Mediterranean Marine Science

Vol 11, No 2 (2010)

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doi: 10.12681/mms.75

Mediterranean Marine Science
Indexed in WoS (Web of Science, ISI Thomson)
The journal is available on line at http://www.medit-mar-sc.net

Research Article

Rainwater in Egypt: quantity, distribution and harvesting

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Received: 22 June 2009; Accepted: 12 April 2010; Published on line: 1 November 2010

Abstract

Egypt has limited water resources, and it will be under water stress by the year 2030. Therefore, Egypt should consider natural and non-conventional water resources to overcome such a problem. Rain harvesting is one solution, but not the only one, particularly on the north coast by the Mediterranean Sea and the Red Sea. In this paper, the rainwater issue is reviewed and discussed in terms of the quantities and distribution at different selected areas in Egypt. The amount of rainfall at different locations in Egypt was collected for a period of 16 months. The data indicated that rainfall in Egypt is very scarce, with an annual average of 12 mm and ranges from 0 mm/year in the desert to 200 mm/year in the north coastal region. The maximum total amount of rain does not exceed 1.8 billion m^3 per year. However, the average annual amount of rainfall water that is effectively utilized for agricultural purposes is estimated to be 1 billion m^3. A harvesting pilot plant was constructed and implemented in Alexandria directly on the Mediterranean Sea. The harvested rain was used for irrigation and treated for drinking. It is, therefore, recommended to develop sustainable catchments at appropriate locations in the rain-fed areas on the north coast as well as cost effective grafting of indigenous technologies with innovative techniques.

Keywords: Rainwater; Water resources; Mediterranean coast; Rain harvesting in Egypt.

Introduction

Rainwater is steadily becoming recognized as an important source of water. But it still has some way to go before it can be accepted as a source of drinking water. Rainwater does not gain any significant share of the global market as a source of drinking water (BOELHOUWER, 2001). There are various reasons why this promising opportunity has been neglected. One of the most significant is the lack of any widespread public awareness, adequate collection and treatment as well as professionally planned marketing. Limited attention has been paid to positioning and promoting rainwater harvesting. Therefore, the business community has yet to grasp this opportunity and recognize its potential.

There is a need to employ the appropriate collection and treatment technology at an affordable price. Local needs must be met, as must the need for distribution of products on a global basis. In addition, the idea of rainwater as a quality, uncontaminated source needs to be promoted (BOELHOUWER, 2001).

Rainwater is often characterized as better quality than other water sources (THOMAS & GREENE, 1993). It may be received in the form of water, snow, sleet or even hail. It should not be allowed to run off into sewers, where it is often wasted or contaminated, but it must be considered as an important source for drinking, domestic or irrigation purposes. The key is harvesting and storing (ABDEL-SHAFY & EL-SAHARTY, 2006). When rainwater falls on roofs, driveways, roads and other impervious surfaces, it picks up pollutants such as dust, oil, sediment, fertilizer and trash.

Rainwater harvesting has been used since ancient times throughout the world. The earliest known evidence of use of rain harvesting comes from northern Egypt, where tanks ranging from 200-2000 m^3 have been used for at least 2000 years. Many are still in operation today. The world's largest rainwater tank is probably the Yerebatan Sarayi in Istanbul, Turkey. It measures 140 m^2 by 70 m^2 and has a capacity of 80,000 m^3.

A study of land impact on the atmospheric hydrological cycle would not be complete without examining rainfall, as water vapor and clouds that are closely related one other (ABDEL-SHAFY & ALY, 2002; JIN & ZHANG, 2002). In this respect, ocean regions generally have greater rainfall than land regions in tropical and subtropical areas, but such differences are further complicated by land cover evapotranspiration. For example, the Amazonian forests have significantly more accumulated rainfall than nearby oceans because of strong evapotranspiration and local convective activity. On continental scales, seasonality of rainfall is significant (TOKAY, 2001b; WELSH & MANCY, 1992).

On the other hand, Drop Size Distribution (DSD) is essential in understanding the physics of precipitation processes; therefore it plays a key role in remote sensing (i.e. radar) estimation of rainfall (TOKAY, 2001b; EL-RAEY, 1993). If the DSD was known within measured radar volume, the surface rainfall could be estimated by incorporating microphysical processes between the altitude of the radar measurement and the surface. In reality, radar measures the return power (i.e. reflectivity) from falling hydrometeors, which are proportional to the sixth moment of the drop size (TOKAY, 2001b). The rain rate, on the other hand, is proportional to the third to fourth moment of the drop size. A nonlinear relationship between measured reflectivity and estimated rain rate (R) relies on the knowledge of the DSD.

For instance, at a given reflectivity, relatively larger drops are found in continental precipitation than in maritime precipitation (TOKAY, 2001b). The DSD exhibits characteristic differences between extra-tropical and mid-latitudinal convection. Also, there have been characteristic differences in convective and stratiform regimes in tropical convection (HOUZE, 1997). NASA Wallops Flight Facility, located on the mid-Atlantic coast, receives extra-tropical systems in the winter, remnants of tropical cyclones and/or hurricanes in summer, as well as precipitation developed through regional convection. Here, we studied the variations of DSD in different rain regimes in two storm systems, both being springtime convection. The DSD measured by impact and optical disdrometers were compared in different rain and wind regimes.

According to the Meteorological Society, a rain intensity of < 2.5 mm hr-1 is called *light* rain, while a rain intensity of > 7.5 mm hr-1 is referred to as *heavy* rain. Rain intensity between 2.5 and 7.5 mm hr-1 represents *moderate* rainfall (EEAA, 1992; HOUZE, 1997). Comparing the composite DSDs, the distribution that corresponds to heavy rain had larger maximum drop size and higher concentrations of medium and large drops.

Materials and Methods

The amount of rainfall at different locations in Egypt was collected over a period of 16 months. The study covered all Egypt, starting from the north coast (at Alexandria, Marsa-Matrouh in the north-west then Al-Arish at the north-east), middle site (at Cairo and Giza) and the Nile valley from Cairo down to the south at Aswan. The data was recorded as the average based on the amount of the rain collected throughout the period of the study.

The variations in the Drop Size Distribution DSD was studied in order to understand the physics of the precipitation processes that plays a key role in remote sensing (i.e. radar) estimation of rainfall (TOKAY, 2001b). The investigation covered two storm systems. Both were at springtime convection. The DSD was measured by impact and optical disdrometers and was compared in different rain and wind regimes according to TOKAY, *et al.* (2001b).

A Harvesting Pilot Plant was constructed and implemented in Alexandria for the first time at the National Institute of Oceanography, located directly on the Mediterranean Sea. Three declining roofs of areas of 38x4, 38x4 and 20x6 m with a slope of 2% each were selected. Gutter pipes were connected to these roofs to collect the falling rain. These gutters were finally connected to storage tanks, from which the harvested rainwater was pumped to irrigate the surrounding landscape areas. Meanwhile, filtration of this harvested water occurred through a small cylindrical sand filter device. The filter was (radius 0.5 m * 1.0 m length) filled with sand. The filtered water passed through a tube equipped with a UV lamp for disinfection. The physical, chemical and biological characteristics of the filtered water were examined to determine its suitability as a source of potable water according to the stringent Egyptian guidelines (EEAA, 1992). This examination was carried out by following the procedures described in APHA, 2005. It is worth mentioning here that the general practice is to discard the first flushing rain water before collecting to the storage tank. This was carried out by directing such flushing rain water to the nearby sea through a side pipe.

Results and Discussions

Nile Basin and water resources

The Nile River is one of the main water resources that run across 10 different African countries. The ground-based rainfall measurements of this Nile basin is given in Table 1. This indicates that Egypt, Sudan and Eritrea contribute to the lowest annual amount of rainfall within the basin (15, 500 and 520 mm/ yr respectively) (ABDEL-SHAFY & ALY, 2002). However, Sudan presents 63.6% of total area of the basin while Egypt presents only 10.5%. Sudan and Zaire present the largest percentage of the total area of the basin of the 10 countries shown in the table. Meanwhile, Sudan, Ethiopia, Egypt and Uganda present the largest areas within the basin (SAID, 1993).

Table 1
Ground based rainfall measurements at NASA Wallops Flight Facility (*).

Country	Total area of the country	Area of the country within the basin	Percentage of total area of basin	Percentage of total area of country	Average annual rainfall in the basin area (mm)		
	(km^2)	(km^2)	%	%	min.	max.	mean
Burundi	27 834	13 260	0.4	47.6	895	1 570	1 110
Rwanda	26 340	19 876	0.6	75.5	840	1 935	1 105
Tanzania	945 090	84 200	2.7	8.9	625	1 630	1 015
Kenya	580 370	46 229	1.5	8.0	505	1 790	1 260
Zaire	2 344 860	22 143	0.7	0.9	875	1 915	1 245
Uganda	235 880	231 366	7.4	98.1	395	2 060	1 140
Ethiopia	1 100 010	365 117	11.7	33.2	205	2 010	1 125
Eritrea	121 890	24 921	0.8	20.4	240	665	520
Sudan	2 505 810	1 978 506	63.6	79.0	0	1 610	500
Egypt	1 001 450	326 751	10.5	32.6	0	120	15
For Nile basin	---	3 112 369	100.0	---	0	2 060	615

(*) According to:
1. SAID, R., (1993).
2. ABDEL-SHAFY, H.I. & R.O. ALY (2002).

The Rainfall Problem in Egypt

Egypt belongs to an arid and semi-arid climate region and about 960 000 km^2 or 96% of the Egyptian area is covered by desert (the Sinai Peninsula, the Eastern Desert and the Western desert). These deserts have an acute shortage of water supplies and as a result a harsh life. In the desert, the primary source of water is rainfall and underground water resources are mostly saline or not available at all. When there is no rainfall, people face drought and famine. Those years without rain also reduce grazing lands, increase livestock mortality and bring additional misery for inhabitants of the areas.

When water is scarce, the need for water management skills and efficient use are required. In such areas the water for growing vegetables and fruit trees as well as for drinking purposes is only provided through rainwater harvesting technologies. Due to constant population growth, there is a necessity for an increased food supply, requiring the use of marginal and desert lands for livestock and farm production. The saline groundwater cannot be used for human and animal consumption or for growing crops and trees. To combat this problem this problem, water harvesting techniques have generally been used to get water.

Water Resources in Egypt

Egypt is potentially one of the countries most at risk from the effects of climate change. The inhabited area of the country constitutes only 4% of the total area of the country (1 001 450 km^2), and the rest is desert. The major source of water is the River Nile that provides about 90% of all water available to the country (ABDEL-SHAFY & ALY, 2002). The source of this water lies far to the south, from rainfall on the Ethiopian plateau (86%) and equatorial lakes (14%). Most of the population of Egypt (over 79 million people in total) is occupied in the agricultural sector, which constitutes 20% of gross national product and consumes about 80% of the water budget (ABDEL-SHAFY & ALY, 2002; WELSH & MANCY, 1992). Water Resources in Egypt (Table 2) indicate that rainfall represents a minor resource at the present time. However, it will play important role in the coastal areas in the near future.

The Coastal Zone of Egypt

The coastal zone of Egypt extends for more than 3 500 km and is the home of more than 40% of the population. This dense population is concentrated around the industrial and commercial cities, including Alexandria, Port Said, Damietta, Rosetta and Suez. Alexandria is one of the oldest and most historical cities on the Mediterranean coast (EL-RAEY, 1993). It is an important tourist, industrial and economic centre. The city has a waterfront that extends for 60 km, from Abu-Qir Bay in the east to Sidi Krier in the west and includes a number of beaches as well as the one of the main harbours in Egypt. Alexandria's beaches are the main summer resort of the country, and its harbours are the most important import/export link between Egypt and Europe. About 40% of Egyptian industry is located within the Alexandria area. Because of its high popu-

Table 2
Water Resources in Egypt (*).

Sources	**109 m^3 / year**	
	2000	**2020 ***
Nile River	55.50	57.50
Shallow GW	5.50	7.50
Deep GW	0.80	2.75
Drainage Water Reuse		
Nile Delta	4.50	8.50
Nile Valley	5.00	5.00
Unofficial	3.00	3.00
Wastewater Reuse	0.20	2.00
Rainfall	0.50	1.50
Desalination	---	0.25
Losses	(3.00)	(2.00)
Total	**72.00**	**86.00**

GW = Groundwater
(*) estimated according to ABDEL-SHAFY, H.I. & R.O. ALY (2002).

lation density and industrial activities, environmental pollution problems have occurred, affecting the socio-economic life of the community in the area (AHMED, 2007).

The Climate of Egypt: Temperature, Humidity and Monthly Precipitation)

Egypt's climate is characterized by hot, dry summers and mild winters. However, according to the climatic data, the southern part of the country is characterized by a continental climate. The range in temperature between day and night, or summer and winter is very great. For instance, the maximum temperature in summer time goes up to 42° C and the minimum in winter goes down to 7° C. While, the maximum temperature prevailing in the areas close or adjacent to the Mediterranean is about 30° C in summer and 18° C in winter (ABDEL-SHAFY & ALY, 2002).

Rainfall

Monthly precipitation is expressed as a rate (average millimeters of accumulated precipitation per day) for easy comparison with other months. Not only does most of the Earth's precipitation fall in the Tropics, a fair amount is concentrated in a narrow band roughly paralleling the Equator, the Inter-tropical Convergence Zone.

Rainfall in Egypt is very scarce, with an annual average of 12 mm (ABDEL-SHAFY & ALY, 2002; SAID, 1993). The mean annual rainfall ranges from 0 mm/year in the desert to 200 mm/year in the north coastal region. The rain falls only in the winter season in the form of scattered showers, i.e., December and January showers (ABDEL-SHAFY & ALY, 2002; KELLY & WELSH, 1992). However, rainwater as concentrated on the northern part of the country is between 150 - 200 mm, and decreases gradually to the south reaching around 24 mm. On the other hand, rainfall on the Mediterranean coastal strip decreases eastward from 200 mm/year at Alexandria to 75 mm/year at Port Said. It also declines inland to about 25 mm/year near Cairo and 1 mm/year at Aswan.

Significant intensities of rainfall are recorded on parts of the Red Sea coast. The most southern part of the country, on the borders with Sudan is marked by these phenomena. Intensities of about 500 mm/year were observed in some years (ABDEL-SHAFY & EL-SAHARTY, 2006). The maximum total amount of rain does not exceed 1.8 billion m^3 per year over the areas under consideration. Nevertheless, some seasonal rain-fed agriculture is practised on the northern coast to the west of Alexandria and in Sinai, utilizing these small amounts of water (SAID, 1993). At present, the average annual amount of rainfall water that is effectively utilized for agricultural purposes is estimated to be 1 billion m^3. In the future, a quantity of 1.3 billion m^3 is planned to be used every year, divided as shown in Table 3. Due to the small quantities, Egypt cannot depend on rain as dependable source of water. In this respect, Table 4 represents the rainfall during November and April (the non-rainy season) on the north coast. It ranges between 28 and 5 mm, while it decreases to zero to the south (Table 4).

Humidity

Humidity is high In the northern part of Egypt as it ranges between 70 and 72% during the summer months. It decreases gradually towards the south. It reaches 13% in the south of the Nile valley at Aswan.

The country is characterized by good wind regimes with excellent sites along the Red Sea and Mediterranean coasts. Sites with an annual average of 8.0-10.0 m/sec have been identified along the Red Sea coast and

Table 3
Quantities of rainwater that could be used at different areas in Egypt.

Quantity of rainwater billion m3/year	Should be used for
1.3	Total amount of rainwater
0.38	as supplement to irrigation in the Nile Delta
0.45	in Sinai
0.20	in the Red Sea Coast
0.27	In Alexandria and Marsa-Matrouh

Table 4
The mean values of temperature and rainfall at Alexandria (by the Mediterranean coast) and Sharm El-Sheikh (Sinai by Red sea).

Weather		Mean Temperature	Rainfall
Alexandria	November	66°F/19° C	1.1"/28 mm
	April	64°F/18° C	0.2"/5 mm
Sharm El Sheikh:	November	73°F/23° C	0"/0 mm
	April	77°F/25° C	0"/0 mm

about 6.0-6.5 m/sec along the Mediterranean coast (ABDEL-SHAFY & ALY, 2002). Meanwhile, the entire territory enjoys a rather high solar radiation intensity of 1.900-2.600kWh/m^2/year. Further intensity up to about 2.400kWh/m^2/year is observed when moving from the sea towards the desert.

Monthly Rainfall Precipitation

Precipitation is one of the key components of the endless circulation of water within the global atmosphere, known as the *hydrological cycle*. The sun's energy evaporates the water, winds carry the water vapor elsewhere, and the water vapor condenses back to its liquid form (cloud formation) and then may precipitate out of the cloud. Precipitation over the oceans is greater than that over land surfaces.

Nevertheless, evaporation over the oceans exceeds precipitation while the opposite happens over land. According to TOKAY (2001b) the surface water balance can then be defined as (averaged over a long period of time and neglecting dewfall):

$$\Delta\int = P - E \qquad (1)$$

where P is the precipitation by rain or snow, E is the evapotranspiration, and $D\int$ is the runoff. Precipitation peaks near the equator, with a secondary maximum in the middle latitudes of both hemispheres. Convection along the intertropical convergence zone (ITCZ) is mainly responsible for producing the heavy precipitation in equatorial regions, while the secondary maximum is associated with mid-latitude weather systems.

Evaporation exceeds precipitation over the sub-tropics where the runoff is negative.

The amount of rainfall at different locations in Egypt was determined. Sampling locations are given in Figure 1. The average annual rainfall is presented in Figure 2 as a distribution pattern (mm/yr). This figure indicates that only the northern part, including Sinai, have a moderate available rain amount within which rain harvesting can be implemented. The rest of the country is very poor in rainwater. Table 5 reports

Fig. 1: Rain water sampling locations along Egypt.

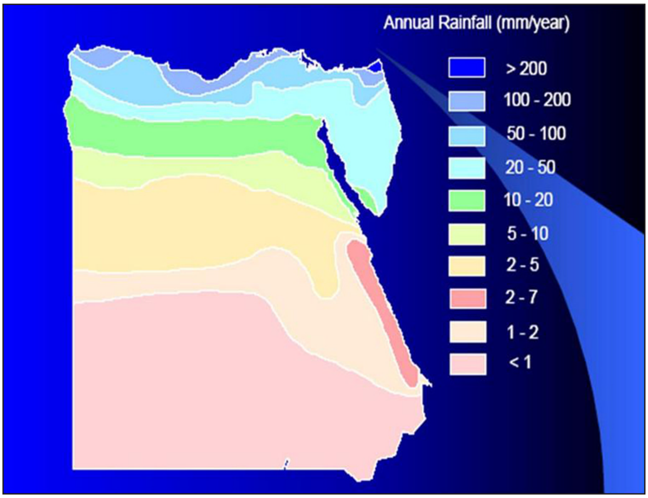

Fig. 2: Distribution Pattern of the annual Rainfall on Egypt (mean mm/yr).

Table 5
Report about surges expectation between 1-31 January.

Region	Storm	Occur				Precipitation (mm/day)	Evaporation (mm/day)	Sun shine (hours)	Wind speed (Knob)	Temperature (˚C)	
		Days	%	Period							
				From	to	Mean	Mean	Mean	Mean	Min.Mean	Max.Mean
Cairo	1	2	58	1/1	6/1	1.6	6.8	---	22	8.9	16.1
	2	3	76	7/1	15/1	2.7	6.4	---	26	7	15
	3	2	62	19/1	20/1	6.8	6.3	---	20	8.1	14
	4	3	72	22/1	30/1	2.0	7.1	---	23	7	15.8
Alexandria	1	3	63	1/1	5/1	6.1	4.0	6.0	25	10	18
	2	4	64	8/1	15/1	5.5	3.6	4.4	27	10	17.5
	3	2	30	17/1	14/1	2.9	3.3	4.6	1	9.7	17.3
	4	3	65	22/1	24/1	5.6	3.3	4.5	24	9.2	16.9
	5	7	69	31/1	12/2	3.6	3.3	5.0	28	9	17
Matrouh	1	3	64	1/1	5/1	4.0	5.0	5.0	25	9	16
	2	4	65	4/1	15/1	6.0	5.0	4.0	26	9	16
	3	2	32	17/1	19/1	2.0	3.0	5.0	28	9	16
	4	3	65	22/1	26/1	3.0	5.0	6.0	26	9	16
	5	7	69	31/1	12/2	3.0	6.0	5.0	24	9	17
Al-Arish	1	3	85	2/1	5/1	3.9	3.4	4.6	21	10.3	18.5
	2	4	72	9/1	13/1	5.2	5.6	4.2	24	8.5	17.4
	3	2	74	18/1	22/1	5.6	3.4	4.8	24	7.9	15.9
	4	3	63	24/1	28/1	5.4	3.9	3.8	26	9.7	17
	5	2	74	30/1	4/2	2.3	5.1	5.6	25	8.7	18

1: Ras El-Sana, 2: Al-Faida Al kabira, 3: Al –Ghetas, 4: Al-Karam, 5: Rest of Al-Karam the surges expectation between 1 and 31 January as average values of the northern cities in correlation with Cairo. The table indicates that Alexandria receives the highest rainfall, followed by Matrouh in the west then Al-Arish at the east. The evaporation rate is almost equal at Alexandria and Matrouh while lowest at Al-Arish. The sunshine (hours) showed the same trends.

Rainwater Harvesting

Rainwater harvesting can be implemented only on the north coast of Egypt due to the available amount of rainfall that can be collected. The rest of the country suffers from a deficiency of rainfall. For rainwater harvesting/conservation different technologies are being applied (DIJKMAN, 1993).

In situ water harvesting: This consists of conserving as much rain as possible where it falls, through land and soil management. The practice is mainly comprised of contour furrowing, contour benches, bed furrow systems and other cultural operations. The guiding principal is to minimize infiltration of the incidental rain and minimize runoff losses.

Catchment-based harvesting: The rainwater is allowed to run off from the upper reaches and is collected at lower reaches for sustained crop/plant production. The underlying principle is to minimize infiltration and maximize runoff on catchment slopes for greater water harvesting on adjacent areas.

Harvesting Pilot Plant at Alexandria: The range of rainfall on the north coast is over 100 mm/yr. The average recorded rainfall at Alexandria is 180 mm/yr. Sometimes, rain reached 47.9 mm/yr and 53.2 mm/yr in one day at Alexandria and Giza respectively. It is worth mentioning that rain reached 168 mm/yr during one month at Alexandria, which means 95% of the total amount of one year (ABDEL-SHAFY & EL-SAHARTY, 2006; ABDEL-SHAFY & ALY, 2002). On the north-west coast it ranges between 120 and 150 mm/yr. It decreases to the east at Port-Said to 80 mm/yr. It decreases gradually to 50 mm/yr at the middle of the Delta, 22 mm/yr at Cairo and 1 mm/yr at Aswan. At the north of Sinai it ranges from 50 to 100 mm. Rain is the main source of water in the north of Sinai.

The physical, chemical and microscopic characteristics of the rain water that was harvested through the constructed pilot plant in Alexandria are given in Table 6. The results show that the filtered and UV disinfected rain water is very good, within the permissible limits according to the Egyptian stringent guidelines (EEAA, 1992). This reflects the importance of rain harvesting and treatment for potable purposes.

Factors Considered For Rain Harvesting In Egypt

- Rainfall pattern and intensity
- Seasonal variation
- Topography
- Evapotranspiration
- Soil type and water holding capacity
- Catchments area and location
- Land use

Benefits of Rainwater Harvesting

It can play a significant role in increasing water resources on the north coast of Egypt; this can enhance agriculture/livestock production. Improvement in the arid and semiarid regions of the country by:

- Collecting surface runoff during excess rainfall markedly decreases the risk involved in rain-fed agriculture.
- Help in restoring self-sufficiency in food production.
- Reducing the surface runoff and the loss

Table 6
Physical, chemical and microscopically analysis of rain water collected at Alexandria after sand filtration and UV disinfection.

PARAMETERS		**Unit**	**Results Min – Max**	**Average value**
Physical Examination				
Turbidity		NTU	0.5 – 0.7	0.55
Electrical Conductivity		μS	520 – 480	508
pH			6.5- 6.9	6.6
Color		CU	(colourless)	(colourless)
Taste and Odour			acceptable	acceptable
Chemical Examination				
Aluminium	as Al	mg/l	ND	ND
Ammonia, total	as NH_3	mg/l	ND	ND
Arsenic	as As	mg/l	ND	ND
Cadmium	as Cd	mg/l	ND	ND
Chromium, total	as Cr	mg/l	ND	ND
Copper	as Cu	mg/l	ND	ND
Hydrogen Sulfide,	as H2S	mg/l	ND	ND
Iron	as Fe	mg/l	0.001-0.002	0.0013
Lead	as Pb	mg/l	ND	ND
Mercury (total)	as Hg	mg/l	ND	ND
Nickel	as Ni	mg/l	ND	ND
Total Dissolved Solids,	at 105 ˚C	mg/l	188-196	191
Zinc	as Zn	mg/l	ND	ND
Biological Examination				
blue green algae		cell / L	Free	free
Bacteriological Examination				
e. coli (thermotolerant coliform)		NR	Free	Free
Fecal Coliform		24 hrs at 37 ˚C	Free	Free
total coliform bacteria			Free	Free
total bacteria (plate count)		24 hrs at 37 ˚C		
		48 hrs at 22 ˚C		
			< 50 cell / ml	< 50 cell / ml
			< 50 cell / ml	< 50 cell / ml
			< 50 cell / ml	< 50 cell / ml

of water due to evaporation in the hot climate.

- Improvement of the environment due to rehabilitation of the area.
- Increasing survival and establishment of plants.
- Improved t socio-economic conditions of the people.

Conclusions

1. Egypt is potentially one of the countries most at risk from the effects of climate change.
2. Rainfall represents a minor resource at the present time in Egypt. However, it will play important role in the coastal areas in the near future via rain harvesting.
3. Rainfall occurs only in the winter season in the form of scattered showers.
4. Rainfall in Egypt is very scarce, with an annual average of 12 mm and ranges from 0 mm/year in the desert to 200 mm/year in the north coastal region.
5. The maximum total amount of rain does not exceed 1.8 billion m^3 per year over the areas under consideration. However, the average annual amount of rainfall water that is effectively utilized for agricultural purposes is estimated to be 1 billion m^3.
6. Some seasonal rain-fed agriculture is practised on the northern coast to the west of Alexandria and in Sinai, utilizing these small amounts of water.
7. Rainwater harvesting and collection systems can play a vital role in providing drinking water for the human and livestock population as well as for small scale agriculture on the north coast of Egypt.
8. The environment of the area can be improved considerably.
9. Groundwater can be recharged.
10. The industrial activities in Alexandria create environmental pollution problems that have affected the socio-economic life of the community in the area.

Recommendations

1. Development of sustainable catchments at appropriate locations in the rain-fed areas on the north coast.
2. Development of cost effective techniques under different soil, climate and socio-economic conditions.
3. Grafting of the indigenous technologies onto innovative techniques.

Acknowledgements

Zer0-M project is funded by the European Commission under the MEDA programme, project Zer0-M no. ME8/AIDCO/2001/0515/59768. The authors are responsible for the content of this paper that does not represent the opinion of the Community.

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