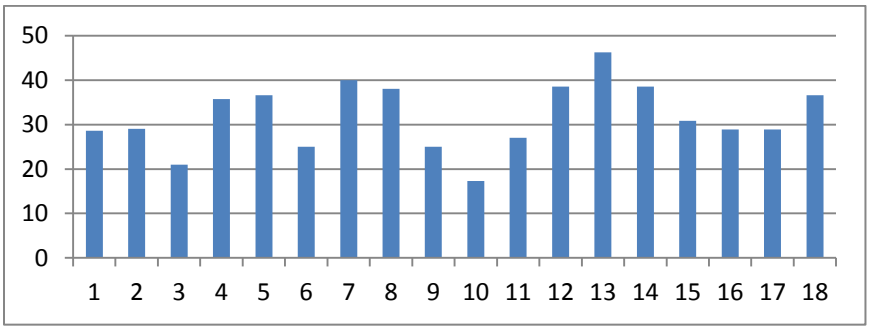

Figure 7: Chloride concentration in the outlet water samples

3.4.7 Sodium Concentration (Na^+)

All water samples have sodium concentration less than the maximum recommended level (200 mg/l) by WHO. The sodium concentration in water samples ranges from 9 mg/l to 30 mg/ as shown in figure (8).

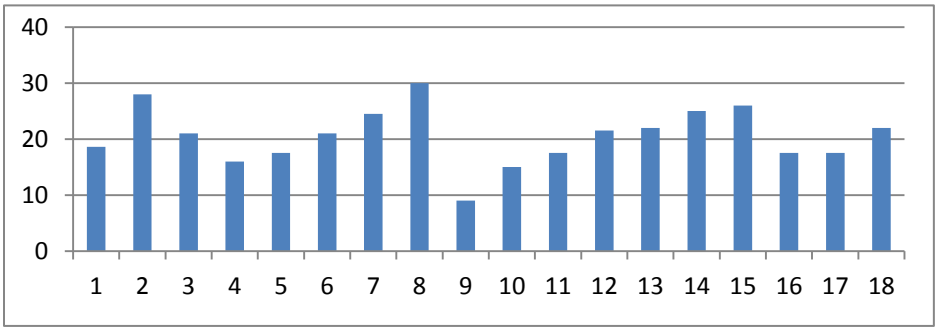

Figure 8: Chloride concentration in the outlet water samples

3.4.8 Nitrate Concentration (NO3-)

The Nitrate concentration in all water samples is less than the WHO recommended level (45mg/l). Nitrate concentration ranges from 2.3 mg/l to 20.6 mg/l as shown in figure (9).

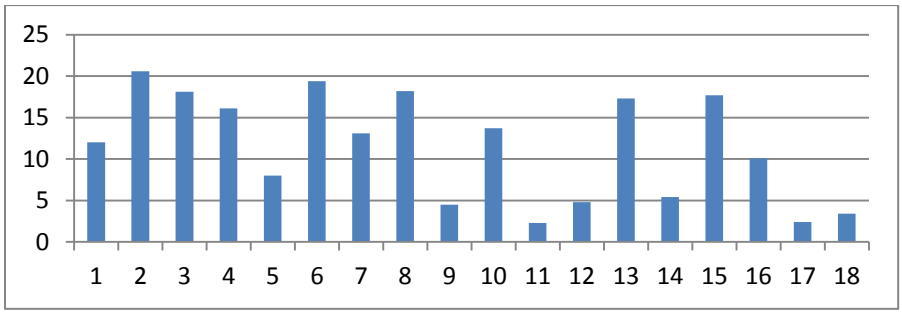

Figure 9: Nitrate concentration in the outlet water samples

3.5 Evaluation of Microbiological water quality

3.5.1 Samples from the Outlet of Desalination Plants

The most important aspect of drinking water quality is microbiological quality. It's not practicable to taste the water for all organisms, which may cause disease (pathogens) .The data analysis of Microbiological tests for the total contamination percentages in outlet water is (5.5% for the total coliforms)**.**

3.5.2 Samples from mobile tanks (delivery trucks)

Microbiological analysis for water samples from mobile tanks according the location of the mobile tanks show that 6 (40%) out of 15 mobile tanks have microbiological pollutants as shown in Table 1

Table1: Microbiological analysis for water samples from delivery trucks

Location	No. of samples	No. of infected samples
Deir AlBalah	3	1
Maghazi	4	4
Nusirat	4	0
Zawaida	1	0
Buraij	3	1
Total	**15**	**6**

3.5.3 Samples from home tanks

Microbiological analysis for water samples from home tanks according the residency of the consumers show that 4(20%) out of 20 samples have microbiological pollutants as shown in table2. Total coliform ranges were very small except on sample has TC= 50 colony/ 100ml.

Table2: Microbiological analysis for water samples from home tanks

Location	No. of samples	No. of infected samples
Deir AlBalah	4	0
Maghazi	3	2
Nusirat	3	1
Zawaida	5	0
Buraij	5	1

Total	**20**	**4**

4. Proposed WSP in Gaza Strip

It is proposed to establish a committee that included list of water engineers, water experts, scientists, chemists and microbiologists. This committee consists from members mainly from PWA, CMWU, MoH, EQA, NGO's and universities professors. The task of this committee is to determine the responsibilities of the individuals on the team and to assessment the water supply from catchment to consumer. Each individual will be responsible for a particular specialty according to his experience and specialization. Table 3 shows the proposed WSP in Gaza Strip with the proposed activities and the targeted institution to implement these activities.

Table 3: Proposed Water Safety Plan in Gaza Strip

plan Item	Activities	Targeted Institution	Recommended Time
Hazardous Identification	• Describe the water supply system.	PWA+ Water Experts	_____
	• Define the microbiological hazard at each stage in the desalinated water distribution system	PWA + MOH+ related NGO's	Monthly
	• Define the chemical hazards which may occur in the desalinated water.	PWA + MOH + related NGO's	Monthly
Control measures	• Conduct periodic sudden inspections for the desalination plants, delivery trucks and some samples from home tanks.	MOH	Every six months
	• Regulate training courses for the staff who work in the desalination plants and water vendors.	PWA +CMWU	Every six months
	• Promote public awareness in the community about the impact of water pollution on the public health.	Municipalities+ related NGO's	Yearly
	• Regulate the use of chemicals and materials which used in water treatment process.	MOH	_____
Control measures	• Controlling the access of people in the desalination plants and provides the appropriate security measures to prevent transfer of hazards.	Plants Owners	_____
	• Controlling the effluent of brine	EQA	_____

Monitoring of control measures	• Regulate the parameter to be monitor.	PWA + MOH	_____
	• Make schedules for water sampling in all stages in the desalinated water distribution system.	PWA + MOH	Monthly
	• Provide the main tools for sampling.	PWA + CMWU Municipalities + related NGO's	_____
	• Provide the requirements for reporting and communications results.	PWA + CMWU Municipalities	_____
	• Provide the requirements for documentation.	PWA + CMWU Municipalities	_____
Management Procedures	• Establish an information center to help the consumers if there are any problems in the desalinated water.	PWA + Municipalities	_____
Management Procedures	• Determine the quantity of the materials used in water treatment.	MOH	_____
Supporting Programs	• Contact with Donors and stakeholders to provide the support for the desalination plants.	PWA	_____
	• Conduct training workshops, training courses and public awareness for the community.	Municipalities	_____
	• Special training courses for the worker in this field in operation and maintenance and hygienic working knowledge.	PWA+MOH	_____
Revision of the WSP	• Regulate periodic meeting between the members of the WSP.	PWA	monthly
	• Reassess the risks that will appear in every stage in the water distribution.	PWA+MOH	monthly

5. Conclusion

Due to the bad quality of Municipal water in Gaza strip, desalinated water use increases and the availability of renewable supplies decreases, using of desalinated water increases by the people. WSP is a process control oriented management system that can help water suppliers to produce and deliver good and safe drinking-water, contributing in this way to improve public health protection.it is best approach to apply in Gaza Strip to assure water quality and assess the hazardous events in the desalination water system. Setting WSP targets is a good starting point for an M&E process. The targets identified should relate to the goals and objectives of the WSP.

The concerned authorities such as PWA, CMWU and the concerned ministries should perform their duties towards the establishment of committee that begins to configure WSP team to apply WSP approach in Gaza Strip. The main hazardous events in the desalination water distribution system were at the second stage in the system (mobile tanks), this is due to the lower level in the hygienic knowledge and the risks of water pollution on the public health. Close coordination between all the parties involved in water issues (such as decision makers, water experts, water research centers, municipalities and lawyers) is required to confirm the implementation of WSP in Gaza Strip. Establishing an integrated monitoring system to follow up the performance of the private and governmental water desalination plants to guarantee the quality of the water during production and distribution stages and the monitoring program should include the delivery trucks and samples from home tanks.it is important to conduct an awareness campaign for the residents of Gaza strip on water issues such as quality and pollution.

6. Acknowledgement

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