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Water Safety Plan for Securing Drinking Water Supply from River Bank Filtration Projects in Egypt – A case Study.

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Abstract

The main objective of water utilities is securing the supply of safe drinking water with adequate quantity to safeguard public health. The Water Safety Plan (WSP) is considered an efficient way to ensure water safety according to the latest published information from the World health organization (WHO). WSP is dependent on a proactive approach to reduce the opportunity of hazards from the water source to the consumers' taps. In this study, an application of the concepts was done to secure the drinking water produced from River Bank Filtration (RBF). Both managerial and technical potential reason for risk was studied and the appropriate corrective action was settled. In general, it was found that however, RBF is considered a well-established water technology with a low cost it still could be vulnerable to different kinds of potential hazards. The study has shown potential risks in the source, RBF, network, and customer community. In RBF, the water resource area is the more sensitive to the potential hazard with risk score reach up to 20 on a scale of 1 to 25. The average risk factor before the implementation of the corrective actions is about 10 which classified as high risk. These corrective actions include short-term with low cost that could be considered as quick-win actions other long-term actions have also been identified. The application of this action will ensure a decrease in the average risk to 3 (low risk). The corporate stakeholders and their liabilities have been identified and a group of (Key performance indicators) KPIs was developed for the process to be manageable. (Non-Governmental Organizations) NGOs have a major role in the application of corrective actions such as facilitating the connection for the poor citizen. The involvement of NGOs in the water management process at Abu Bisht will allow direct interaction between the industry and community which overall will increase the social responsibility of the company and at the same time increase the valuation of water at the mentality of the customers.

Keywords: Water Safety Plan; River Bank Filtration; Risk management; Sustainability.

1. Introduction

Providing good and safe drinking-water is worldwide considered to be a fundamental issue for public health protection and must be the primary objective of water supply systems. Access to safe drinking water is a basic need and is one of the most important contributors to public health. According to the WHO and UNICEF report, one-sixth of humanity lack access to any form of safe and improved water supply within 1 kilo meter of their home, and one-fifth of humanity lack access to any form of adequate and improved excreta disposal **(Davison et al., 2010).** Endemic and epidemic disease derived from unsafe water supply affects all nations. Outbreaks of waterborne disease continue to occur in both developed and developing countries, leading to loss of life, disease, and economic burden for individuals and communities **(Summerill et al., 2010; Shamsuzzoha et al., 2018).**

Drinking-water quality control has currently been based on detection of pathogens and toxic concentrations of chemicals by means of monitoring programs and compliance with national or international guidelines and standards, relying mainly on indicator bacteria and chemicals' maximum concentration levels. However, this methodology is

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often slow, complex, and costly **(Vieira, J. M. Pereira 2007).** Even for sophisticated and well-operated systems, these monitoring schemes have proved to be inefficient in preventing waterborne diseases like, for instance, Giardia or Cryptosporidium outbreaks **(Figueras, and Borrego, 2010).**

From this evidence, we can conclude that end-product testing is a reactive rather than preventive way to demonstrate confidence in good and safe drinking water. This justifies the need for the formulation of a new approach in drinking-water quality control based on the understanding of system vulnerability for contamination and on preventive means and actions necessary to guarantee the safety of the water supplied to the consumer **(Vieira, J. M. Pereira 2007).**

The effective management of drinking water supply systems is critical to ensure the delivery of safe drinking water. WSPs offer an internationally recognized systematic risk management approach to enhance water quality from source to tap that has been used in both developed and developing countries **(Bartram et al., 2009).** Through the implementation of this risk management approach, water systems have seen improved water quality, regulatory compliance, communication, asset management, and public health outcomes **(Gunnarsdottir et al., 2012).**

The main objective of a WSP is to ensure water quality for human consumption through the use of good practices in water supply systems. These include the minimization of contamination in water sources, the reduction or removal of contamination during the treatment processes, and the prevention of post contamination during storage and distribution. Thus, a WSP reflects an organized operating system of water quality management in which four basic stages can be identified:

- System Evaluation – process analysis and risk assessment encompassing the entire supply system, from the water source to the consumers' taps;
- Operational Monitoring – identifying and monitoring critical control points in order to mitigate the identified risks;
- Management Plans – development of effective management control systems as well as operational plans to meet routine and exceptional operating conditions.
- Assessment validation - Determine and validate control measures reassess and prioritize the risk **(Roeger and Tavares, 2018).**

The future looks miserable if Egypt does not succeed in formulating and implementing water resources management approach which can match the limited fresh water supply with the increasing demand **(El Bedawy, 2014).**

The main problems facing the surface water supplies and groundwater abstraction could be summarized in chemical releases into river accidental oil spills, extreme climate events were and severe water shortage. The siltation phenomena which have negative impacts on surface water intakes, Groundwater deterioration, and lest but not last the population growth and its consequences socially and economically, Moreover, desalination production in Egypt needs to special kind of consumers based on the economic evaluation of the desalination process.

To keep the cost of these investments and the price of water services affordable, scientists, experts, and policymakers have to seek to find acceptable technologies with low cost to produce enough quantity of water with high quality. In this track, Riverbank filtration (RBF) could represent a suitable and good choice from environmental, technological, and economical aspects to be sufficient for different kinds of consumers.

Riverbank filtration is a process in which pumping wells located along riverbanks Induce a portion of the river water to flow toward the wells (Figure 1). Groundwater wells located adjacent to a body of surface water (river, lake) may, over time, withdraw enough water from the flow system to reverse flow gradients and induce water from the surface source. Wells are commonly placed in close proximity to riverbanks and lakes to take advantage of this induced infiltration thereby maximizing the water-supply potential of the area. Because it is a natural process, bank filtration wins support from consumers who want safe, but not highly treated, drinking water supplies. Bank filtration is an inexpensive and natural method for raw water treatment.

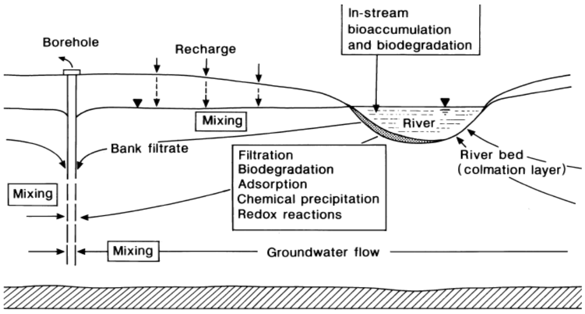


Figure 1 | Schematic diagram of riverbank filtration **(Grischek and Paufler. 2017).**

The most recent literature and with consideration of field investigations, RBF has a great potentiality in many sites along the River Nile, especially in Upper Egypt than in the Delta region. This is according to the geological and hydro-geological conditions. **(Shamrukh and Wahaab 2008; Abdalla and Shamrukh 2011; Abdel-Lah 2013).**

A number of RBF test-sites in Egypt have been previously constructed and designed by Affiliated water companies of the Holding Company for Drinking Water and Wastewater (HCWW) as groundwater wells along the river Nile and main canals banks. Some of these sites were successful and others have either failed to deliver a substantial amount of bank filtrate or failed after short term operation, the technical and operation reason of failure to deliver sustainable safe drinking water can be summarized as follow:

- Lack of specialized training for the operation team.
- Social unacceptance of the new technology by the community.
- Inadequate water quality

This paper aims at improving the compensation ability of the Abu Bisht RBF site to ensure the sustainable supply of safe drinking water via full application of WSP concepts and providing a way of communication with the community in order to improve the social acceptance of RBF technology within the context.

2. Context.

Minya is one of the governorates of Upper Egypt contains 9 cities; 3,375 villages; and 10,875 hamlets. Minya Governorate is an important agricultural and industrial region. Its principal crops are sugarcane, cotton, beans, soybeans, garlic, onions, vegetables of various sorts, tomatoes, potatoes, watermelons, and grapes. Among the leading local industries are food processing (especially sugar and the drying and grinding of onions), spinning and weaving of cotton, perfumes, oils and fats, cement-making, quarrying (especially limestone), and brick-making.

The north of Minya is Beni Suef governorate, the south is Assiut governorate, while Red Sea governorate in the eastern side, and the New Valley governorate in the western side. The water utilities in Minya are Nemours with different types (Conventional – mobile(ultrafiltration) - compact - ground) table (1) represents the number of each type of utilities: -

Table 1 | Types of water utilities in Minya

WTP type	Number
Conventional	20
Compact	11
Slow sand filtration	16
Small mobile unit	26
Large mobile unit	11
Ground units	121
Total	205

The total production capacity of these 205 WTPs is around 290 Mm3/year. The number of customers in Minya governorate is 900,000 inhabitants. The water coverage is around 95% and sewage coverage is about 25% (HCWW, 2017). The city of Maghagha is one of the centers of the Minya Governorate on the western bank of the Nile. The District is about 70 Km northward from El-Minyia City on the western bank of the Nile, and about 60 km from Beni Suef. It is famous for its cotton ginning, onion factory, and some large agricultural areas for growing corn or wheat. The center consists of six (6) major 41 villages. The total population of the city is approximately 101,756 people, and the area of the center is approximately 52,092 acres, and the population of their villages, table (2) represents the local units and their dependencies.

Table 2| the local units and their dependencies of Maghagha District.

Local units	dependencies
The city of Maghagha	Izbat al-Sa`ida - Izbat Ali Pasha Fahmy - Izbat al-Khasas
Aba Al-Waqf	Aba Al-Waqf - Abbad Sharouna - Qadhah - Abbasid
Sharona	Sharona - Sharona Island
Tanbedy	Tanbedy - Lamlum facility - Sheikh Ziyad - Dahrout - Nazlet Dahrout - Eshnin - Bani Khalaf
Bartat	Bartat - Bani and Al Lamas - Manashat Niazi - Al-Tahrir - Kom Al-Hasil - Al-Zorah - Al-Balaaztin - Kafr Al-Salihin - Al-Tawfiq
Sham al-Bahriya	Sham al-Bahriya - Sham al-Qibliya - Nazlet Shiha - Nazlat Ahmad Yunus - Bani Khalid - **Abu Bisht** - Nazlat Bani Khalaf - Deir al-Jarnous
Miyana	Mayana al-Waqf - Malatya - Zawiyat al-Jadami - Nuzlat al-Sheikh children - Bilhasa - Izbat Jaber - Nazlet Belhasa - Kafr al-Mawar - Atniyeh - Al-Kom Al-Akhdar - Hamida Al-Jundi - Dahmro.

Abu Bisht RBF plant serves an area of population 17,185 thousand people where:

- The domestic houses have no water storage tanks.
- The area is not served by sanitation.

- Society is rural, and most of them work in agriculture.

3. Materials and methods.

Water safety plans are the most effective way to ensure the safety of drinking water resources at all times, and rely on a comprehensive approach to risk assessment and management that covers all stages of the water supply from source to consumer the following graph summarizes the steps that have been carried and considered during the implementation phase of WSP **(Deere et al., 2001; Bartram et al., 2009).**

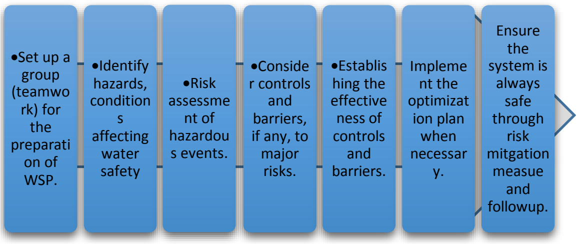


Figure 2 | Water Safety and Security Management Chart.

3.1. Risk Analysis and Assessment.

The evaluation of the drinking water supply system is the basis for the next stages in the preparation of a water safety and security management plan under which effective strategies for monitoring sources of risk are planned and implemented. Risk analysis and assessment in the drinking water supply system can be improved through the preparation of a risk assessment chart. The charts provide a general description of the drinking water supply system, including source characterization, identification of possible sources of pollution, resource and resource protection measures, processing processes, and storage and distribution infrastructure. It is very important that the drinking water supply system be represented accurately" in the imaging of the system components. If the chart is not correct," it could lead to the omission of potentially significant sources of risk **(Hrudey et al., 2006; Bartram et al., 2009).**

Data on the presence of pathogens and chemical agents in source water, together with information on the effectiveness of monitoring processes, help to assess the feasibility of achieving health-related objectives using existing infrastructure and also help to identify the management measures of the water supply system, processes and distribution system that are expected to be implemented. Reasonably, if improvements are needed, achieve those goals. To ensure an accurate evaluation, it is necessary to consider at the same time all components of the drinking water supply system (resource and source protection, processing, and distribution) and to take into account interactions and impacts between the various components and their overall impact. The assessment was done by using the product of both the "frequency of risk occurrence, severity, and severity of the risk and the outcome is the final risk value.

Table 3| Risk assessment table

Value	Frequency of risk	Value	Severity of the hazard
5	Always (once daily)	1	Not effective
4	Confirmed-occurrence (once a week")	2	Minimal compliance effect
3	Average occurrence (once per month")	3	Moderate visible effect
2	Low (once a year)	4	A great regular effect
1	Rare (once every five years)	5	A catastrophic impact on public health
Risk factor = Risk frequency* severity of hazard			

Risk assessment is done by using the assessment matrix, which shows the severity rating of Tier 1 green color and includes a risk of non-risk 25 red colors and has a catastrophic impact on health **(Bartram et al., 2009).**

3.2. Design of the study.

The study includes gathering a team from the different departments concerned with the drinking water supply at the Abu Bisht context. The task force includes the operation and maintenance department, quality department, network department, planning department, and public awareness department. A meeting was held to coordinate the essential steps required to identify and quantify the hazard. A complete system description was conducted to highlight the mean potential hazard. The system description includes the following main clusters: -

- Water resource.
- Water treatment plant.
- Network distribution.

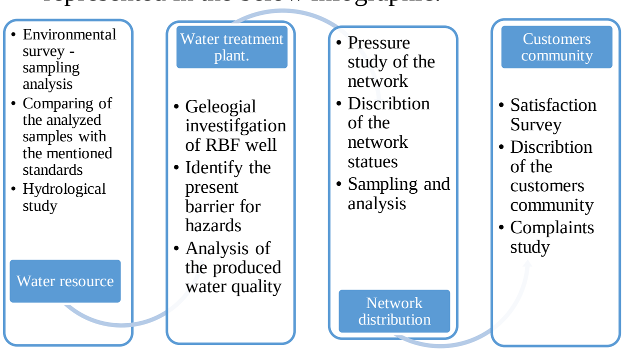
- Customers community.

Table 4| Risk Matrix

Risk Matrix		Describe the probabilities of the risk occurring				
	Value (degree)	**rare occurrence**	**Poor occurrence**	**Average incidence**	**Almost certainly**	**Permanent occurrence**
Description result	**Ineffective**	**1**	**2**	**3**	**4**	**5**
	Slight conformal effect	**2**	**4**	**6**	**8**	**10**
	Moderate phenotypic effect	**3**	**6**	**9**	**12**	**15**
	Great regular effect	**4**	**8**	**12**	**16**	**20**
	Catastrophic impact on public health	**5**	**10**	**15**	**20**	**25**

The following activities were done in order to carry the system description. These activities were done according to WHO guidelines for Water Safety Plan Implementation **(WHO, 2009. Water Safety Plan Manual; Obeng et al., 2020).**

The study was designed via the following sequence represented in the below infographic:



The potential Hazards have been identified through these four clusters and quantified according to the previously mentioned risk analysis. The required corrective actions have also been addressed that are essential to mitigate or eliminate the hazards. In order to ensure full and sustainable safety of the produced water. Other stakeholders that concerned with water in the context have been also addressed. The coordination meeting was held with members of the Ministry of Water Resource and Irrigation (MWRI), Ministry of Environmental Affairs (MoE), Ministry of Health (MoH), and NGOs. The required corrective action has been submitted to them and an action plan was developed with the timetable of implementation.

4. Results and discussion.

4.1. System description.

Bahr Youssef Canal is the source of the RBF site, which is about 25 meters from the unit. The depth of the water source is 3-6 meters and the speed of the water flow is 3-4 km / h.

4.1.1. Water resource

A) Environmental survey - sampling analysis.

Conducting an inspection of the scope of the environmental study for a distance of (3 km) upstream and (1 km) downstream (this distance according to the relevant regulations and laws) relative to the point directly in front of the RBF units. The inspection is carried out in order to identify and allocate the potential hazards that could affect the source.

Water samples were taken from the source in order to determine the water quality, and the sampling points were also signed using the GPS devices. The following map represents the location of the taken samples.

Figure 3 | Map that illustrate the samples location in water source at Abu Bisht.

The inspection indicates some activities that could be a potential source for pollution of the water body, the following table summarizes the major activities.

Table 5| Potential hazard activities in water resource.

location	Activity
Upstream by 400 m	The presence of some population centers', as well as some bad behavior by the people, such as washing dishes.
Upstream by 1200 m	The agricultural activity increased on both sides of the Bahr Youssef Canal, in addition to the presence of some localities.
Upstream by 2000 m	The presence of population activity represented in the presence of settlements on the banks of the Bahr Youssef Canal, in addition to the presence of animal and agricultural activities.

Downstream by 300 m	The spread of agricultural activity, weeds and aquatic plants on the west bank of the Bahr Youssef Canal and the presence of population activity on the eastern bank of the canal.

Samples were taken from the water source and analysed in the central laboratory to know the characteristics of the water and to determine the quality of the water at the source.

The following graphs representing the main finding in the water resources with respect to law 48 for the year 1982, which specify the water quality at the River Nile and its branches.

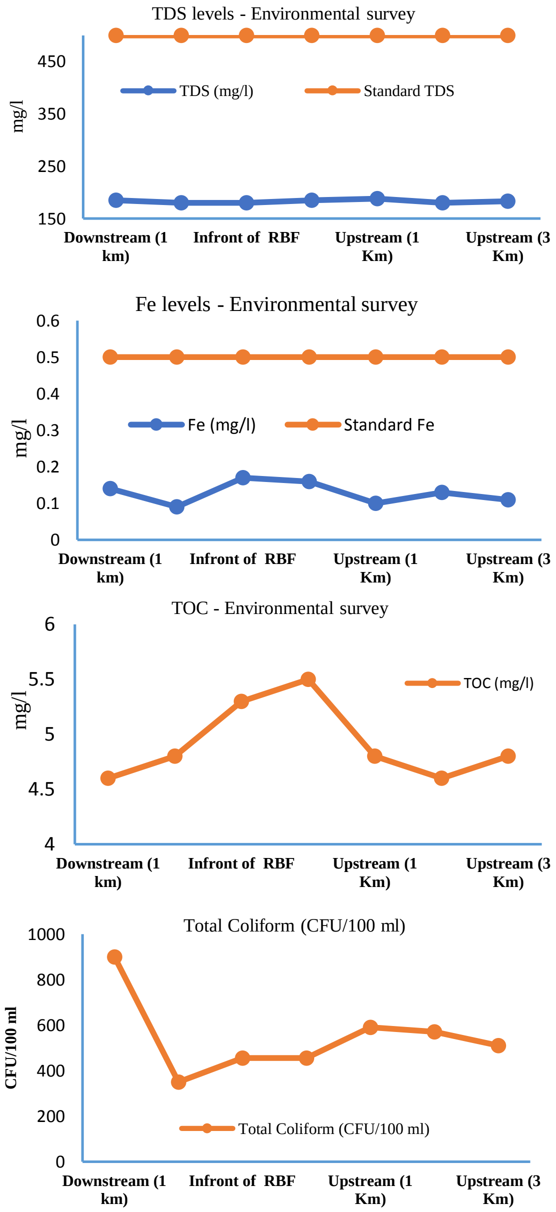


Figure 4 | Environmental survey for the water source at Abu Bisht

Reviewing the results from the environmental survey illustrate the impact of different activities at the water quality. At point upstream from the RBF unit by 500 m an increase in the concentration of TOC which can be explained by the unfavorable behavior of the local communities that use the water resources for washing cooing pans and dishes. Lack of awareness has also been noticed by the awareness team. However, the results of the samples indicated that they are in compliance with Article 49 of Law 48 of 1982 and its implementing regulations No. 92 of 2013.

B) Hydrological study for the water stream at the study area.

In Egypt, the River Nile as the surface water source is suffering in some cases from sudden threats as well as creeping threats. In other cases, a low level of water may be even lower than the considered one during the design of surface water treatment plants Intakes **(Nemec, 2012).**

In such cases, the water supply stops which is a real threat to any community. Accordingly, having a backup water supply that cannot be affected by such threats as RBF will help to avoid such a situation that happens from time to time, or seasonally.

Nile valley is hydrogeologically characterized by the existence of a quaternary reservoir. This reservoir is the most productive groundwater reservoir. Semi-permeable layers with thickness varying from 1 to 15 meters appear along the Nile mainstream, compared to 1-30 meters at the south and middle Delta and up to 60 m at North Delta. This layer is followed by a permeable layer which is suitable for RBF wells yield. The thickness of such sandy/gravel layer differs from south to north.

The water Quality of the Quaternary reservoir is considered as good quality especially in areas closer to the River Nile stream. The following chemical characteristics are extracted from previous studies:

- TDS Valley 500- 3000 ppm Delta 500 ppm at South to 10000 at North.
- Chlorides Valley 100-400 ppm Delta 100 ppm at south to 5000 at North.
- Sulphates Valley 25-150 ppm Delta 25 ppm at south to 1000 at North.

Other important parameters would be iron and manganese as well as organic pollution which should be identified on the site level during the detailed technical investigation which is out of the scope of this study.

The Nile Valley in the study area is bounded from the east and the west by the Eocene Limestone plateau. The cultivated area is wider in the western part than it is in the eastern one of the River Nile. The area is generally sloping from the south to the north. The elevation of the western and eastern limestone plateaux ranges from + 120 to + 220 m, whereas the elevation of the floor of the studied area varies from + 50 to + 60 m above sea level. It is underlain by clays, salt, sand, and gravel **(Moneim et al., 2016).**

4.1.2 River Bank Filtration plant.

This part of the study concerned with the investigation of the potential causes of hazards that could affect water safety as a result of failure or inadequate performance of one or more steps of the RBF plant itself.

A) Geological study of the study area.

In terms of geology, the study area is characterized by the presence of sediments dating back to the Quaternary Period, which are Holocene deposits, which are clay and sand deposits, and Pleistocene deposits, which are sandy deposits interspersed with lenses of clay sediments; These sediments are considered underground water reservoirs.

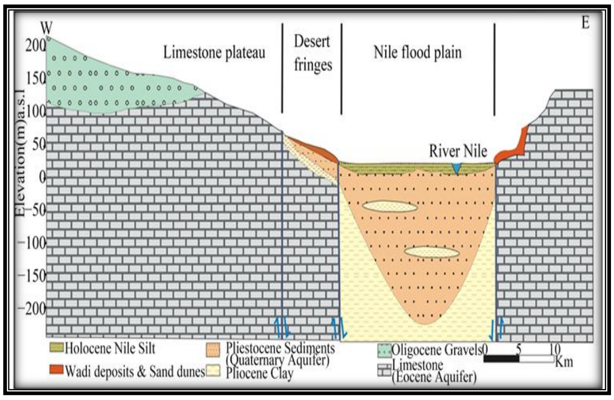


Figure 5 | Geological cross section of the study area (RIGW 1989; RIGW 1992)**.**

According to National Feasibility Study and roadmap for River Bank Filtration in Egypt and based on the national zoning, the Nile River valley can be geographically divided into three main zones as the following: (1) Nile Delta Zone (Greater Cairo Zone - North of Cairo Zone); (2) Nile Valley Zone (Northern part of Upper Egypt Zone - Middle part of Upper Egypt Zone - Southern part of Upper Egypt Zone); (3) Fayoum Depression Zone.

For Minya -Western side areas with respect to the River Nile mean stream is a very good potential area for the RBF in terms of geological, hydrogeological, and geotechnical aspects. - As for the eastern side it has also very good potential for RBF. - Almost most of the districts have good potential for RBF implementation in terms of defined parameters.

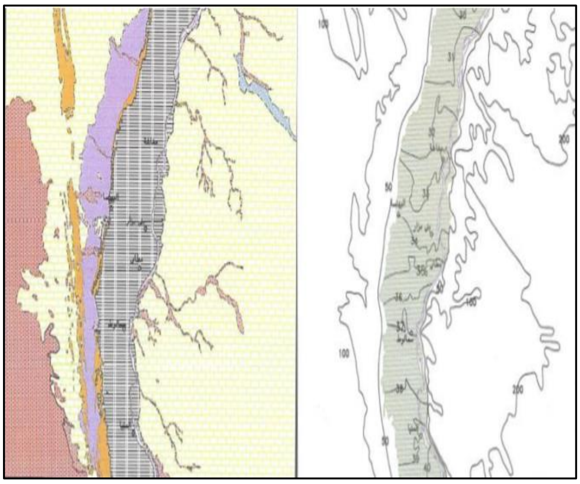


Figure 6 | left: Alluvial Plain of MINYA, right: Topography of Minya

B) Identify the present barrier for hazards within the treatment plant.

In order to be able to identify the natural and artificial barrier in the water plant, a complete investigation of its components was done.

Station location: The station is located in the northwest of Minya Governorate - the western region of Maghagha Center (the western shore of Bahr Youssef Canal)

- The design capacity of the station: 108 m^3 / hour.

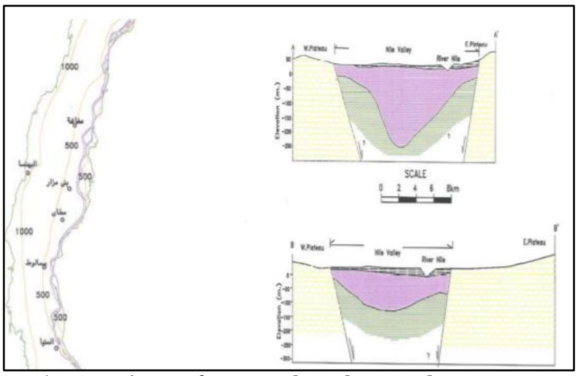


Figure 7 | Aquifers Depth and Extend in Minya Governorate

- Scope of service: Abu Bisht village, Shiha village, Sham al-Basal marine village
- Start-up date: 2013

Station components:

- (1) RBF- filtration unit.
- (1) room for the chlorine injection system.
- (2) water tanks.

Technical specifications of the natural filtration unit:

- Depth: 26 meters.
- Diameter: 16 inches.
- Length of the plumb pipes: 14 meters.
- Length of the refinery: 12 meters.
- Distance from the water source: approximately 25 meters.

The following map represents the location of the RBF site:

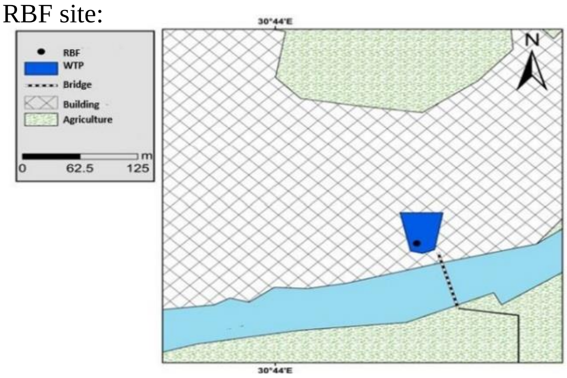


Figure 8 | Location of the RBF site with respect to the water stream.

The following showing the rock sequence and well design of the Abu Bisht process, where the rock content of the process consists of a clay about 4 meters thick, followed by a layer of the clay with fine sand, then a layer of coarse sand on top of a layer of coarse sand with gravel and finally a layer of coarse sand.

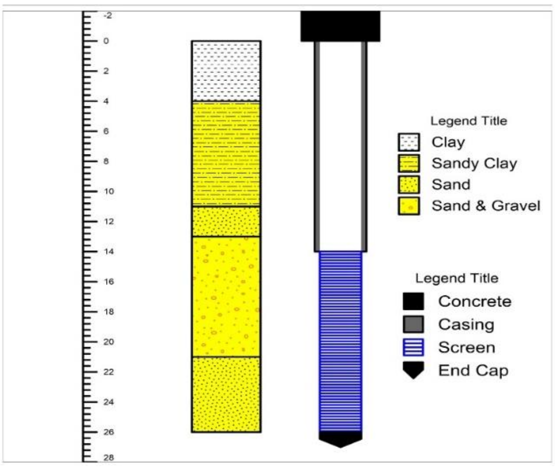


Figure 9 | The rock sequence and well design of the Abu Bisht process.

The filtration, medium represents the main barrier that reduces and eliminates the microbiological pollution via an effective infiltration process as well be shown in the part of sampling and analysis. Continuous operation is a must to ensure the hydrological connection between the infiltrate and the produced water. The sudden stop of the good operation causes the loss of the connection of the infiltrate which could lead to the direct abstraction of groundwater that decreases the water safety and affect the water securing process.

The location of the RBF well is surrounded by a fence that keeps a buffer distance between its location and the local residence. However, these communities are not served by wastewater which could be a potential source of biological contamination.

Figure 10 | Photographic picture of the RBF well

The plant is equipped with two water tanks for storage and chlorine disinfection. One of the water tanks has malfunctioned and has stopped working this considered one of the potential hazards that could affect water safety.

The location isn't equipped with an alternative electricity source (i.e., generator) which could be a potential source for hazard and affect the sustainability of the drinking water supply within the context.

One of the potential hazards is the lack of training of the operation stuff an interview has been done for the measurement of the competence of the operation staff. The questioner includes technical and managerial points that directly linked with an index to evaluate the competencies the following figure representing the results of interviewing the staff.

Measuring staff competence has shown a great gap between technical competencies and managerial ones. The staff is relatively well trained in terms of technical aspects however, the application of this training isn't well elaborated in terms of a complete understanding of the requirement of the technology hen e staff sometimes doesn't translate the training into SOP that is obligatory for application.

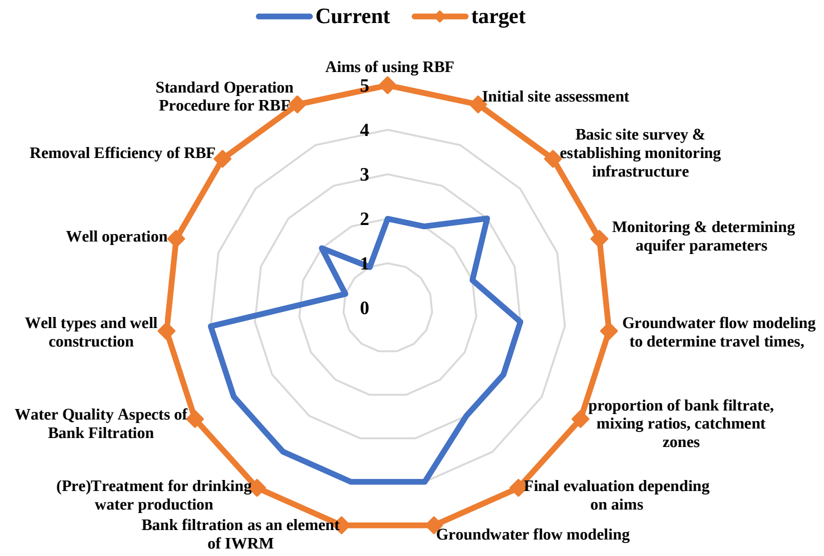
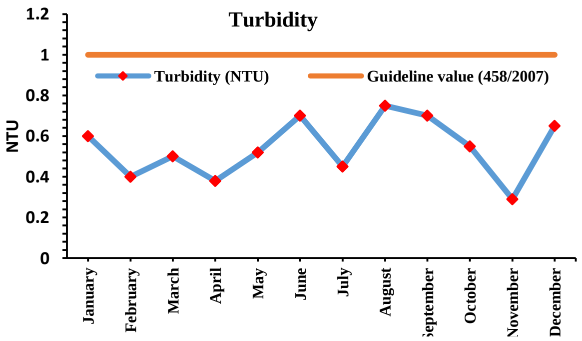
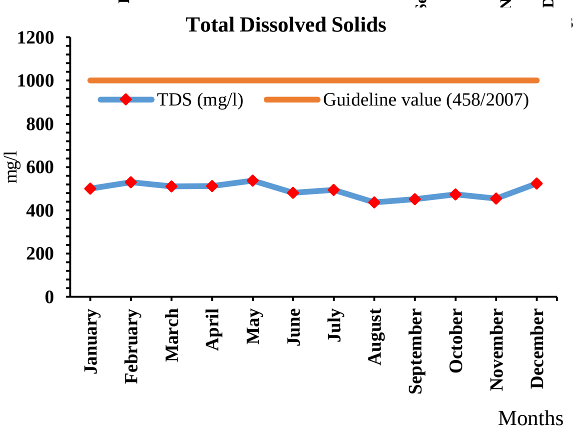


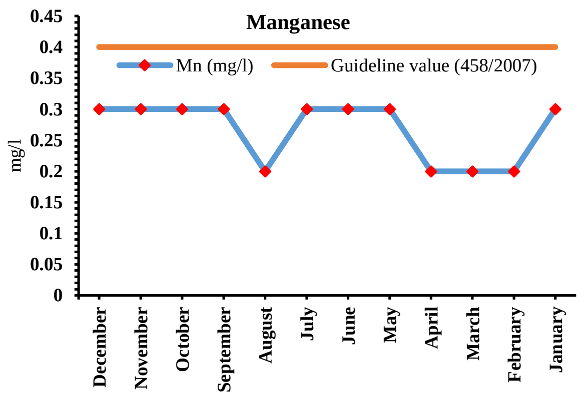
Figure 11 | Measuring Abu Bisht Staff Competences concerning RBF technology

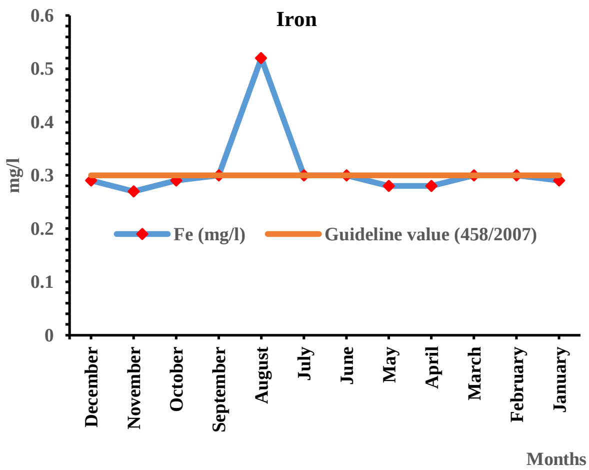
C) Analysis of the produced water quality.

Water quality produced from the natural filtration unit was tested and the results of the water produced from the well during the year 2020 were sequentially studied and charts were drawn for it as follows:









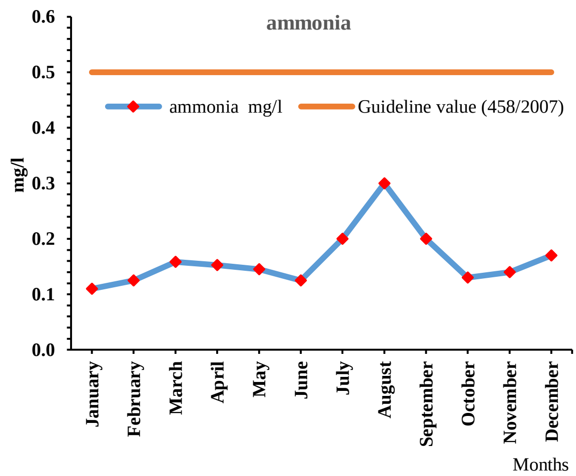


Figure 12-16 | Chemical aspects of RBF outlet

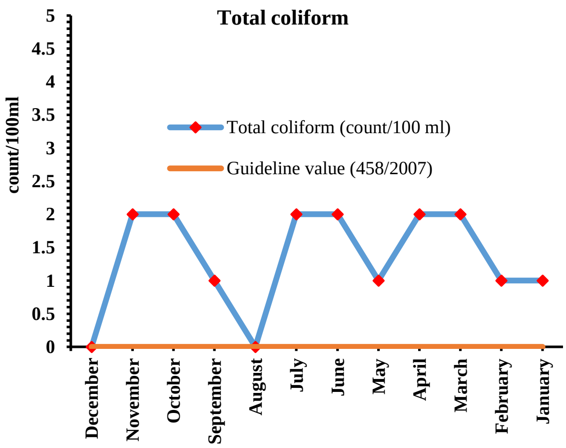


Figure 17| Microbiological aspects of RBF outlet

The results show that the water quality produced from the RBF of Abu Bisht generally is acceptable. Moreover, some turbulence in water quality has been noticed. This fluctuation in results could be attributed to the sudden stop of the well which takes around one week to re-stabilize and reaches the ordinary levels of different parameters. It worth saying that the microbiological aspects are totally acceptable and this before even the injection of chlorine. The injection of chlorine is necessary to ensure water safety in the water network.

4.1.3. Network distribution.

One of the main sources of hazards and should brought great intension is the water network hence this part is to describe and investigate the water distribution network in the area of study.

A) Description of the network statues.

The distribution network lines of water within the study area consist of several types: Polyvinyl chloride (P.V.C). Asbestos (ASB), plastic, polyethylene (P.E.), iron. It covers an area of about 4,736 meters of total capacity, and it serves a total of 17,185 inhabitant.

The Abu Bisht and Nazlet Shiha network was established from the 1960s to the 1990s, and some of them were completed in some deprived areas in 2007. Seasonal faults (fractures and explosions) in the winter due to increased pressures and less demand for water as a result of the wear and tear of some connections (as more than 80% of the connections are worn out), such as connections and tools attached to the connections, and the faults decrease in the summer due to a large number of pressures inside the networks.

There are (2) technicians working in the maintenance centre of Abu Bisht network and Nazlet Shiha. They are responsible for network maintenance. They have been trained on maintenance work for faults, fractures and explosions in the networks. The following table represents Diameters, types and lengths of networks fed into the drinking water supply system in Abu Bisht.

Table 2| Type and diameter of the distribution network.

Type/Diameter (mm)	100	125	150	200
Asbestos (ASB)	3366	278	37	
Poly Vinyl Chloride (PVC)	21504		2779	804
polyethylene (P. E)			1898	2119
Stainless Steel (ST)	75		13	162
Glass Reinforced Polymer (GRP)				1651

Figure 18 declares that most of the distribution network is recently changed into PVC by a percentage of 72%. The second major percent is polyethylene. However, still, a considerable percent of the network is from asbestos that is old and is subjected to frequent breaks.

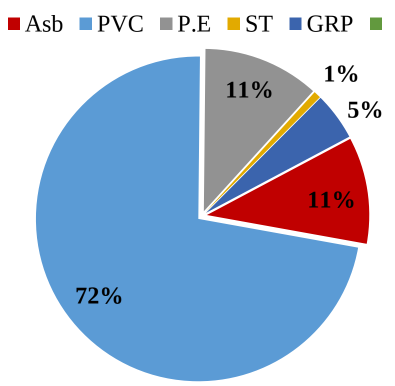


Figure 18 | Percentage of different material type of the distribution network

B) Pressure study of the network

A pressure study has been done through the GIS-sector of the company. This kind of study help to indicate the potential hazards coming from low water pressure at the network. Field measurement has indicated that all of the networks have a sufficient water pressure of 2 bar figure (19).

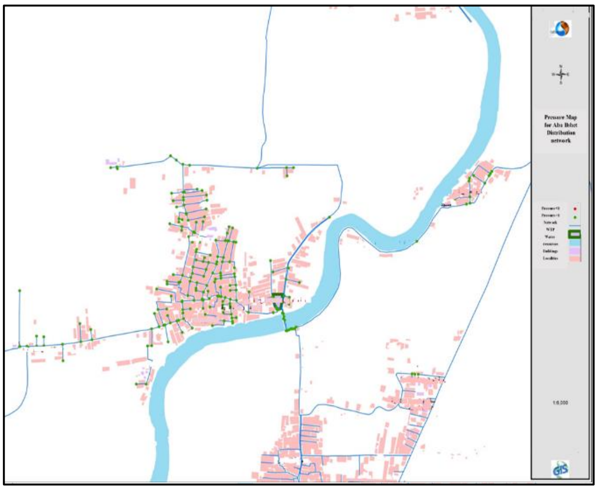


Figure 19 | Network Distribution System Pressure Map for Abu Bisht village.

C) Water quality in networks:

The sub-laboratory at Maghagha district regularly uptake samples from the Abu Bisht distribution network and ensures the presence of free chlorine remaining at the edges of the network to ensure bacteriological conformity, in addition to taking samples from the outlet and the network and analyzing them in compliance with the Minister of Health Resolution 458 of 2007.

The two general departments for quality control and central laboratories of the laboratory sector of the company also pass and supervise the subsidiary laboratories, collect samples and analyze them in the central laboratories. Periodic technical visits by the General Administration of Quality and Environmental Affairs and the reference laboratory of the Holding Company for Drinking Water and Sanitation. The Environmental Health Department also undertakes periodic routine monitoring by collecting and analyzing samples and field traffic at stations and preparing reports on those operations in addition to passing by the sovereign authorities over stations and networks such as the Environmental Affairs Agency and the General Administration of central laboratories in the Ministry of Health, the Consumer Protection Agency, and others. The analysis of samples has shown that the samples are in compliance with the Egyptian standard for drinking water.

3.1.4. Customers community.

In many cases, the customers' behavior is considered one of the potential sources of hazards that could affect water safety. The customers' lack of awareness and illegal activities is the main causes behind these hazards.

A) Customers census.

The District of Maghagha is considered one of the largest centers in the Minya Governorate, and it is the first center in Minya, and it is bordered to the north by the center of Al-Fashn, to the south by the center of Bani Mazar, to the east by the Nile River and the village of Sharouna, and to the west by the center of Al-Adwa. The center consists of six (6) main villages and 41 affiliated villages. The area of the center is approximately 52,092 acres, the population of the villages is approximately 493,474, and the city's population is approximately 101,756 people.

The most famous industries in Maghagha: Port Said Cotton Ginning Company - El Nasr Company for Drying Agricultural Crops - Bertbat Carpet Factory - Dry Kum Green Onion Factory. Abu Bisht RBE water well supplies the water to the following areas: Abu Bisht village - Sham al-Basal village and their dependencies with an average population of 17500 capita.

The following table contain the main water consumers in the community and their different distribution:

Table 7| Classification of customers in the context.

Category	Consumer type	Number	Average water daily consumption (m^3)
Places of worship	Governmental bodies	17	400
Schools	Governmental bodies	5	700
Localities and public entities	Governmental bodies	6	120
Super market – restaurant – industrial activities and etc.	Commercial bodies	100	2000
Building communities	Households	1800	2200

Homes do not have upper water tanks, but there are tanks in schools and some government departments in general there is two observations:

- The area is not served by sanitation and most of the people depend on the septic tank that is locally discharged by the private sector. Some people tend not to evacuate their own septic tank which in general could affect the groundwater quality with time.

- The society is rural, and most of them work in agriculture.
- The schools haven't contracted with a professional company for the water intake regular cleaning and disinfection.
- Lack of awareness about water value is generally observed.

B) Customers complaints and Satisfaction Survey

Most of the customer complaints are summarized in water cuts complaints, and there are four complaints related to water quality only in the year 2019. Most of these interruption and breakage complaints do not go through the official way through hotline 125 or the company's branch, but the complainants contact directly to the head of the network, as this is one of the behaviors of the villagers. They know each other and contact officials close to them in a friendly manner.

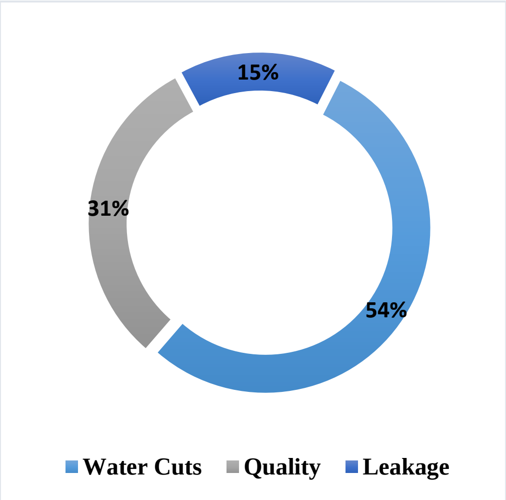


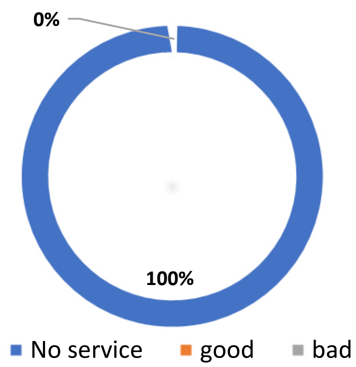
Figure 20 | Different type of compliant percent at year 2019.

The laboratory in the Maghagha branch also conducts a periodic program and plan to collect samples from parcels and networks of stations belonging to the Maghagha branch, including the Abu Bisht station and its networks, to determine the quality of water in the networks, and it also examines complaints about quality and corrects errors in case of non-conformity in coordination with maintenance centers' to take the necessary, then follow up The sample after the disappearance of the reasons for non-conformity, and the following values are presented for the complaints for the year / 2019. Summary of complaints received by hotline and it is clear that most of the complaints are water cuts, however, this chart doesn't represent the real situation as it was mentioned most of the complaints are received unofficially.

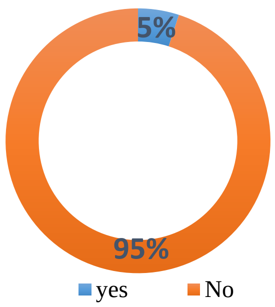
The company's awareness department creates a protocol for cooperation with schools in Minya Governorate, to educate students on how to deal with treated water, rationalize water use, the danger of storing water in a wrong way, and how to deal with water in areas with weak pressures. 20 consumers were interviewed in the Abu Bisht water network, and the questioners include the following main questions:

- (Quest. 1) Do you have any problems related to wastewater service?
- (Quest. 2) Do you know that the company offers disinfection services?
- (Quest. 3) Do you ever use the service of the hotline?
- (Quest. 4) Do you see any awareness activities of the company?
- (Quest. 5) Do you trust the water quality?
- (Quest. 6) Do the pressure of water is sufficient?
- (Quest. 7) Do the service continuity all-over the day?

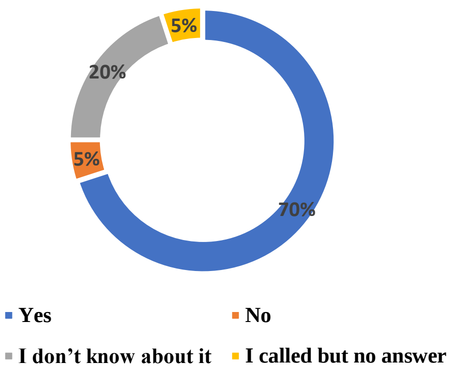
The following figure represents the different survey outcomes illustrated by the percentage out of the response of the interviewee.



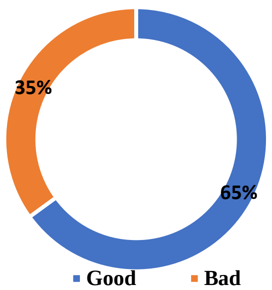
(Quest. 1)



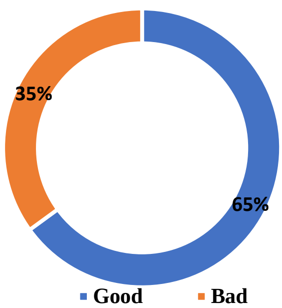
(Quest. 2)



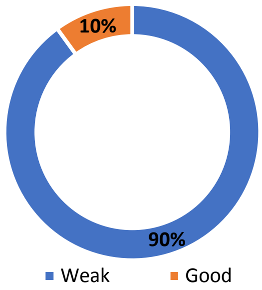
(Quest. 3)



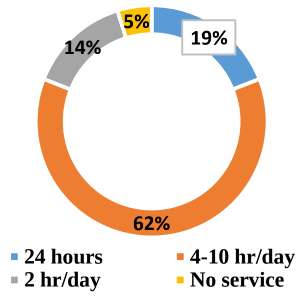
(Quest. 4)



(Quest 5)



(Quest. 6)



(Quest. 7)

Figure 21 | The customers survey.

The survey results indicate the main potential hazards as follow:

- Illegal connections (frauds and faults)
- Connecting Abyssinian pumps to the network and using it in case of water failure or interruption
- Construction of ground tanks to drain sewage water, in violation of technical conditions and specifications, especially in villages
- Caissons were thrown to drain sewage water to great depths in villages.
- Water continuity is not 24/7.
- Lack of awareness about companies' activities.
- No wastewater services
- Low impact of awareness activities

4.1 Risks Identification and management

The description and assessment of the system allow to indicate the following potential hazards which was prioritize according to the risk assessment matrix and the following table summarize the finding of their activities **(Vieira 2011).**

Table 8| Risk identification and scoring

Section	Location	Risk/causes	Frequency	Impact	Risk score
Water resource	Upstream by 400 m	The presence of some population centers, as well as some bad behavior by the people, such as washing dishes which could have microbiological pollution.	Always (once daily) – 5	A great regular effect - 4	20
	Upstream by 1200 m	The agricultural activity increased on both sides of the Bahr Youssef Canal, in addition to the presence of some localities leads to an increase in the percentage of organic pollutants.	Average occurrence (once per month") -3	Moderate visible effect-3	9
	Upstream by 2000 m	The presence of population activity represented in the presence of settlements on the banks of the Bahr Youssef Canal, in addition to the presence of animal and agricultural activities, lead to microbiological pollution.	Low (once a year)-2	A great regular effect - 4	8
	Downstream by 300 m	The spread of agricultural activity, weeds, and aquatic plants on the west bank of the Bahr Youssef Canal and the presence of population activity on the eastern bank of the canal.	Low (once a year)-2	Moderate visible effect-3	6
RBF Well	The surrounding environment-buffer zone	The area isn't served with a wastewater system. Septic tank is used for the sewage discharge which leads to potential microbiological contamination of the groundwater.	Average occurrence (once per month") -3	A great regular effect - 4	12
	The water reservoir	Only one water reservoir is working and the other is not, the possibility of the stop of the well or direct supply to customers with no chlorine disinfection.	Average occurrence (once per month") -3	A great regular effect - 4	12
	Power source	The presence of one electricity source leads to a temporary stop of the RBF well and customers will be vulnerable to the inadequate water resource.	Average occurrence (once per month") -3	A great regular effect - 4	12
	Staff	Lack of capacity of the staff about SOP of RBF technology.	Low (once a year)-2	Moderate visible effect-3	6
Network distribution system	Abu Bisht network	The physical pollutants (turbidity) reach the distribution network as a result of poor water and the people's use of motors to abstract water.	Average occurrence (once per month") -3	Moderate visible effect-3	9
	Abu Bisht network	Connection of illegal underground pump which leads to microbiological contamination of the network due to low pressure and high cost of new connection.	Low (once a year)-2	A great regular effect - 4	8
Customers community	Schools	The water storage tank is not disinfected regularly due to a lack of awareness – the students are vulnerable to microbiological risks from water.	Average occurrence (once per month") -3	A great regular effect - 4	12
	Households	Water storing at the communities in an inadequate tank for using at water cuts.	Low (once a year)-2	A great regular effect - 4	8

Based on the main causes of risks a group of short- and long-term corrective actions has been developed. the related responsible stakeholders have also been identified, the related impact and the performance indicator are represented in the following table.

Table 9| Corrective actions and responsible stakeholders to implement them.

Section	Corrective action	type	Stakeholders involved	Impact	KPI
Water resource	Installing fence around the water resource.	Short term (1 year)	Project management unit -water company	prevent unauthorized approach	Percentage of fecal coliform in the water stream%
	Unleash awareness campaign targeting student, women, and farmers	Short term (3 months)	Awareness dept.- water company	Increase the awareness and valuing of the water by customers	Percentage of customers that use the hotline%
	Supply the nearby instalment by the sewage system	Long term (5 years)	National Organization of Potable Water and Sanitation (NOPWASD)	Reduce the probability of microbiological pollution	Percentage of noncompliance samples from RBF%
RBF Well	Draft a protocol with the local government to regularly evacuate the septic tank of the communities beside the RBF well	Short term (6 months)	Localities - water company	Reduce the probability of microbiological pollution	Percentage of noncompliance samples from RBF%
	Rehabilitation of the spare water reservoir	Long term (2 years)	Project management unit -water company	Service continuity and high pressure in the network	No. of complaints related to water cuts
	Installing a spare power resource	Short term (1 year)	Project management unit -water company	Service continuity and high pressure in the network	No. of complaints related to water cuts
	Capacity building of the staff	Short term (6 months)	R & D department at the Holding Company for water and wastewater	Enhance customers satisfaction and reduce the number of non-compliance samples	Customers satisfaction%
Network distribution system	Draft a protocol with Misr El Khir for connection of the poor customers	Long term (2 years)	Awareness dept. and NGOs	Enhance the water quality at the network	Water quality index
	Conduct a survey for removal of illegal connection and illegal ground water pump connection	Short term (1 year)	Operation and maintenance department	Enhance the water quality at the network	Water quality index
Customers community	Draft a contract with the schools in Abu Bisht for regular disinfection of the water tanks	Short term (1 year)	Water tanks disinfection, department, localities and NGOs	Reduce the probability of water born disease at the schools	Customers satisfaction%
	Unleash awareness campaign through the internet influencers	Long term (2 years)	Awareness department and water safety plan department	Enhance the customers awareness	Customers satisfaction%

5. Conclusion

This study approach is directly related to what has been learned from the practice and collective experience of the Minya Water Company team. The guideline of WHO named Water Safety plan was a lead way in order to come with the results. It was found that however, RBF is considered a well-established water technology with a low cost it still could be vulnerable to different kinds of potential hazards. The study has shown potential risks in the source, RBF well, network, and customer community. The most affected section is the water resource with high risk reach up to 20 from the scale of 1 to 25. The average risk factor before the implementation of the corrective actions is about 10 which classified as high risk. A group of corrective actions has been settled. These corrective actions include short term with low cost that could be considered as a quick-win action other long-term actions have also been identified. The application of this action will ensure a decrease in the average risk to 3 (low risk). The stakeholders that could be responsible directly for the application have also been identified and a group of KPIs has also been identified which makes this process manageable. NGOs have a major role in the application of corrective actions such as facilitating the connection for the poor citizen. The involvement of NGOs in the water management process at Abu Bisht will allow direct interaction between the industry and community which overall will increase the social responsibility of the company and at the same time increase the valuation of water at the mentality of the customers.

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