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EFFECT OF HOUSE STORAGE ON WATER'S QUALITY IN RURAL AREAS OF TANGIER-TETUAN REGION (MOROCCO)

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ABSTRACT

Rural residents of Tangier-Tetuan Region (Northern of Morocco) are still pending on groundwater supplies for drinking water without any treatment. The storage of this water in household containers for a long time as well as the handling might lead to a quality deteriorated and become unsuitable for human consumption.

In order to evaluate the effect of long storage on the chemical and bacteriological quality, households stored water of twenty springs were selected for the investigations on chemical and bacteriological parameters.

The physicochemical properties showed that the majority of the stored water samples are considered acceptable, except some samples that don't meet the standards recommended. Our study revealed also a positive correlation between storage and concentrations of microbial agents.

Monitoring the chemical and bacteriological quality of stored drinking water is essential to prevent population health risks.

Keywords: Morocco, household, water quality, storage, health.

RESUME

La population rurale de la Région Tanger-Tétouan (Nord du Maroc) dépend encore des eaux souterraines pour l'approvisionnement en eau potable et ce sans aucun traitement. Le stockage de cette eau dans des réservoirs pendant une longue période ainsi que la manipulation inadéquate contribuent à la dégradation quantitative et qualitative des ressources en eau qui deviennent ainsi impropres à la consommation.

Afin d'évaluer l'effet de stockage de longue durée sur la qualité chimique et bactériologique, vingt points de stockage d’eau de sources ont été sélectionnés pour l’étude des paramètres chimiques et bactériologiques.

Les propriétés physico-chimiques ont montré que la majorité des échantillons d'eau étudiés sont acceptables sauf quelques échantillons qui ne respectent pas les normes recommandées. Notre étude a révélé également une corrélation positive entre le stockage et le nombre de bactéries.

Suivi de la qualité chimique et bactériologique de l'eau stockée destinée à la consommation est essentiel pour prévenir les risques sanitaires.

Mots clés : Maroc, ménages, qualité de l'eau, stockage, santé.

INTRODUCTION

Groundwater is an important supply of drinking water for population around the world, principally in rural areas and it’s must be judiciously managed and protected (Jackson et al., 2001; Guergazi et al., 2005). Safe drinking water must have an acceptable quality that obeys physical, chemical and bacteriological parameters (Sobsey, 2008; Belghiti et al., 2013). These parameters have been used to determine the general quality of drinking water worldwide (Kremer et al., 2011).

Insufficient drinking water, sanitation and hygiene are significant health risk factors by making water a carrier of multiple illnesses. According to WHO, there are approximately 2.5 billion people without access to improved sanitation and nearly 748 million people lack access to improved drinking water (Who and Unicef, 2014). In fact, high occurrence of diarrhea is related to the polluted drinking water and it's most pronounced in children, seniors and immunocompromised individuals (Saha, 2010 ; Yongsi, 2010).

Water quality degradation between the sources and point-of-use may be due to several reasons such as the hygienic condition of the water storage containers and the environment of storage (Trevett et al., 2004; Cronin et al., 2006; Singh et al., 2013).

Significant deterioration of the water quality has been detected during its storage at home in rural and urban areas throughout Africa, Asia and Latin America (Trevett et al., 2004; Hoque et al., 2006; McGarvey et al., 2008; Kausar et al., 2012).

While rural areas of Morocco are connected to water supply, its population still prefers spring's water that they store in traditional conditions to have amount of drinking water available (Aghzar et al., 2002) and Tetuan-Tangier Region is one of these cases.

In fact, Water's storage for days may cause water deterioration quality and became not suitable for drinking (Trevett et al., 2004). In order to prevent water diseases in the Tangier-Tetuan Region, the assessment of the stored water quality become crucial.

The aim of this research was to examine the effect of long storage on the chemical and bacteriological quality of water and households storing water of twenty springs were selected for the investigation.

MATERIAL AND METHODS

Our sampling sites are located in Tangier-Tetuan Region, Northen of Morocco (fig.1). The studied area covers about 12 426 Km^2 (OREDD RTT, 2013), within the coordinates 35° 15' 0" N / 5° 55' 0" W.

Households storing water of twenty springs were selected for this investigation and samples were collected during March 2015. Samples were transported in cold boxes (at 4°C) to be subjected to some bacteriological and chemical parameters measurement in the laboratory.

Faecal bacteria were enumerated by the membrane filter technique using specific media (Tergitol and Slanetz) and different incubation conditions (44°C for faecal coliforms and 37°C for both total coliforms and faecal streptococci).

After 24 hours, number of bacteria was calculated and expressed in Colony-Forming Units per 100 ml (CFU/100 ml). Water physicochemical analysis was conducted using methods described by Rodier (Rodier, 2009).

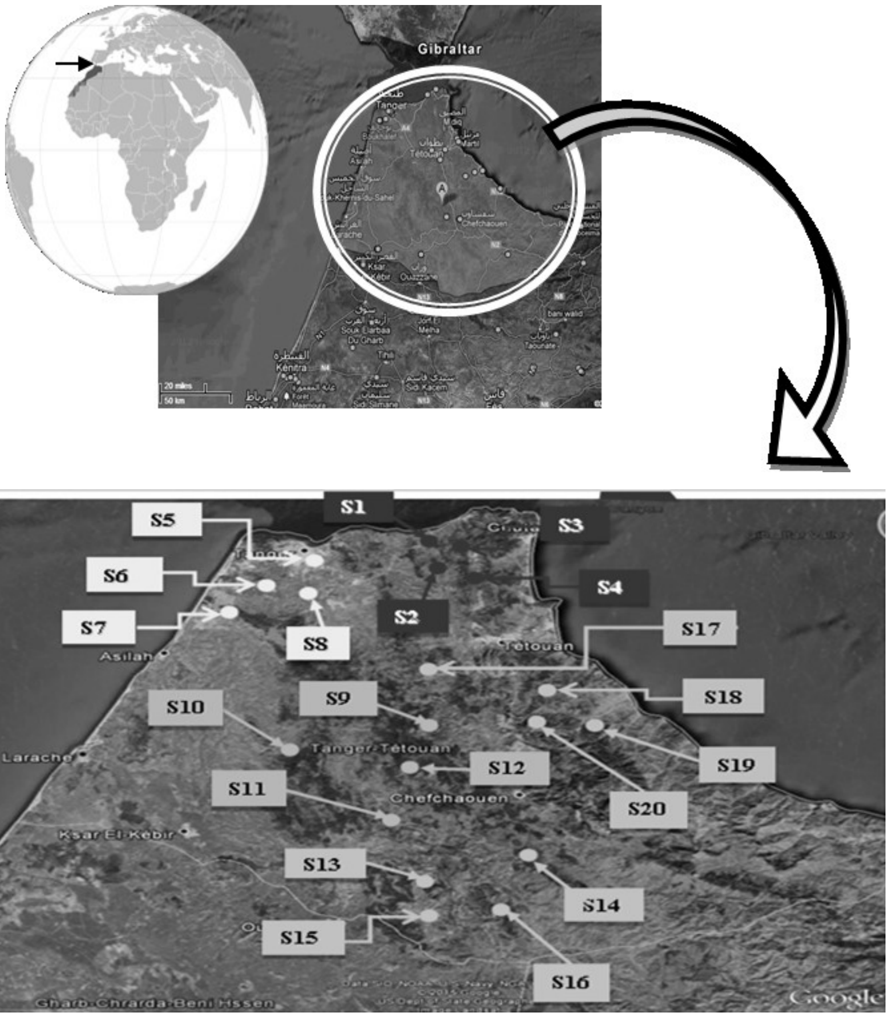


Figure 1 : Location of sampling stations in the study area.

Our results were expressed as mean ± standard error of six replicates. The following hypotheses were examined:

- There was a significant difference between the numbers of microorganisms initially present in the water and those present after storage for 15 days at ambient temperature.
- There was a significant difference between chemical parameters initially measured in the water and those measured after storage for 15 days at ambient temperature.

In order to test these hypotheses, data were subjected to analysis of the Student's t test using GraphPad Prism software version 6.00 (San Diego, CA, USA). The chosen level of significance was $P < 0.05$.

RESULTS AND DISCUSSION

Bacteriological quality

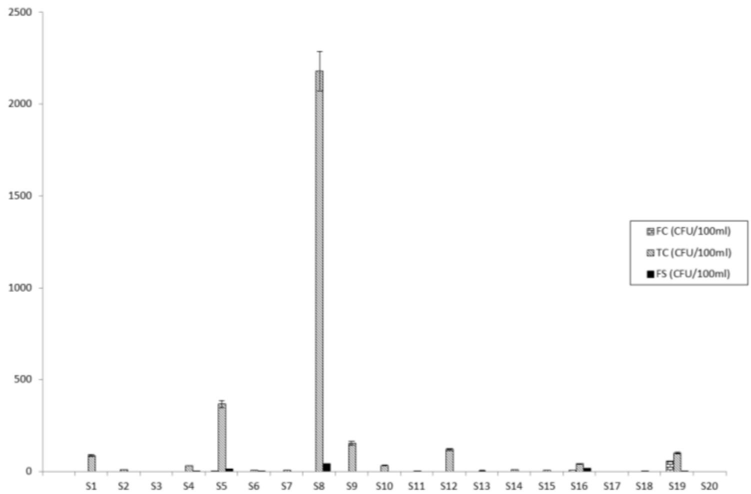
The results of bacteriological analysis of water samples over time in relation to storage conditions are presented respectively in figure 2 below.

Data fell into two clearly defined phases (initial phase of testing and a second phase of testing after storage for two weeks in shaded daylight and at ambient temperature). The calculated probability values demonstrate that water quality becomes worse after collection and storage in 90% of simples with an overall increase in microbial numbers (faecal coliforms, total coliforms and faecal streptococci values were higher than the required values) with the exception of S3 and S20 that showed zero levels of pollution initially and after storage for two weeks.

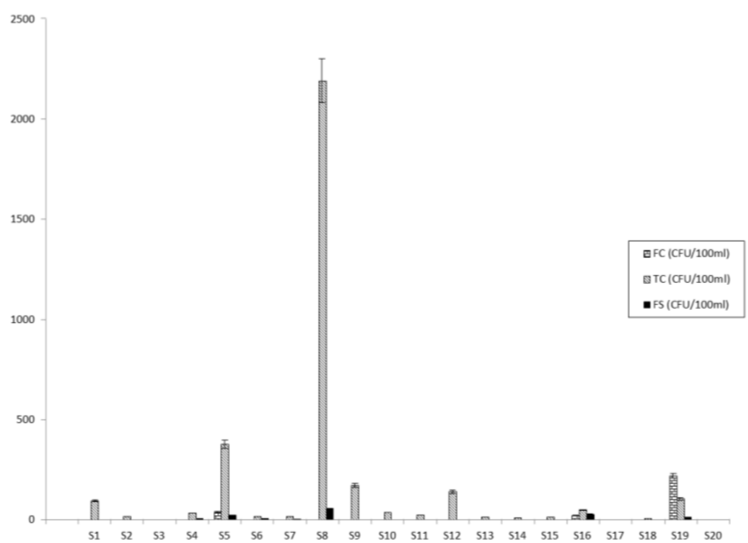
Assessment of the water quality following collection and storage at home could be done by the study of its bacteriological and physico-chemical parameters (Onigbogi and Ogunyemi, 2014).

Previous researches have reported a significant deterioration of water quality after collection (Trevett et al., 2005; Clasen et al., 2003; Jensen et al., 2002).

Our investigation highlights a relationship between the storage and the increase of microbial numbers (faecal coliforms, total coliforms and faecal streptococci) with the exception of S3 and S20 that showed zero levels of pollution initially and after storage for two weeks. It is judicious to indicate that the quality of some water samples was poor before the storage.



(A)



(B)

Figure 2 : Bacteriological analysis of water samples measured at source (A) and in household storage (B). Each point represents the mean ±standard error.

These results agree with those found by Singh et al. (2013) who showed that water quality deteriorated relative to the source. Momba and Kaleni (2002) have also reported a development of indicator microorganisms on household containers during the storage. Our results also confirm the findings of Jagals et al. (2003) concerning the increase of microbiological contamination of water in plastic household containers.

In contrast, Onigbogi and Ogunyemi (2014) have obtained that water contamination was higher at the source than in storage containers.

Physico-chemical analysis

Physico-chemical analyses of water samples over time are given in table 1 below. The comparison of initial phase of testing (A) and the second phase after storage (B) showed a significant ($P<0.05$) decrease of pH value in stored water and a significant ($P<0.05$) rise of electrical conductivity and calcium concentration. However there were no significant differences between the others chemical parameters that respect the reference values of the drinking water regulation.

In fact, the pH value at source (A) was within the guideline levels and ranged from 6.53 to 8.47 but after storage (B), it's varied from 6.12 to 8.21. Electrical conductivity at source (A) varied between 105.40 and 1212.33 (µs/cm) and between 110.13 and 1221.33 (µs/cm) after storage (B). No variation was detected in nitrate value that was between 0 and 1.80 (mg/l) in both initial phase (A) and after storage (B). Sulfates concentration fluctuated between 0 and 81.50 (mg/l) at source (A) and 0 and 83.67 (mg/l) after storage (B). For the calcium value, it's was around 0.24 and 4.41 (mg/l) at source (A) and 0.30 and 4.47(mg/l) after storage (B). The total Hardness at source (A) varied between 8.17 and 70.31 (mg/l) and between 9.06 and 69.90 (mg/l) after storage (B). No variation was detected in the chloride concentration that fluctuated between 46.06 and 246.67 (mg/l) in both initial phase (A) and after storage (B). Oxydability was around 0.24 and 3.31 (mg/l) at source (A) and around 0.18 and 3.31 (mg/l) after storage (B).

Table 1 : Variation of water physicochemical parameters measured at source (A) and in household storage (B). Each point represents the mean ±standard error.

(A)

Sampling sites	pH	Electrical conductivity (µs/cm)	Nitrite (mg/l)	Nitrate (mg/l)	Sulfate (mg/l)
S1	7.90 ±0.04	710.33 ±1.53	0.00 ±0.00	0.00 ±0.00	63.83 ±1.04
S2	8.44 ±0.05	740.00 ±2.00	0.00 ±0.00	0.00 ±0.00	54.17 ±1.04
S3	8.47 ±0.07	328.67 ±1.52	0.00 ±0.00	1.80 ±0.20	72.33 ±2.52
S4	8.3 ±0.08	587.83 ±1.04	0.00 ±0.00	0.00 ±0.00	81.50 ±1.50
S5	7.62 ±0.02	1212.33 ±2.52	0.00 ±0.00	1.80 ±0.26	10.33 ±0.58
S6	8.45 ±0.01	558.67 ±1.53	0.00 ±0.00	0.00 ±0.00	61.67 ±1.53
S7	8.30 ±0.02	611±1.00	0.00 ±0.00	0.00 ±0.00	59.17 ±0.76
S8	7.96 ±0.01	248±1.00	0.00 ±0.00	0.00 ±0.00	80.67 ±1.15
S9	6.53 ±0.01	333 ±2.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
S10	6.89 ±0.05	432.67 ±1.52	0.00 ±0.00	0.00 ±0.00	27.33 ±1.15
S11	7.05 ±0.02	431.83 ±0.76	0.00 ±0.00	0.00 ±0.00	39.80 ±0.35
S12	7.23 ±0.04	105.40 ±0.36	0.00 ±0.00	0.00 ±0.00	20.67 ±0.57
S13	7.72 ±0.01	614.17 ±0.76	0.00 ±0.00	0.00 ±0.00	30 ±1.00
S14	7.97 ±0.01	401 ±1.00	0.00 ±0.00	0.00 ±0.00	25.50 ±0.86
S15	7.85 ±0.03	119.97 ±1.00	0.00 ±0.00	0.00 ±0.00	20.67 ±0.57
S16	7.54 ±0.03	612.33 ±2.52	0.00 ±0.00	0.00 ±0.00	25.17 ±0.28
S17	7.92 ±0.04	279.67 ±2.51	0.00 ±0.00	0.00 ±0.00	41.33 ±2.30
S18	7.75 ±0.01	230 ±1.00	0.00 ±0.00	0.00 ±0.00	30.33 ±0.57
S19	7.47 ±0.02	287 ±2.00	0.00 ±0.00	0.00 ±0.00	24.67 ±0.57
S20	7.53 ±0.02	374.67 ±4.16	0.00 ±0.00	0.00 ±0.00	36.50 ±0.86

Sampling sites	Calcium (mg/l)	Total Hardness (mg/l)	Chloride (mg/l)	Oxydability (mg/l)
S1	3.82 ±0.01	16.22 ±0.25	74.52 ±0.50	0.52 ±0.03
S2	3.93 ±0.06	30.35 ±0.56	94.36 ±0.55	0.62 ±0.04
S3	1.99 ±0.02	11.99 ±0.03	65.36 ±2.93	0.68 ±0.01
S4	3.42 ±0.11	27.52 ±0.50	71.69 ±0.59	0.42 ±0.00
S5	2.22 ±0.19	70.31 ±0.32	191.43 ±2.23	0.68 ±0.00
S6	2.69 ±0.16	31.64 ±0.55	91.83 ±5.34	1.61 ±0.01
S7	3.19 ±0.17	26.56 ±0.51	86.59 ±0.37	1.01 ±0.01
S8	0.97 ±0.03	8.75 ±0.31	142.74 ±0.25	1.44 ±0.01
S9	1.27 ±0.12	15.20 ±0.20	153.24 ±2.14	1.70 ±0.01
S10	0.49 ±0.07	14.50 ±0.50	246.67 ±3.54	3.31 ±0.01
S11	0.24 ±0.04	9.33 ±0.31	175.62 ±0.33	2.23 ±0.02
S12	0.36 ±0.04	8.17 ±0.21	186.37 ±2.72	0.76 ±0.00
S13	3.33 ±0.15	44.30 ±0.26	78.14 ±0.35	0.50 ±0.09
S14	2.11 ±0.08	35.73 ±0.64	46.06 ±2.23	0.42 ±0.01
S15	0.28 ±0.03	10.80 ±1.05	78.91 ±1.36	0.24 ±0.03
S16	3.43 ±0.05	41.43 ±2.23	56.79 ±3.59	0.50 ±0.08
S17	3.33 ±0.20	43.67 ±1.52	46.36 ±1.72	0.76 ±0.01
S18	2.91 ±0.08	40.67 ±1.15	60.91 ±5.61	0.66 ±0.04
S19	1.92 ±0.03	26.87 ±0.12	46.21 ±1.89	0.41 ±0.01
S20	4.41 ±0.10	69.53 ±0.50	57.18 ±16.57	0.55 ±0.05

(B)

Sampling sites	pH	Electrical conductivity (µs/cm)	Nitrite (mg/l)	Nitrate (mg/l)	Sulfate (mg/l)
S1	7.53 ±0.15	715 ±4.00	0.00 ±0.00	0.00 ±0.00	62.83 ±2.56
S2	7.94 ±0.01	764.67 ±1.52	0.00 ±0.00	0.00 ±0.00	55.67 ±1.15
S3	8.21 ±0.01	330.33 ±2.51	0.00 ±0.00	1.73 ±0.11	72.67 ±2.51
S4	7.79 ±0.01	650.33 ±1.53	0.00 ±0.00	0.00 ±0.00	80.67 ±1.15
S5	7.33 ±0.02	1221.33 ±1.52	0.00 ±0.00	1.80 ±0.26	10 ±2.00
S6	7.58 ±0.02	633.67 ±1.53	0.00 ±0.00	0.00 ±0.00	62 ±1.73
S7	7.75 ±0.00	634.67 ±1.52	0.00 ±0.00	0.00 ±0.00	60.33 ±0.57
S8	7.80 ±0.01	249 ±1.52	0.00 ±0.00	0.00 ±0.00	83.67 ±3.21
S9	6.39 ±0.01	366.67 ±1.00	0.00 ±0.00	0.00 ±0.00	0.00 ±0.00
S10	6.70 ±0.02	455.67 ±1.52	0.00 ±0.00	0.00 ±0.00	27.17 ±0.76
S11	6.87 ±0.02	438.00 ±1.53	0.00 ±0.00	0.00 ±0.00	40.33 ±0.57
S12	6.91 ±0.01	110.13 ±1.00	0.00 ± 0.00	0.00 ±0.00	21.33 ±0.58
S13	7.63 ±0.02	629.37 ±0.15	0.00 ±0.00	0.00 ±0.00	31 ±1.78
S14	7.78 ±0.01	419.90 ±0.15	0.00 ±0.00	0.00 ±0.00	26.33 ±0.57
S15	6.12 ±0.05	126.02 ±0.09	0.00 ±0.00	0.00 ±0.00	21.33 ±0.58
S16	7.23 ±0.02	628.20 ±0.06	0.00 ±0.00	0.00 ±0.00	25.67 ±1.15
S17	7.51 ±0.05	589.67 ±0.2	0.00 ±0.00	0.00 ±0.00	39.33 ±1.15
S18	7.44 ±0.01	473.33 ±2.08	0.00 ±0.00	0.00 ±0.00	30.67 ±1.15
S19	7.22 ±0.01	615.83 ±1.25	0.00 ±0.00	0.00 ±0.00	25.33 ±0.57
S20	7.08 ±0.03	731.50 ±1.32	0.00 ±0.00	0.00 ±0.00	37.50 ±0.86

Sampling sites	Calcium (mg/l)	Total Hardness (mg/l)	Chloride (mg/l)	Oxydability (mg/l)
S1	3.77 ±0.06	16.09 ±0.08	74.52 ±0.50	0.52 ±0.03
S2	3.94 ±0.05	30.35 ±0.56	94.36 ±0.55	0.62 ±0.04
S3	1.99 ±0.02	11.97 ±0.03	65.36 ±2.92	0.68 ±0.006
S4	3.52 ±0.07	27.52 ±0.50	71.69 ±0.59	0.42 ±0.003
S5	2.36 ±0.05	23.95 ±0.06	191.43 ±2.23	0.68 ±0.00
S6	2.70 ±0.14	31.64 ±0.55	91.83 ±5.34	1.61 ±0.01
S7	3.41 ±0.08	26.56 ±0.51	86.59 ±0.37	1.01 ±0.01
S8	0.94 ±0.04	9.06 ±0.25	142.74 ±0.25	1.44 ±0.01
S9	1.27 ±0.30	14.90 ±0.36	153.24 ±2.14	1.70 ±0.007
S10	0.47 ±0.06	23.23 ±0.25	246.67 ±3.54	3.31 ±0.01
S11	0.30 ±0.11	21.28 ±0.66	175.62 ±0.33	2.23 ±0.02
S12	0.47 ±0.16	15.99 ±0.01	186.37 ±2.72	0.76 ±0.003
S13	3.50 ±0.30	44.83 ±0.37	78.14 ±0.35	0.50 ±0.1
S14	2.07 ±0.03	36.83 ±1.04	46.06 ±2.23	0.39 ±0.04
S15	0.30 ±0.02	10.67 ±1.15	78.91 ±1.36	0.18 ±0.08
S16	3.43 ±0.05	40.67 ±1.15	56.79 ±3.59	0.41 ±0.15
S17	3.40 ±0.1	44.53 ±0.50	46.36 ±1.72	0.62 ±0.23
S18	2.83 ±0.02	40.33 ±0.41	60.91 ±5.61	0.49 ±0.27
S19	1.92 ±0.02	27.27 ±0.64	46.21 ±1.89	0.53 ±0.21
S20	4.47 ±0.03	69.90± 0.26	57.18 ±16.57	0.41 ±0.20

Our study showed a decrease of the pH value, in stored water samples. This may be related to the bacterial development and activity. Our results are in agreement with previous studies (Achadu et al., 2013).

Electrical conductivity of water guesses the total of solids dissolved in water and depends on the water temperature (Barron and Ashton, 2005). In fact, our results show an increase of the electrical conductivity level and we found also an increase of calcium concentration in stored water samples. Such effects were also seen by Achadu et al. (2013).

Nevertheless, no significant differences between the others chemical parameters were seen and the values do not exceed the standard of drinking water in all studied samples before and after storage.

CONCLUSIONS

The results of bacteriological analysis show that the studied stored water present risks to human health. So, basic water supply and safe water storage are needed.

Nevertheless, we suggest that a preventive water quality intervention should be conducted for a safe storage using boiling or disinfectant (such as chlorine, sodium hypochlorite or natural plant extracts). Our work is now in progress.

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