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Full Length Research Paper

Seasonal Variation of Hafirs` Water Quality in North Kordofan State-Sudan

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Abstract

This study was carried out in year 2012 to identify the seasonal variation of water quality of Hafirs in North Kordofan State. The study covered four Hafirs, in Shaken Locality (Abu Haraz administrative unit) of 2500 M^3 designing capacity and all used as traditional Hafirs without any treatment facilities: Almamsouca village Hafir, Alayaira village Hafir, Algalabai1 village Hafir and Algalabai2 village Hafir. Qualitative characteristics of Hafirs` water were measured in four periods: March, June, September and December, using onsite membrane filtration technique for biological analysis (E-coli and total coliform) and standard laboratory techniques for chemical and physical tests. Also data were collected from the nearest central healthcare facility in the study area to investigate the predominance of water related diseases. Biological quality of all studied hafirs was found to be very poor with very high levels of E-coli and Fecal coliform counts in most seasons with peaks in June and minimum in December and this can be simply correlated to intensive run-off from faecally polluted dry soils to Hafirs positions. Investigation of water related diseases in nearby healthcare facility for last three years shows a very high cases of all water related infections with noticeable incidents of deaths and increasing numbers of bilharzia cases were recorded suggesting a direct reflection of poor biological water quality. Little seasonal variation in all physico-chemical properties of water samples can be noticed but most values comply with the standards of the World Health Organization and Sudanese Meteorology Organization except iron in Alayara and Algalabia Hafirs and turbidity in all hafirs throughout the seasons with peaks in rainy time (June - September). It is recommended that all hafirs must be fitted with slow sand filters and chlorination tanks and surrounding protection fences to improve bacterial and physico-chemical properties of water. Householders should be made more aware on hazards arises from using polluted water and trained to use traditional methods to enhance their drinking water quality.

Keywords: Hafirs; North Kordofan; Water quality; Membrane Filtration.

INTRODUCTION

In semi-arid zones in Sudan such as West region, safe drinking water is rare. In particular, areas in North Darfur and Kordofan States rely on groundwater supply (wells) or water storage methods called *hafir* or earth dams for their water supply (Mohamed-Ali et al., 2009). In Sudan, the climate ranges from arid in the north and northwest to wet-and-dry tropical weather in the southwest, the annual rainfall average varying from 120 cm (47 in) in the south to less than 10 cm (4 in) in the north (Helen,1991). Rainfall collection is one of water sources in Sudan and rainwater harvesting (RWH) methods can be implemented to improve the production of crops and livestock in the region (WHO, 2008). Agricultural production and domestic water needs would be very difficult to sustain without the use of locally viable rainwater harvesting techniques to enhance water supply; and the reduction of water demand by water conservation In North Darfur, where the duration of rainfall is short, domestic rain water harvesting, a types

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of water collection scheme, has been explored extensively (Burt and Keiru, 2009; Bromwich et al., 2007).

Definition of Hafir

"Hafir" is an Arabic word derived from "Hafir," — "to dig" — and has now come to mean an excavation made either by hand or machinery and used for the conservation and storage of surface water. In the past most hafirs, which usually ranges from 500 to 10,000 cubic meters in volume, were dug by hand, but today heavy machinery is used when building larger hafirs (Rima and Hanspeter, 2013).

Storage is usually below ground level, but in suitable areas the soil banks are utilized to increase the storage above ground level. Filling of Hafir is obtained from either a Khor (seasonal watercourse) or by hill catchment. When filled from a Khor a short connecting canal is sometimes required and when from hill catchment, contour terracing leading in to the Hafir is necessary (Robertson, 1950). There is no absolute guarantee of the filling of any Hafir in the Sudan; rains are capricious and erratic and may entirely miss a large area one year and cause destructive erosion to earthworks in other years. The most reliable site for a Hafir is therefore on a large, slow flowing Khor, known to run at least several days every year and draining wide area. "Mayas" or natural depressions which normally fill every year are also very reliable sites. This necessity of having to depend on Khors or hill catchment for filling, very often means that the Hafir has to be sited some considerable distance from where it is required, and water has to be carried to the cultivation or the villages as the case may be (Rice, 1992).

The rainwater runoff which fills Hafirs usually flows over the ground that is contaminated. Catchment areas are often covered with animal droppings, human excreta and other debris that can pollute the water. While this water is suitable for watering livestock or for small scale irrigation, and construction work, it is not safe for drinking (UNDP, 2006). If the purpose of the Hafir is to get clean water for domestic purposes, then the water should be drawn from a hand-dug well sunk in a seepage line downstream of the Hafir wall. Drinking untreated water from open water sources is not recommended, unless it has first been boiled, or sterilized by the sun's ultraviolet rays in a transparent bottle for 6 hours of sunshine. This technique of water treatment is called solar disinfection of water (SODIS). Drinking water that has not been treated may lead to waterborne diseases such as dysentery, diarrhea or typhoid.

If waterborne diseases, such as schistosomiasis (bilharzia) carried transmitted by water snails is present prevalent in the area, then entry of the water by people should be discouraged (Erik, 2006).

A hafir is often at considerable distance from the area that it supplies. Because of the requirement for a clay soil type and a nearby annual water source, a hafir is normally found in areas where no underground seepage occurs. This formation is known as a "basement complex". This underscores the reliance of many towns in Sudan on the water that Hafirs can store. Water from the source is diverted to the hafir through a dug canal. The hafir can vary in size and shape an average volume would be 30000 m^3, the hafir is often conical in shape with an average depth of approximately 3.5 m. During times of high flood the large quantity of inflow water does not allow enough period for of clay particles resulting in entry of turbid water. To prevent this occurring, the inlet pipe is closed when the flow is at its maximum (WHO, 2008).

Improved Hafirs

Hafirs are considered improved, only when they are associated with appropriate water treatment systems. The types of water treatment systems that are currently utilized with hafir differ from place to place, and from state to state. They are either infiltration galleries or slow sand filtration systems. For instance, some Hafirs in North Kordofan are attached to a series of wells (Figure 1). The first well, which is packed with layers of gravel, serves as a valve control and the first filter chamber. The water exiting this well is conveyed by gravity to the second well, where it is filtered again through a gravel pack, then moves to a third well which is fitted with twin hand pumps**.** Although Hafirs are simple hydraulic structures that deal with impoundment of water, they must have the necessary components for efficient service provision. These are feeding facilities which are structures that easy the flow of water to the hafir with a minimum sediment load by controlling the velocity ($v \leq 1m/s$) of flow. This can be achieved through construction (provision) of weirs, drops and diversion structures (drainage facilities which are structures that drain excess water away and prevent overtopping the body of a hafir). The provision of spilling structures (spillways) minimizes partial or total damage during high floods or during uncontrolled flow of water. Seepage control structures: These are provisions like lining of Hafirs that minimize or avoid see page through the body or floor of Hafirs. Plastic or concrete lining can be applied as mitigation measures if affordable. Design and peak flows must be estimated by a hydrological study. Schematic flow diagrams of improved Hafirs for raw water sources from rain water harvesting and irrigation canals/streams are presented Figure 2.

Figure1. Improved Hafir with Two filtration Wells in North Kurdfan (UNICEF ,2009)

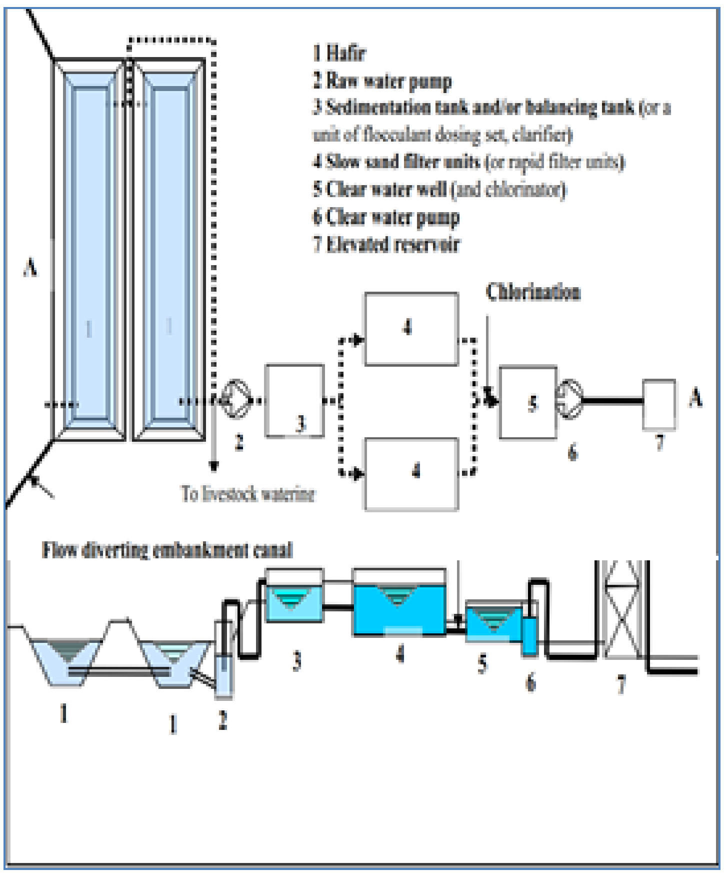

Figure 2. Schematic Diagram of Improved Hafir. (UNICEF, 2009)

MATERIALS AND METHODS

Study area

This study was conducted at administrative unit Abu Haraz, Shikan locality, North Kordufan State (latitudes 12:93.6 to 373' N and longitudes 29:86.8 to 554 E). The mean annual rainfall ranges from 75 mm in the extreme north to about 500 mm in the south. In the absence of any sufficient feature, the main isohyets are nearly

Figure 3. Almamasouca Hafir

Figure 4. Alayaira Hafir

parallel to the latitudes (Walch, 1991). Most of the rains in north Kordufan occur in the form of heavy thunder storms of short duration and localized nature (El Tahir et al., 1999). The region has a hot to warm weather. The mean annual temperature is 27 °C. Mean relative humidity ranges from 20 % in winter to 75% in August at the middle of the rainy season (Walsh, 1991). The population is 75163 (Administrative unit Abu Haraz, 2013). This area has been surveyed and found that more than twenty Hafirs are existing in Abu Haraz area. Most of habitats and their animals have been depending on these hafirs for drinking water and other household uses.

For this study four hafirs in different villages namely Almamasouca, Alayaira, Algelabia1 and Algelabia villages which were used only for drinking of human and their animals in addition to other households needs were chosen. Brief historical accounts of these hafirs are given:

The Almamasouca village Hafir: The hafir in this village (figure 3) is designed as (developed Hafir) but used now as traditional one and located outside the village about 1km northwest. It is designed to a storage capacity of 250 000m^3 and estimated to be hold 200 000m^3 of water now. This Hafir was constructed in year 2007 by the people of the village with the support of the German Embassy and World Food Program, This area is inhabited by Bedaria, Bargo, Gaumaa, tribes and other tribes who practice cultivation and livestock husbandry. Millet and sorghum are grown as the main staple crops, groundnut, watermelon; roselle and sesame are grown as cash crops.

The Alayaira village Hafir: It is designed as (Developed Hafir) but used now as traditional one, and located outside the village about 1km west. It is designed to a storage capacity of 250000m^3 and holds an estimated volume of to be 200000m^3 now, population is about (1000) from Barti, Bedaria, Gaumaa tribes and others. Cultivation and livestock husbandry were the general practices. There was a basic school and a Health Unit in the village. (Figure 4)

The Algelabia1 village Hafir: This hafir is (traditional Hafir) and located outside the village about 1km east with a population of about 1000. It is designed to storage capacity of 250000m^3 and estimated hold 200000m^3 of water. It was depended on for grazing of animals and agriculture. The tribes in Almamasouca Village were found in this village also. (Figure 5)

The Algelabia village Hafir: This Hafir is designed as (developed Hafir) but used now as traditional one. It was built in May 2011 by Project Ward of the Effects of Drought, North Kordufan program of construction and rehabilitation of Hafirs (water harvesting), and its storage capacity is 250000 m^3 and is located east of the village. Hafir was dug by machineries and constructed with complex of several villages rely on it in the drinking water for humans and animals, population is about (2000) and they are depending on grazing and agriculture on their Economic activities. (Figure 6)

Sampling

To assess seasonal variation of hafirs water quality,

Figure 5. Algelabia1 Hafir

Figure 6. Algelabia Hafir

samples were taken (using sterile bottles), from each Hafir in four different periods in year 2012 specifically in March, June, September and December representing pre-rainy, rainy, pre-dry and dry seasons respectively. Samples were collected in the morning and at depth of (30-40) cm and at (1-2) meters away from the Banks edge. Samples were analyzed immediately for bacterial (E*. coli* and total coliform) loads while those for physico-chemical analyses (Fe, Mn, K, Zn, Ca Cl and SO_4^2, pH, TDS, turbidity, total hardness and alkalinity) were stored in an ice box and brought within 24 Hrs to the Environmental Engineering Laboratory in Sudan University of Science and Technology. (Figure 7)

Bacteriological analysis

In this test the membrane-filtration method was been used onsite to identfy indicator organsims, namely E. Coli and fecal coliform. In the Membrane-Filtration method, a minimum volume of 10 ml of the sample (or dilution of the sample) was introduced aseptically into a sterile or properly disinfected filtration assembly containing a sterile membrane filter (nominal pore size 0.2 or 0.45µm). A vacuum was applied and the sample drawn through the membrane filter. All indicator organisms were retained on or within the filter, which was then transferred to a suitable selective culture medium in petri- dishes. Following a period of resuscitation, during which the bacteria become acclimatized to the new conditions, the Petri-dishes were transferred to an incubator at the appropriate selective temperature where it was incubated for a suitable time (24 hrs) to allow the replication of the indicator organisms.

Visually identifiable colonies were formed and counted, and the results expressed in numbers of “colony forming units” (CFU) per 100 ml of original sample.

Annual reports from a local hospital in the study area (Kuwiti Hospital) were invistigated to identfy the percentage and the predominance of water related diseases. (Figure 8 and 9)

Physico-chemical water quality Analysis

Tests are carried out in water samples to define its main characteristics. Some of chemical elements identification tests were conducted in laboratory using Aqua nova spectrometer. The standard procedures for analyses of Fe, Mn, K, Zn, Ca Cl and SO_4^2, pH, TDS, turbidity, total hardness and alkalinity prescribed by the Aqa-Nova Spectrometer manual and APHOSM (1992) were adopted

RESULTS

Biological Parameters

Large number of E. coli and total coliform were found in most of water samples through the yea**r.** Generally bacteria were increased from June up to September,

Figure 7. Collection of samples from hafirs

Figure 8. Incubator used for onsite bacteriological analysis

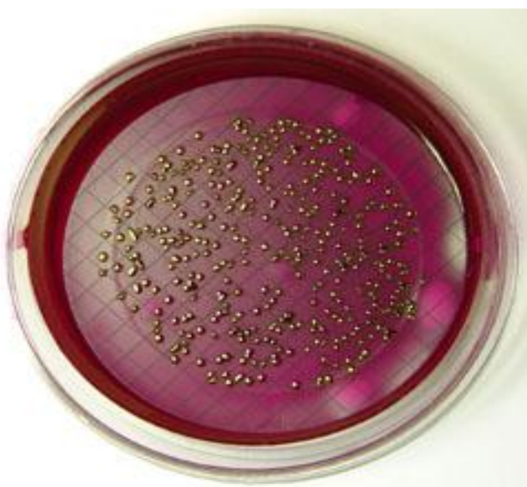

Figure 9 Colony forming unit

Table 1. Number of E.coli in different periods in water samples (CFU) /100 ml:

Period	Almamasouca	Alayaira	Algalabai1	Agalabai2
March	Uncountable	Uncountable	Uncountable	Uncountable
June	Uncountable	Uncountable	Uncountable	Uncountable
Sep.	Uncountable	Uncountable	Uncountable	Uncountable
Dec.	Uncountable	5	25	0

then decreased gradually up to December started increasing up to March (Tables 1 and 2). The numbers of cases of water related diseases are also presented (Figure 10).

Physico-chemical Parameters

Generally the Chemical water quality of the studied Hafirs was found to be within the limits of WHO guideline

Table 2. Number of Total coli form in different periods in water samples (CFU) /100 ml

PERIOD	ALMAMASOUCA	ALAYAIRA	ALGALABAI	ALGALABAI
March	Uncountable	0	Uncountable	Uncountable
June	Uncountable	Uncountable	Uncountable	Uncountable
September	Uncountable	Uncountable	Uncountable	Uncountable
December	Uncountable	Uncountable	Uncountable	4

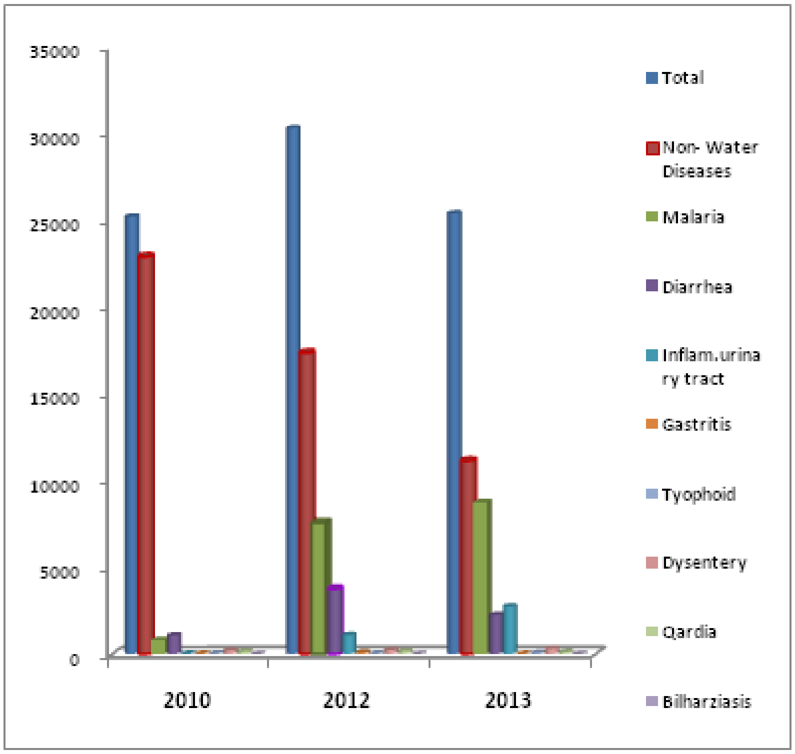

Figure 10. Water Related Diseases in the Study Area

values and Sudanese standards except Iron in Alayaira and Alglabia Hafirs (Figures 11, 12, 13, 14, 15, 16, 17, 18, 19 and 20). Turbidity was found to be very high especially in June (rainy season) (Figure (21).

DISCUSSION

Seasonal variations of water quality have been investigated in several tropical areas and multiple studies have shown the highest faecal coliform counts in surface water sources after the start of the rainy season (Musa et al., 1999). The association of high intensity rains causing run-off from faecally polluted dry soils is given as the explanation of these findings. Such relationships may vary where rainfall patterns and environment differ.

In the present study, the seasonal variations in total coliform and E-Coli counts were highest in rainy season and decreased in some areas in December (Tables 1 and 2) and this may be due to natural sterilization by day sunlight.

Increased levels of water related diseases prove the deterioration of bacteriological water quality and address the urgent needs for mitigation actions to save the life of the people living in this area.

High levels of Iron noticed in some areas especially Alairiaarea may be due to natural composition of soil in this district. Ingesting iron from drinking water is not directly associated with adverse health effects although trace impurities and microorganisms that are absorbed by iron solids may pose health concerns. The effects associated with iron contamination can be mainly aesthetic effects which are undesirable tastes or odors. Iron in quantities greater than 0.3 milligrams per liter (mg/L) in drinking water can cause an unpleasant metallic taste and rusty color. This can stain laundry or household items. Discolored water is one of the most

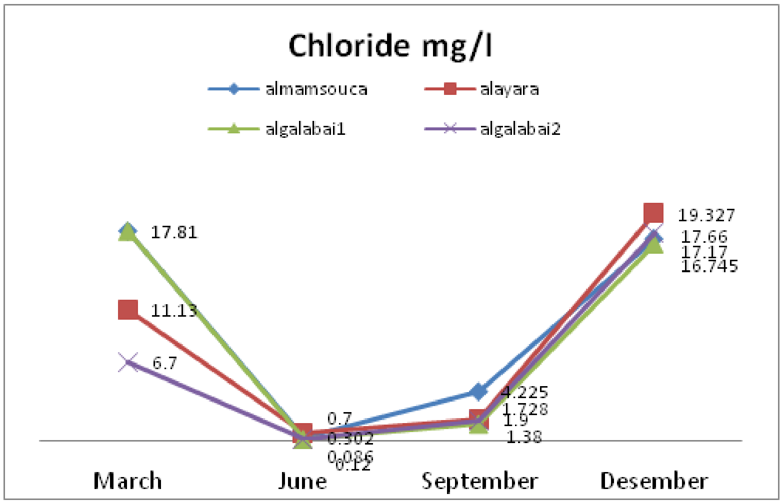

Figure 11. Chloride in water samples

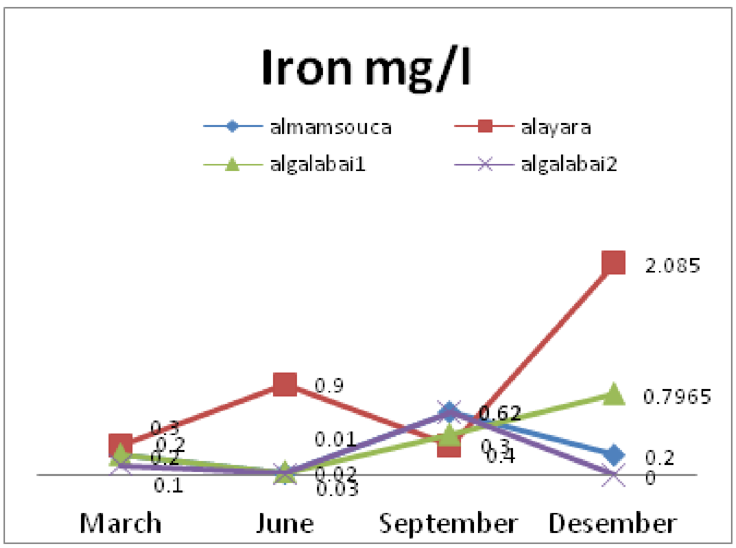

Figure 12. Iron in water samples

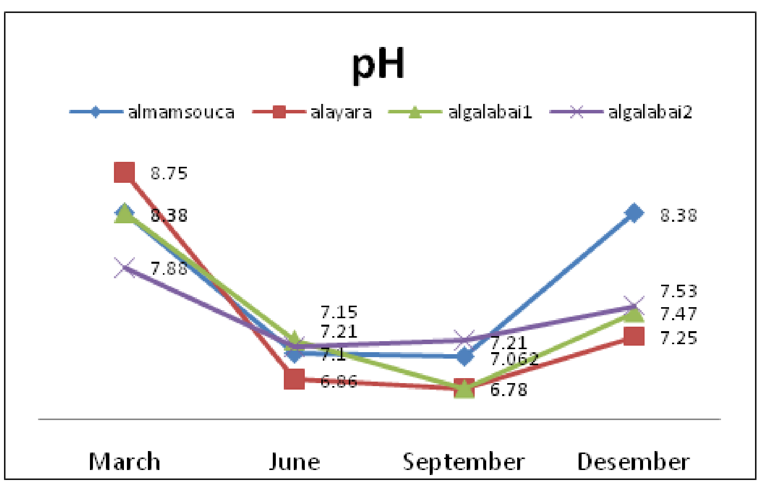

Figure 13. pH in water samples

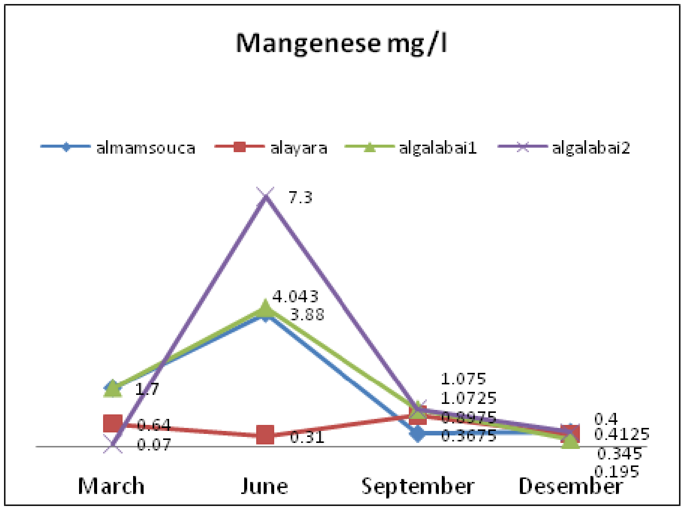

Figure 14. Manganese in water samples

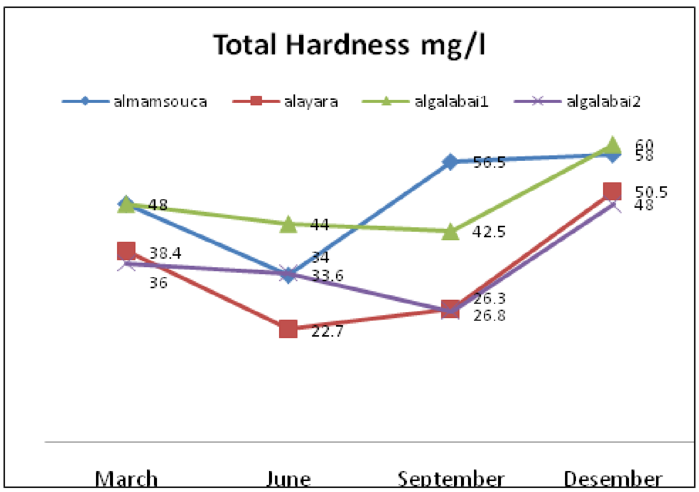

Figure 15. Total Hardens in water samples

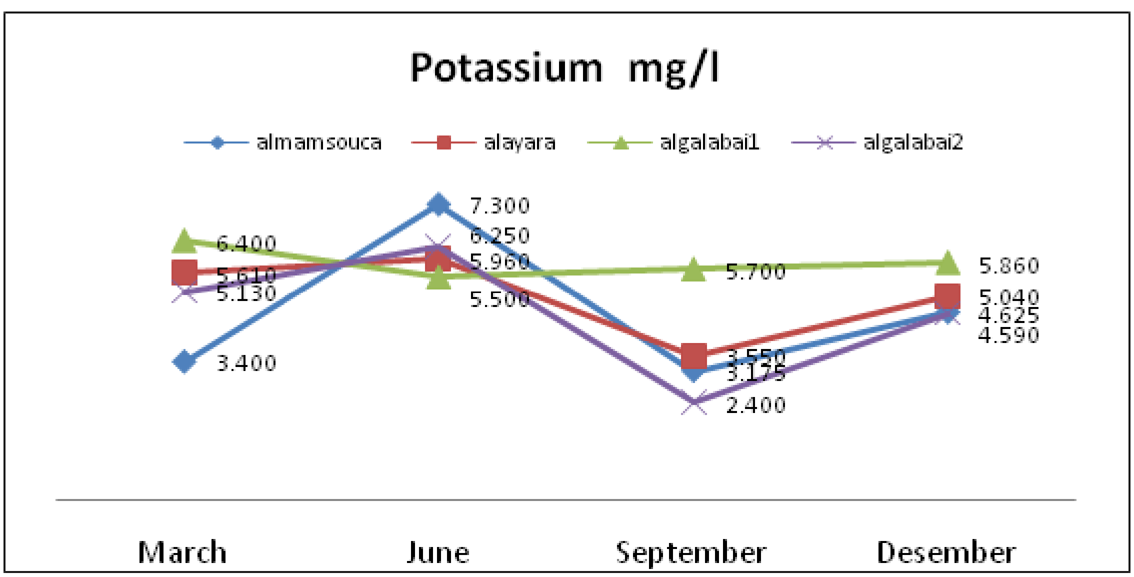

Figure 16. Potassium in water samples

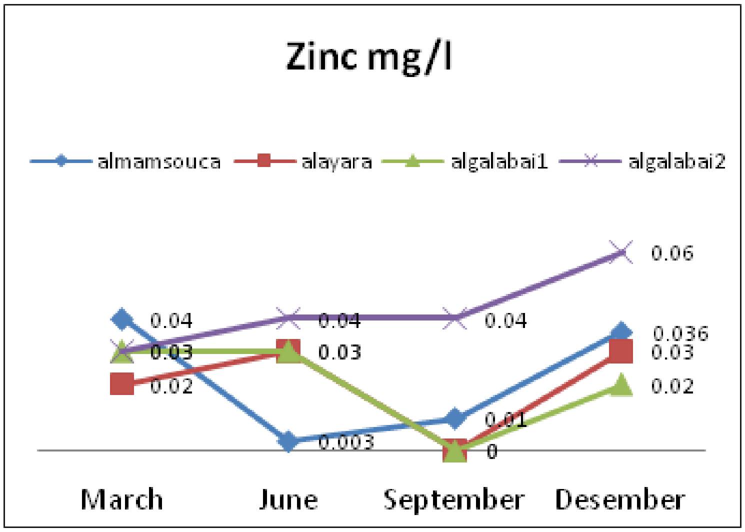

Figure 17. Zinc in water samples

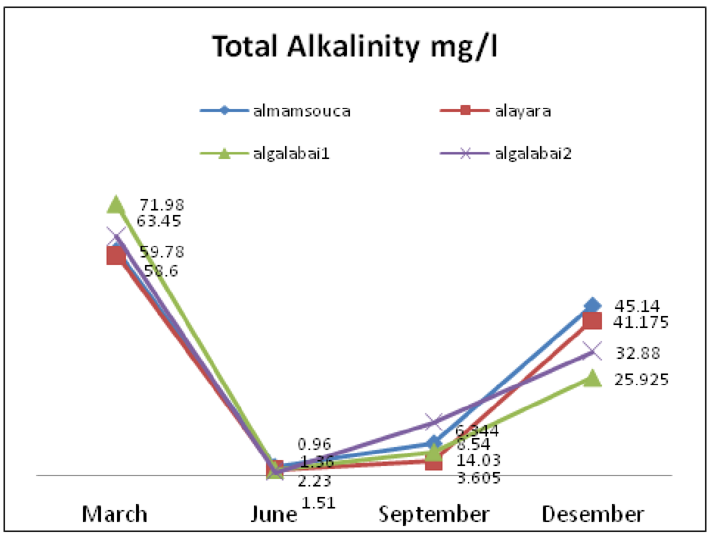

Figure 18. Total Alkalinity in water samples

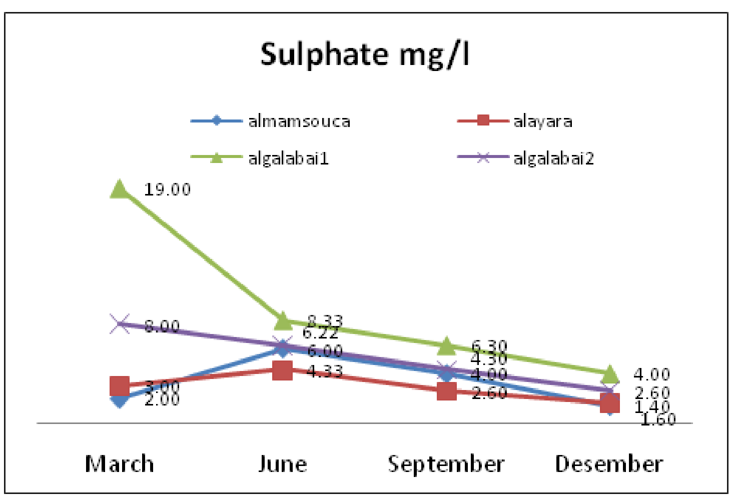

Figure 19. Sulphate in water samples

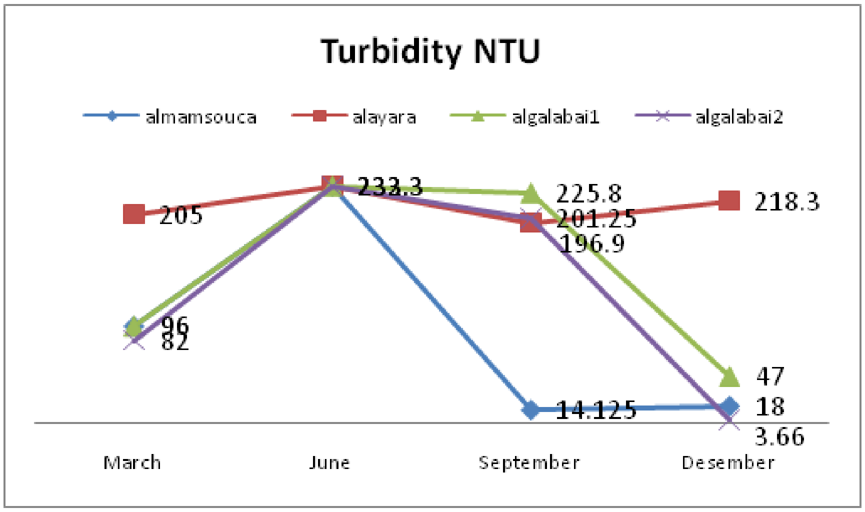

Figure 20. Turbidity in water samples

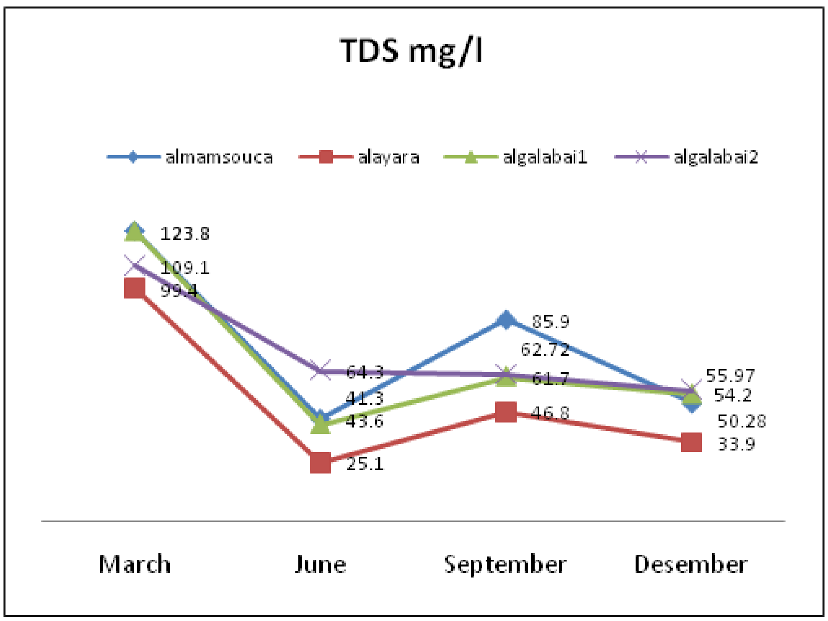

Figure 21. Total Dissolved Solids in water samples

frequent consumer complaints about drinking water (WHO, 1996**)**.

Also Water turbidity in rainy season in all hafirs deviated from recommended standards for water quality. Excessive turbidity, or cloudiness, in drinking water is aesthetically unappealing, and may also represent a health concern. Turbidity can provide food and shelter for pathogens. If not removed, turbidity can promote growth of pathogens leading to waterborne disease outbreaks. Although turbidity is not a direct indicator of health risk, numerous studies show a strong relationship between removal of turbidity and removal of protozoa. Traditional methods using local natural agricultural products as coagulant proved to be very effective to reduce water turbidity (EPA, 2004) and (Samia and Hamid, 1979) and can be enhanced to be used publically by the Hafirs users.

All other physico-chemical parameters show normal levels throughout the seasons and with typical variation trends in all hafirs because of the similarity of climatic and geological factors within the study area.

Recommendations

All hafirs must be fitted with filters and chlorination tanks to improve bacterial and physical quality of water.

- All hafirs must be fenced to protect from animal and human entrance.
- Householders should be made more aware on hazards arises from using polluted water and must be trained to use sunlight for sterilization for reduction of pathogenic bacteria content and to use simple local materials for coagulation to reduce turbidity.
- Strict regulations and Sudanese Engineering Design Manuals for hafirs must be produced to assure the desired water quality and to get the maximum benefits from this effective rain water harvesting technique.

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