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Assessment of Water Sources Used by Rural Communities in Socotra Island - Yemen

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ABSTRACT
In rural areas of Socotra Island, the available water sources for local communities are mainly found as rainwater harvesting cisterns (Kareef), streams, springs and shallow wells. The objective of this study is to assess the water quality of the main water sources used by communities in rural areas of Socotra.21 villages were targeted for water quality assessment. 27 water samples were collected and subjected to physical, chemical and microbiological tests and analysis.The physical tests results show 13 samples (i.e. 48%)with high values compared to WHO and Yemeni standards for safe drinking water, especially for Kareefs, chemically all samples show acceptable values, whilemicrobiologically all the samples were contaminated.The contaminations ranges from low, moderate and high risk with 14.8%, 44.4% and 40.8% respectively.66.7% of water samples collected from Kareefs show high risk of contamination. It was found that, Kareefs represent the worst source of water used by rural communities in Socotra Island.

Keywords: Rain Harvestingcisterns (Kareef), Water Quality Testing, Microbiological contamination.

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I. INTRODUCTION

Socotra is an archipelago of four islands located in the Arabian Sea, the largest island of which is also known as Socotra.

The island of Socotra constitutes around 95% of the landmass of the Socotra archipelago. It lies some 240 km east of the Horn of Africa and 380 km south of the Arabian Peninsula. The island is very isolated, home to a high number of endemic species; up to a third of its plant life is endemic. It has been described as "the most alien-looking place on Earth [1]. The island measures 132 km in length and 49.7 km in width [2].

The archipelago consists of the main island of Socotra (3,665 km^2), the three smaller islands ofAbd al-Kuri, Samhah and Darsa as shown in Fig.(1), as well as small rock outcrops like Ka'lFir'awn and Sābūnīyah that are uninhabitable by humans but important for seabirds [3].

Fig.(1): The Main Islands Involved in Socotra Archipelago

The main island (Socotra) has three geographical terrains: the narrow coastal plains, a limestone plateau permeated with karstic caves, and the Higher Mountains. The mountains rise to 1,503 meters [4] as shown in Fig.(1).

The climate of Socotra is a tropical desert climate and semi-desert climate with a mean annual temperature over 25 °C. Yearly rainfall is light, but is fairly spread throughout the year.Due to orographic lift provided by the interior mountains, especially during the northeast monsoon from

October to December, the highest inland areas can average as much as 800 mm per year and receive over 250 mm per month in November or December [5]. In an extremely unusual occurrence, the western side of Socotra received more than 410 mm of rain from Cyclone Chapala in Nov. 2015 [6].

Almost all inhabitants of Socotra, numbering nearly 50,000, live on the homonymous main island of the archipelago[7]. The principal city, Hadibu (with a population of 8,545 at the census of 2004); the second largest town, Qalansiyah (population 3,862); and Qāḍub (population 929) are all located on the north coast of the island of Socotra. Only about 450 people live on 'Abd-al-Kūrī and 100 on Samha; the island of Darsa and the islets of the archipelago are uninhabited [8].

In Socotra, the main types of water sources available are: Wells, Streams/Wadies, Springs, and Kareefs/Rain water harvesting cisterns (most popular in rural areas).

In urban areas like in Hadibuand Qalansyah, there are water supply schemes underthe Socotra Local Water and Sanitation Corporation(LWSC-Socotra). The main water sources for these schemes are either wells or streams/wadies. These schemes comprise the main water supply components (i.e. main tanks and pipe networks), and lack water treatment units (Chlorination unit), which areessential for the quality improvement of the water supply.

In rural areas the available water sources for local communities mainly found as rainwater harvesting cisterns/Kareefs, springs, streams/wadies and shallow wells. Most of these water sources are contaminated.

Rainwater harvesting in its various forms represents the major source of water supply for domestic and livestock uses.Twotypes of Kareefs are found: Open Kareefs wherein the quality of water is too bad and these need frequent cleaning and desilting in order to be suitable for drinking,The other type is closed/roofed Kareefs, the quality of water in these Kareefs is far better than the water in the open Kareefs. Other forms of rainwater harvesting techniques that are found in other parts of Yemen like terracing or dams are not existing in the Socotra island [9].

Ground water sources in terms of shallow water wells represent the second important source of water for domestic uses. These wells are very sensitive to variation in annual precipitation. Knowledge about other deeper aquifers is lacking and need to be investigated [9].

A number of springs are available and discharge their water all over the year. These springs are consumed in a very simple way,discharge data is lacking and no monitoring are found in place. Small streams/wadies are another source of water used by rural communities. The surface runoff is not utilized welland all streams discharge their water to the ocean[9].

The Yemeni-German program on conservation and sustainable use of biodiversity (GIZ/BioDiv) had implemented a feasibility study on sustainable rainwater harvesting in 2013 which recommends supporting local communities with water filters to improve drinking water quality. The filters distribution program aimed to improve drinking water quality for targeted communities in Socotra Island.

In the beginning of 2014, the BioDiv program in partnership with Environmental Protection Authority (EPA - Socotra) have implemented the first phase of water filters distribution program in Socotra. 200 filters were distributed for more than 200 families that have poor access to clean water in several villages around the island.

Accordingly; in April 2017, the BioDiv program required more than 1377 water silver filters to cover more villages in the second phase. Thus; a total 1651 families have been covered by the distribution program of water filters in 78 villages. 92 villages in Socotra island were covered in the two phases.

Therefore; BioDiv program conducted an assessment on the efficiency and sustainable use of water filters to improve drinking water quality in Socotra Island. This work is a part of “Assessing water quality and the use of purification water filters” carried out for GIZ/BioDiv Program.

1. OBJECTIVE

The objective of this study is to assess the water quality of the main water sources for targeted communities around Socotra Island.

2. STUDY AREA

21 villages among the targeted villages were selected to assess the water quality of their main water sources, this represents more than 27% (21/92=22.8%) of the total villages targeted in the filters distribution program which covered in this assessment.

The total number of water samples collected were 27 samples from various water sources. The selected villages, locations, Nos. of samples collected and type of water source are listed in Table (1).

Table (1): List of Selected Villages, Locations and Nos. of Samples Collected

S. No.	Village Name	Coordinates		Center	No. of Samples Collected	Type of Water Source
		Latitude	Longitude			
1	Desaften	12.48959	53.99475	Deksam	1	Kareef
2	Zahq	12.38504	54.12686	Noged	1	Stream
3	Asteroh	12.33847	53.92152	Noged	1	Spring
4	Goa'a	12.53839	54.16834	Goa'a	1	Spring
5	Deshil	12.52062	54.17529	Goa'a	2	Stream
6	Neah	12.50054	54.17145	Goa'a	1	Spring
7	Trobah	12.52909	54.21439	Taeda'a	1	Spring
8	Readh	12.52635	54.25563	Taeda'a	1	Spring
9	Masalb	12.51694	54.24606	Taeda'a	1	Stream
10	Doabas	12.54617	54.35245	Momi	1	Kareef
11	Raqof	12.5378	54.34715	Momi	2	Kareef
12	Falang	12.49988	54.38344	Momi	1	Kareef
13	Homairoh	12.48979	54.39394	Momi	2	Stream
14	Hofag	12.53327	54.33711	Momi	2	Kareef
15	Arent	12.53671	54.29758	Momi	1	Stream
16	Bagobi	12.52572	54.29651	Momi	1	Stream
17	Roshi	12.5128	54.31986	Momi	1	Well
18	Ghodhoa	12.65273	53.65097	Qalansiyah	2	Kareef
19	Khorso	12.63037	53.60259	Qalansiyah	1	Stream
20	Laska	12.59226	53.72633	Al-Ghrbih	1	Kareef
21	Dahnoa	12.66638	53.47166	Al-Ghrbih	2	Kareef

The locations of the selected villages were presented in the general map of Socotra Island as shown in Fig.(2).

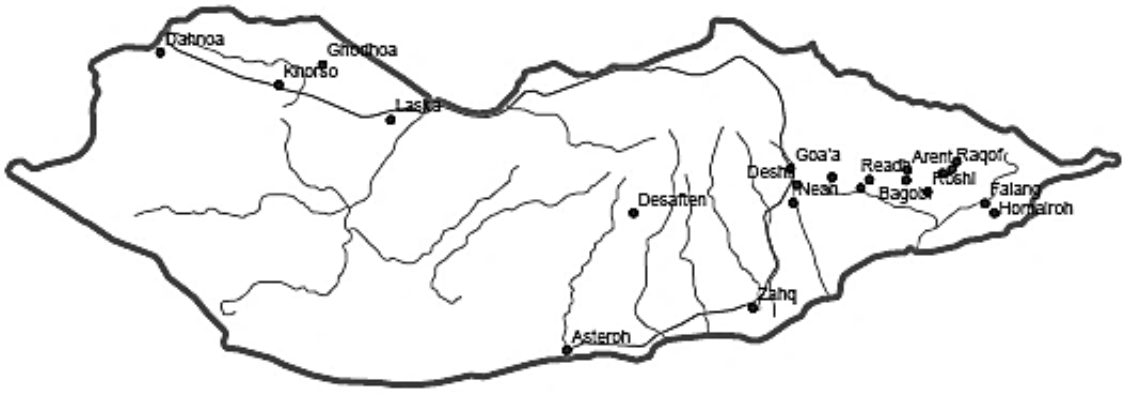

Fig.(2): Locations of Villages Selected for Water Quality Assessment

II. MATERIALS AND METHODS

The methodology adopted for the assessment includes the following procedures:

1. Site visit and collection of water samples,
2. Conduct physical, chemical and microbiological tests, and
3. Analyse tests results in comparison to standards.

2.1 Field Work

A sitevisit to Socotra Island was conducted during the period of 18th Feb. to 1st March 2018to collect water samples from various water sources, and to conduct physical, chemical and microbiological tests on the collected samples.

2.2 Water Quality Testing

The following water quality testing were conducted to the collected water samples.

- **Physical Tests:** The physical characteristics of water samples were tested and measured in the site and laboratory such as:Color, Taste and smell/odour, Hydrogen, Ion Concentration (pH), Turbidity test, and Conductivity.
- **Chemical Tests:** The chemical tests determine the amounts of mineral and organic substances that affect water quality. The main chemical tests are:Total dissolved solids (TDS),Nitrite Test, Total Iron, Total Alkalinity, and Manganese.
-**Microbiological Test:** The microbiological test examined the contamination of water by fecal coli form bacteria. This measure indicates wither the water is safe or unsafe for drinking in accordance to WHO and Yemeni stander. The main bacteriological tests are:Total Coli form at 35 ^{o}C,Faecal E. Coli. At 45 ^{o}C, andResidual Chlorine.

2.3 Materials and Instruments

The materials and instruments used to perform the water quality tests were: DelAgua set, TDS meter, PH & Chlorine Comparator, and Palintest device (Potatest set for biochemistry test).

2.4 Results Comparison with Standards

Results of physical, chemical and microbiological tests of the collected water samples were analysed and compared with WHO and Yemeni standards for safe drinking water. Based on these comparisons the quality assessment of the water sources was prepared.

III. RESULTS AND DISCUSSION

Watersamples collected from variouswater sourceswere subjected to physical, chemical and microbiological tests. The water quality testing results and analysis are presented in tabular form in Table(2).

Table (2):Quality Testing Results & Analysis for Water Sources

S. No.	Sample Location		Water Source Type	Physical Parameters							Chemical Parameters					Microbiological Parameters			Remarks
				Temp.	Color	Taste	Odor	Turbidity	pH. Value	E.C.	T.D.S.	Total Alkalinity, $CaCo_3$	Nitrate, NO_3^-	Total Iron, Fe^{++}	Manganese, Mn^{++}	Total Coli form at 35 °C	Faecal E. Coli. at 45 °C	Residual Chlorine	
				°C	Unit			Unit	mg/l	µs/cm	mg/l	mg/l	mg/l	mg/l	mg/l	No.	No.	mg/l	
				WHO Gide Line															
				25	< 15			< 5	6.5 - 8.5	450 - 2000	< 1000		< 45	0.3	0.1	0	0	_	
				Yemen Gide Line															
	Village	Center		20 - 25	5.0 - 15			1.0 - 5	6.5 - 8.5	450 - 2500	650 - 1500		45 - 60	0.3 - .01	0.1 - 0.2	0 - 2	0 - 1	0.2 - 0.5	
				TEST RESULTS															
1	Desaften	Deksam	Kareef	28	Green	Yes	Yes	> 5	7.2	1180	720	80	50	0.04	0.01	Yes (30)	Yes (10)	Zero	High Risk
2	Desaften	Deksam	Stream	30	Nil	Nil	Nil	< 5	8	1532.7	935	135	12.5	0.1	0.01	Yes (20)	Zero	Zero	Moderate Risk
3	Asteroh	Noged	Spring	40	Yellow	Yes	Yes	> 5	7.6	1105.5	647.3	70	30	0.2	0.02	Yes (50)	Zero	Zero	High Risk
4	Neah	Goa'a	Spring	35	Nil	Nil	Nil	< 5	7.8	1950.8	1190	175	25.5	0.4	0.2	Yes (20)	Zero	Zero	Moderate Risk
5	Goa'a	Goa'a	Spring	35	Nil	Nil	Nil	> 5	8.1	1393.4	850	175	30	0.3	0.03	Yes (15)	Zero	Zero	Low Risk
6	Deshil	Goa'a	Stream	20	Nil	Nil	Nil	< 5	7.6	1180	720	180	18	0.45	0.02	Yes (30)	Zero	Zero	Moderate Risk
7	Deshil	Goa'a	Stream	30	Nil	Nil	Nil	< 5	7.4	1187.8	724.6	170	17.8	0.67	0.35	Yes (30)	Zero	Zero	Moderate Risk
8	Trobah	Taeda'a	Spring	30	Nil	Nil	Nil	< 5	7.4	1109.8	677	110	12.1	0.3	0.1	Yes (20)	Zero	Zero	Moderate Risk
9	Readh	Taeda'a	Kareef	30	Green	Yes	Yes	> 5	7.6	1272	776	130	17.2	0.02	0.01	Yes (50)	Zero	Zero	High Risk
10	Masalb	Taeda'a	Stream	37	Nil	Nil	Nil	< 5	7.2	1481	904	110	18.6	0.03	0.02	Yes (20)	Zero	Zero	Moderate Risk

S. No.	Sample Location		Water Source Type	Physical Parameters							Chemical Parameters					Microbiological Parameters			Remarks
				Temp.	Color	Taste	Odor	Turbidity	pH. Value	E.C.	T.D.S.	Total Alkalinity, $CaCo_3$	Nitrate, NO_3^-	Total Iron, Fe^{++}	Manganese, Mn^{++}	Total Coli form at 35 °C	Faecal E. Coli. at 45 °C	Residual Chlorine	
				°C	Unit			Unit	mg/l	µs/cm	mg/l	mg/l	mg/l	mg/l	mg/l	No.	No.	mg/l	
				WHO Gide Line															
				25	< 15			< 5	6.5 - 8.5	450 - 2000	< 1000		< 45	0.3	0.1	0	0	_	
				Yemen Gide Line															
	Village	Center		20 - 25	5.0 - 15			1.0 - 5	6.5 - 8.5	450 - 2500	650 - 1500		45 - 60	0.3 - .01	0.1 - 0.2	0 - 2	0 - 1	0.2 - 0.5	
				TEST RESULTS															
11	Arent	Momi	Stream	28	Nil	Nil	Nil	< 5	7.6	1437	876.6	130	19.5	0.3	0.03	Yes (20)	Zero	Zero	Moderate Risk
12	Roshi	Momi	Well	20	Nil	Nil	Nil	< 5	7.6	1565.5	955	130	15	0	0.03	Yes (15)	Zero	Zero	Low Risk
13	Bagobi	Momi	Stream	28	Nil	Nil	Nil	< 5	7.4	1485	906	90	117.5	0	0.03	Yes (30)	Zero	Zero	Moderate Risk
14	Doabas	Momi	Kareef	24	Yellow	Yes	Yes	> 5	7.5	213	130	100	20	0.1	0.02	Yes (30)	Yes (30)	Zero	High Risk
15	Raqof	Momi	Kareef	32	Nil	Nil	Nil	< 5	7.2	298	182	65	12	0.03	0.05	Yes (10)	Zero	Zero	Low Risk
16	Raqof	Momi	Kareef	20	Yellow	Yes	Yes	> 5	6.8	319.6	195	50	29.5	0.3	0.09	Yes (50)	Zero	Zero	High Risk
17	Falang	Momi	Spring	35	Green	Yes	Yes	> 5	7.7	1143	697.3	80	12.5	0.3	0.1	Yes (30)	Zero	Zero	Moderate Risk
18	Homairoh	Momi	Stream	29	Nil	Nil	Nil	< 5	6.8	852.4	520	85	25	0	0	Yes (30)	Zero	Zero	Moderate Risk
19	Homairoh	Momi	Stream	28	Nil	Nil	Nil	< 5	7.8	1279.5	780.5	100	22.5	0.2	0.01	Yes (50)	Zero	Zero	High Risk
20	Hofag	Momi	Kareef	23	Green	Yes	Yes	> 5	7.2	1164	710	110	30.2	0.4	0.2	Yes (20)	Yes (15)	Zero	High Risk
21	Hofag	Momi	Kareef	29	Green	Yes	Yes	> 5	6.8	1319.6	805	70	25	0.5	0.3	Yes (30)	Zero	Zero	Moderate Risk
22	Khorso	Qalansiyah	Stream	20	Green	Yes	Yes	>5	8.06	2191	1336.6	230	23	0.2	0.1	Yes (50)	Zero	Zero	High Risk

S. No.	Sample Location		Water Source Type	Physical Parameters							Chemical Parameters					Microbiological Parameters			Remarks
				Temp.	Color	Taste	Odor	Turbidity	pH. Value	E.C.	T.D.S.	Total Alkalinity, $CaCo_3$	Nitrate, NO_3^-	Total Iron, Fe^{++}	Manganese, Mn^{++}	Total Coli form at 35 °C	Faecal E. Coli. at 45 °C	Residual Chlorine	
				°C	Unit			Unit	mg/l	µs/cm	mg/l	mg/l	mg/l	mg/l	mg/l	No.	No.	mg/l	
				WHO Gide Line															
				25	< 15			< 5	6.5 - 8.5	450 - 2000	< 1000		< 45	0.3	0.1	0	0	_	
				Yemen Gide Line															
	Village	Center		20 - 25	5.0 - 15			1.0 - 5	6.5 - 8.5	450 - 2500	650 - 1500		45 - 60	0.3 - .01	0.1 - 0.2	0 - 2	0 - 1	0.2 - 0.5	
				TEST RESULTS															
23	Ghodhoa	Qalansiyah	Kareef	15	Green	Yes	Yes	>5	6.8	152.5	93.3	27	37.5	0.1	0.04	Yes (30)	Yes (10)	Zero	High Risk
24	Ghodhoa	Qalansiyah	Kareef	35	Nil	Nil	Nil	<5	6.8	501.6	306	80	19.5	0.05	0.03	Yes (15)	Zero	Zero	Low Risk
25	Laska	Al-Ghrbih	Kareef	22	Nil	Nil	Nil	< 5	7.6	869	530	95	11	0	0	Yes (20)	Zero	Zero	Moderate Risk
26	Dahnoa	Al-Ghrbih	Kareef	26	Yellow	Yes	Yes	> 5	7.2	213	130	40	20	0.3	0.01	Yes (50)	Zero	Zero	High Risk
27	Dahnoa	Al-Ghrbih	Kareef	22	Yellow	Yes	Yes	> 5	7.4	1109	676.6	130	28	0.4	0.2	Yes (30)	Yes (10)	Zero	High Risk

Over Limit Value

The water quality testing result of water sources were analysedand summarized as shown in Table (3).

Table (3): Analysis of Water Quality Testing Results of Water Sources

Source of Water	No. of Samples Collected	Number of Samples in Terms of Contamination				
		Physical	Chemical	Microbiological		
				Low Risk	Moderate Risk	High Risk
Kareef	12	9	0	2	2	8
		75.0%	0.0%	16.7%	16.7%	66.7%
Spring	5	3	0	1	3	1
		60.0%	0.0%	20.0%	60.0%	20.0%
Stream	9	1	0	0	7	2
		11.1%	0.0%	0.0%	77.8%	22.2%
Well	1	0	0	1	0	0
		0.0%	0.0%	100.0%	0.0%	0.0%
Total	**27**	**13**	**0**	**4**	**12**	**11**

2.5 Physical Tests Results

The physical characteristics of water samples tested include: Color, Temperature, Taste, Odor, Turbidity, Total Dissolved Solids (TDS), pH and Conductivity.
Physical tests results for Kareefs, Springs and Streams showed physically contaminated water sources with 75%, 60% and 11% respectively, (i.e. tests values are high compared to WHO and Yemeni standards for safe drinking water).

2.6 Chemical Test Results

Chemical tests determine the amounts of mineral and organic substances that affect the quality of drinking water.
The chemical testing results of samples showed acceptable values according to WHO and Yemeni standards for safe drinking water. Therefore all the water samples collected are chemically acceptable for human use. This because most of these water sources are surface water unaffected with chemicals.

2.7 Microbiological Test Results

The microbiological testingwere done within 24 hours of collecting the sample to get real and accurate results. All the samples collected were subjected to microbiological test.
Microbiological test results of all water samples collected showed contamination with different risk ranges (i.e. low, moderate and high). The contamination was by Total Coli Form or combined with Faecal E. Coli., this contamination make the water unsafe for drinking according to WHO and Yemeni standards.
The microbiologicalcontamination especiallywith Faecal E. Coli is due to feces of Cattle whish are widely available in rural areas of Socotra Island.
Open Kareefs represent high contaminated source of water with 67% of samples collected, while springs and streams represent moderate contaminated sources of water with 60% and 78% of samples collected respectively, since most of water supplied from Springs or Streams are collected and stored by the users in unsuitable open tanks or unclean barrels/tubs which makes the water contaminated.
The analysis findings of the water quality test results were presented in graphical forms as shown in Figures(3a – 3d).

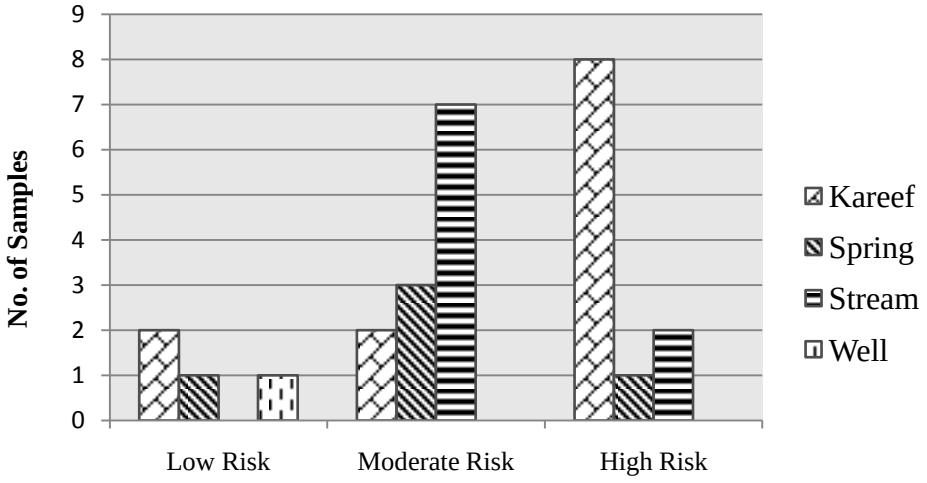

Fig.(3a): Ranges of Contamination for Various Water Sources

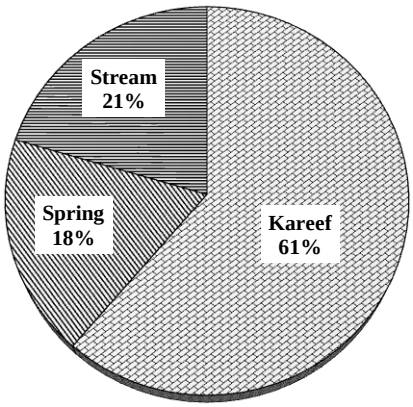

Fig. (3b): % of Water Samples with <u>High</u>Contamination

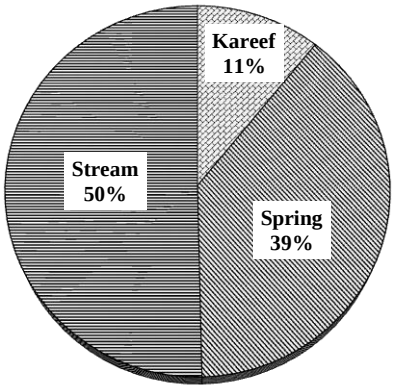

Fig. (3c): % of Water Samples with <u>Moderate</u> Contamination

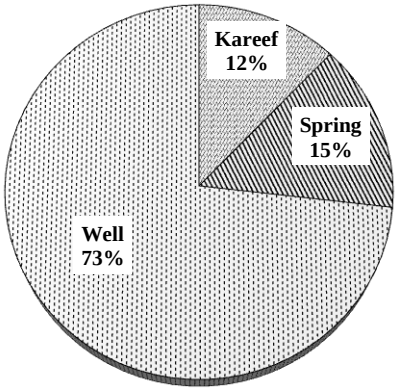

Fig. (3d): % of Water Samples with <u>Low</u> Contamination

IV. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

The evaluation of water quality forvarious water sources used by local communities in rural areas in Socotra Island is of great importance in order to improve the quality of water used by the communities. For the 27 water samples collected from various water source (i.e. Kareefs, Streams, Springs and Wells), the Physical tests results for 13 samples show high values compared to WHO and Yemeni standards especial for Kareefs (i.e. 8 samples). Chemically all the samples show normal values. Microbiologically all the samples werecontaminated, Kareefs represent high contaminated source of water with 67% of samples collected, while streams and springs represent moderate contaminated sources of water with 78% and 60% of samples collected respectively. Contamination with Total Coli form makes the water source either low or moderate contaminated,it was found that 40% (i.e. 5 samples) of the samples collected from Kareefs show additional pollution with Faecal E. Coli., which make the water source highly contaminated. Therefore, open Kareefs can be considered as worst source of water used by local communities in Socotra Island.

Kareefs found to have high bacterial contamination. In addition; high turbidity, bad smell and taste have been physically noticed in the rainwater harvesting points (kareefs) which, are almost the available water sources accessible to both humans and animals in highly populated rural and semi desert areas in Socotra.

4.2 Recommendations

The following recommendations are to be considered:

- Shallow groundwater and aquifers need to be investigated.

- Volumes of water discharged from springs must be measured and monitored for better utilization and management.
- Streams/Wadiesneeds to be gauged and investigated (flow rate, duration, quality … etc.).
- A proper design and construction for Kareefsmust be followed to avoid contamination of harvested water.
- Develop water treatment projectfor various water sources used by local communities.
- Water wells must be deepen to reduce the pollutants intrusion.

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