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Determination of the microbiological characteristics and traces of heavy metals in rainwater harvested in urbanized areas to develop their uses: Case study of downtown Souk Ahras, Algeria

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Abstract

Rainwater storage tanks designed with diverse materials may host sustainable microbial systems; such systems are found in areas where a potable water source is not readily available. The variations in the water stored can also affect the levels of heavy metals and the physic-chemical parameters. The types of tanks and their composite materials can significantly influence the values of some chemical elements, especially heavy metals, essential nutrients, as well as pH, EC, and turbidity. In this study, two types of tank materials were used for the harvested rainwater systems in Souk Ahras city: concrete and plastic. Twenty-one samples were collected and analyzed for different time scales for both types of tank materials: one week, three weeks, and three months. Results of the determination of the essential nutrients as well as the concentrations of heavy metals, such as lead (Pb), copper (Cu), nickel (Ni), chromium (Cr), iron (Fe), cadmium (Cd), and arsenic (As), were present in moderate concentrations. In addition, pathogens, such as salmonella, yeast, mold spores, fecal coliforms, and streptococci, were undetected in the rainwater samples of all tanks. However, the concrete tanks showed a very interesting resistance to the growth of aerobic germs, where 99.7% of the germs were eliminated by the third week. However, the opposite behavior was recorded after this period.

Keywords: roof-harvested rainwater, microbial quality, heavy metals, physic-chemical, tank material.

الملخص

قد تحتوي صهاريج تخزين مياه الأمطار المصممة بمواد متنوعة على أنظمة ميكروبية مستدامة؛ توجد مثل هذه الأنظمة في المناطق التي لا يتوفر فيها مصدر مياه الشرب بسهولة. يمكن أن تؤثر الاختلافات في المياه المخزنة أيضًا على مستويات المعادن الثقيلة والمعايير الفيزيائية والكيميائية. يمكن أن تؤثر أنواع الخزانات وموادها المركبة بشكل كبير على قيم بعض العناصر الكيميائية، وخاصة المعادن الثقيلة، والعناصر الغذائية الأساسية، وكذلك الأس الهيدروجيني، والتركيبة الكهربية، والعكارة. في هذه الدراسة تم استخدام نوعين من مواد الخزان لأنظمة تجميع مياه الأمطار في مدينة سوق أهراس: الخرسانة والبلاستيك. تم جمع واحد وعشرون عينة وتحليلها لمقاييس زمنية مختلفة لكلا النوعين من مواد الخزان: أسبوع واحد، وثلاثة أسابيع، وثلاثة أشهر .نتائج تحديد العناصر الغذائية الأساسية وتركيزات المعادن الثقيلة مثل الرصاص (Pd) والنحاس (Cu) والنيكل (Ni) والكروم (Crl) والحديد (Fe) والكادميوم (Cd) و الزرنيخ (As)، كان موجودا في تركيزات معتدلة. بالإضافة إلى ذلك، لم يتم الكشف عن مسببات الأمراض، مثل السالمونيلا، الخميرة، جراثيم العفن، القولونيات البرازية، والمكورات العقدية، في عينات مياه الأمطار لجميع الخزانات. إلا أن الخزانات الخرسانية أظهرت مقاومة مثيرة للغاية لنمو الجراثيم الهوائية، حيث تم القضاء على 99.7٪ من الجراثيم بحلول الأسبوع الثالث. ومع ذلك، تم تسجيل السلوك المعاكس بعد هذه الفترة.

الكلمات المفتاحية: مياه الأمطار من الأسطح، الجودة الميكروبية، المعادن الثقيلة، الفيزيائية والكيميائية، مواد الخزان

Introduction

Water is a resource, which is unevenly distributed and scarcely available. Experts in the water resource sector are considering an alarming scenario for North Africa and Algeria due to the increase in water demands in the medium term (Guebail et al., 2011). This pending consequence is caused by climate change, high evaporation rates of surface water, economic development (industrial and agricultural), as well as a significant growth rate in the number of inhabitants and impressive losses in the water distribution networks (Zeghadnia, 2007), and a lack of alternative water resource management strategies.

However, the dynamic management strategy for water resources is essential for seizing an opportunity that lies in the use of unconventional water-related methods. These methods include water harvesting from the roofs of houses. This alternative, which compensates for water resource shortfalls, remains highly recommended worldwide for use in predefined rainwater areas. This concept is especially important for fulfilling drinking needs in particular in rural and isolated areas, which are deprived of drinking water supply networks (WSN) (Bensoltane et al., 2021a).

Water pricing in Algeria is lower than the cost of water (Boukhari et al., 2011), so it does not favor the development and application of this solution. However, its probable disposition at a household level by harvesting can justify the positive intention. Furthermore, it creates an opportunity to use the water recovered and stored by satisfying certain conditions to the more advanced domestic needs, such as health and approved drinking water, by simulating its qualities to the limits referred to for conventional drinking water. However, some needs require the government to design a water related economic system. The recovery is a solution of choice to apply the accurate price of water or financial incentives encouraging citizens to adopt this method.

Numerous studies have shown that due to contamination following contact with the catchment surface, stored rainwater often does not satisfy World Health Organization (WHO) guideline standards for drinking water, especially with respect to microbiological quality criteria, traces of heavy metals, and some essential physic-chemical parameters. The most significant issue relating to the use of harvested rainwater is the potential health risk associated with the presence of various pathogenic organisms in such waters (Thomas and Greene, 1993; Grove, 1993; Malema et al., 2018; Warish et al., 2011).

This research was conducted to determine and quantify the potential hazards due to the presence of pathogens or heavy metals in roof-harvested rainwater and to confirm the need for people to use water harvested in good conditions.

Materials and Methods

Study Area Sample Collection

The Wilaya of Souk-Ahras is located in northeastern Algeria (36° 17' 11" N, 7° 57' 4" E) (Benmalek et al., 2018). It is characterized by a dry to semi-arid climate with a nonhomogeneous and uneven distribution of rainfall; the evaporation rate has been estimated at 74% (Bouroubi–Ouadfel et al., 2018). The drinking water distribution network of the city of Souk-Ahras has a high rate of water loss which exceeds 50%. (Guebail et al., 2011; Bensoltane et al., 2018; Bensoltane et al., 2019; Bensoltane et al., 2020 ; Boukhari et al., 2020).

This study is mainly based on the use of reclaimed water described by Fewkes (1999), who classifies the uses of rainwater as follows:

Drinking water or its complement (in developing countries) (Bensoltane et al., 2021a);

Supplement to drinking water (in developed countries).

Sampling

The collection areas can have a different quality compared with one another, according to industrial and other economic dynamics. The pollution of rainwater produced before being collected also has a decisive role in determining the quality of these waters (Guebail et al., 2017b).

For availability of data and facilities of storage tanks, and for similarity of expandable studies case for other areas (climate and philosophies of analysis), the study area covers Souk Ahras city, which is represented by three different areas (A), (B), and (C). Two types of materials were used in the tanks in the harvesting system:

Plastic,

Concrete.

The sampling sites were selected (Figure 1) based on several parameters (wind direction, distance between different sites, location of polluting companies, and manufactories) to better cover the different types of contamination patterns in precipitation (control samples especially, to determine heavy trace metal concentrations and analyze the physic-chemical properties) and understand the influence of the two different composite materials used for rainfall water storage.

Meaningful and reliable sampling assures the validity of analytical findings (Haylome et al.,2015). To determine microbiological levels of heavy trace metals and to analyze the physic-chemical properties of the stored rain fall water, 21 samples were collected from two rainwater-harvesting systems situated at various sites in downtown Souk Ahras. Each sample was collected for one week, two weeks, and three months for the first six months of the year 2020 for both types of tank materials.

Polyethylene sterile bottles of one liter were used to transport the water samples into the laboratory (Guebail et al., 2017b); these samples were then stored in a cooler at a temperature of about 4°C – 6 °C (Rodier et al., 2009; Tuzen and Soylak, 2006). These sterilized polyethylene bottles were rinsed and washed before being used (Haylome et al., 2015).

A reference sample, also known as the control sample, was used to assess the influence of the material on the microbiological quality of the harvested samples. This sample was not stored in tanks, instead, it was analyzed directly after it had been collected from rainfall events at each collection system site. Finally, to eliminate the presence of residues on the collection surfaces that may influence the results of the analyses, the water collected from the first rainfall was not incorporated into the sampling collection.

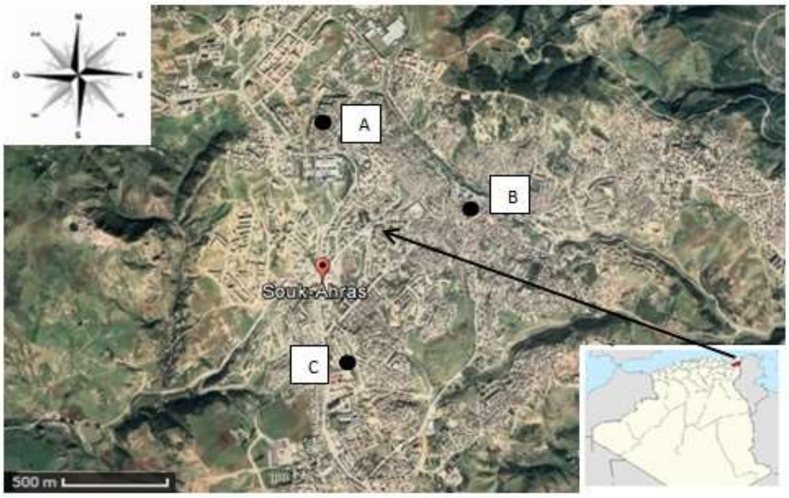

Figure 1. Sampling locations in downtown Souk Ahras (Google Earth).
A, B, C: Locations of harvesting systems.

Analysis Methodology

A membrane filtration analysis mode protocol, as described by Rodier et al. (2009), was used to determine the microbiological characteristics of the collected and stored water samples and examine the presence of referential germs (aerobic germs, aerobic coliforms, fecal coliforms, fecal streptococci, salmonella, yeast, and mold) with different temperatures.

The coliform bacteria were determined using the technique with the most probable number in the liquid medium technique using two consecutive tests, namely, the presumption test, which is dedicated to the search for total coliforms, and the confirmation test, which is dedicated to the search for fecal coliforms from the positive tubes of the presumption test. The search and enumeration of fecal streptococci and salmonella were performed using colorimetry in liquid media (Lin, 1974).

Then, the heavy trace metal concentrations of the collected rainwater were compared with the drinking water standards. All samples were analyzed at Souk Ahras University Analytical Laboratory by using acidification of 50ml for each water sample of about10 ml $HClO4$. Each acidified water sample was well-mixed and digested on a hot plate for one hour at 100°C and transferred to a 100ml volumetric flask diluted with distilled water and mixed thoroughly. The digested sample was analyzed for traces of copper (Cu), cobalt (Co), cadmium (Cd), chromium (Cr), iron (Fe), manganese (Mn), nickel (Ni), lead (Pb), zinc (Zn), mercury (Hg), fluoride (F), arsenic (As), and sodium (Na) by using an atomic absorption spectrophotometer (Varian AA240FS) (Haylome et al., 2015) according to Rodier et al. (2009). The volumetric titration method was used to determine the concentrations of calcium (Ca) and magnesium (Mg). This titrimetric technique (Nilusha et al., 2013; Rodier et al., 2016), which uses the Karl Fischer method, allows satisfactory quality control results of the water to be obtained.

Naturally, to illustrate the analysis methodology, we carefully collected all the analysis samples from storage tanks without any special interventions; that is, we did not make water changes between a rainfall event and during period of sampling.

Finally, some values of physic-chemical properties, such as hydrogen ion concentration (pH), electrical conductivity (EC), and turbidity, in all collected water samples were analyzed on pH/EC meter and turbidimeter using anephelometry technique (Theofanis Lambrou et al., 2009; WHO, 2017, Bensoltane et al., 2021b).

Data analysis

To properly structure the data, Excel software was used in the treatment of the results because each sample analyzed was affected by each parameter; the results are shown in table 1.

Results and Discussion

To confirm the approach with that of the WHO (2017), the harvested water was stored under good conditions and according to the recommendations of the authors; the water can be used as drinking water or for domestic tasks (Guebail et al., 2017b). The water quality followed that of the current government regulations on drinking water. In this section, the methodology of analysis is exposed to develop some necessary recommendations that can promote advanced domestic use of harvested and stored water in different types of tanks during different periods; three sites are simulated as areas of collection and use of this water. The use of this water collected and stored as drinking water depends on the comparison of many result values of qualities obtained by the recommended references of WHO.

Microbiological characteristics

In general, the greatest microbial risks are associated with the ingestion of water that is contaminated with human or animal (including bird) feces. Feces can be a source of pathogenic bacteria, viruses, protozoa, and helminthes. Fecally derived pathogens are the principal concerns in setting health-based targets for microbial safety (Bensoltane et al., 2021c). Therefore, along with air and soil, water is part of the elements that serve either as a place of accommodation for native species, or a channel to carry bacteria in transits eliminated by humans, animals, and plants (Rodier et al., 2009). Fecal indicator bacteria and pathogens can enter through an aerosol deposition. Elevated opportunistic pathogen concentrations have been linked to old water ages, a lack of disinfectant residuals, elevated temperatures, and tank materials (Wang et al., 2012). To assess the bacterial pollution in the roof-harvested rainwater, the following values were used:

Table 1. Microbial values in roof-harvested rainwater.

Pathogenic Germs	Control sample CFU/100 ml	Concrete Tank (01 week) CFU/100 ml	Plastic Tank (01 week) CFU/100 ml	Concrete Tank (03 weeks) CFU/100 ml	Plastic Tank (03 weeks) CFU/100 ml	Concrete Tank (03 months) CFU/100 ml	Plastic Tank (03 months) CFU/100 ml
Aerobic Germs (22°C)	/	49	37	14	50	200	100
Aerobic Germs (30°C)	/	/	/	/	/	/	/
Aerobic Germs (37°C)	/	20	4	/	14	100	50
Aerobics Coliforms	/	4	/	/	/	90	80
Faecal Coliforms	/	/	/	/	/	/	/
Faecal Streptococci	/	/	/	/	/	/	/
Salomonella	/	/	/	/	/	/	/
Yeast	/	/	/	/	/	/	/
Mould spores	/	/	/	/	/	/	/

No significant differences were recorded in any of the sites for which we presented the maximum results in Table 1. Pathogens, such as salmonella, yeast, mold spores, fecal coliforms, and streptococci were undetected in rainwater.

The concentrations of the aerobic germs were recorded in all tanks and for all times and temperatures; these aerobic germs reduce the biochemical oxygen demand and create an environment that allows higher level life forms to exist including ciliates, flagellates, protozoa, and rotifers.

In general, the rainwater is relatively free from impurities except for those picked up by rain from the atmosphere as recorded in the control sample. The highest count was obtained for concrete tanks stored for three months: 200 (CFU/100ml), the best result was also recorded for concrete tanks for rainwater stored for three weeks, whether the temperature of the concentration was 0–14 (CFU/100ml). The aerobic germs continued to decrease until the third week when the growth was noteworthy. On the contrary, in the plastics tanks a faster growth of the germs was recorded, with the number increasing up to 26% after three weeks and 61% after three months, than in the concrete tanks, where the number of germs decreased by 99.7% after the first week. However, in the third month, the opposite effect of the concrete tank was observed with an increase of up to 99.75% in germs.

Heavy trace metals traces

The results of all measurements and laboratory tests that were conducted to determine the qualities of water harvested and stored in tanks made of one of two different materials, such as plastic and concrete, for different periods, were controlled by the results of the control samples for all three sites in Souk Ahras city. The aims were also to compare them with the specifications of the WHO for drinking water. Table 2provides the concentrations of Cu, Co, Cd, Cr, Fe, Mn, Ni, Pb, Zn, Hg, F, As, Na, Ca, and Mg as heavy elements alongside the WHO referenced limit values of drinking water. Figures 2, 3, and 4 show the pH, EC, and turbidity in Nephelometric Turbidity Units (NTU) for the samples and the detection limits of each value. Heavy metals in drinking water samples are related to chronic diseases (Chaitali et al., 2013).

Overconsumption of toxic heavy metal elements by humans can pose serious health risks. However, the existence of some heavy metal elements (Fe, Mn, Cr, and Cu) in drinking water in small amounts is essential and beneficial for life and human health; crossing their approved levels is associated with an increased risk of cancer (Hassan Amin et al.,2013), (Jyothi, NR, 2020).

First, results show no traces of As, Hg, and Cr in the sampled waters. Arsenic is a metal, which is toxic to human health and whose limit value recommended by the WHO (2006) is around 0.10 (mg/l). In water, as is mostly present as arsenate (+5), and it is usually present in natural waters at concentrations of less than 0.1–0.2 (mg/l) (FAO/WHO, 2011; WHO, 2011; IPCS, 2001; ISO, 1982; USNRC, 2001; WHO, 2017). Logically, from what has been previously reported and according to most other authors, this condition explains its absence in the analyzed samples. Experts of the WHO (2010, 2017) have previously reported that epidemiological studies have examined the risk of cancers associated with ingestion through drinking water. Many are ecological-type studies, and many suffer from methodological flaws, particularly in the measurement of exposure. The International Program on Chemical Safety (IPCS) concluded that long-term exposure to drinking water is causally related to increased risks of cancer in the skin, lungs, bladder, and kidneys. Mercury is used in the electrolytic production of Cl, in electrical appliances, in dental amalgams, and as a raw material for various Hg compounds (IPCS, 2003; WHO, 2005). The toxic effects of inorganic Hg compounds are mainly observed in the kidneys of humans and laboratory animals, following short-term and long-term exposure (IPCS, 2003; WHO, 2005). Chromium in turn can exist with valences of +2 to +6. In general, food appears to be the major source of intake (WHO, 2003). Still, according to experts of the WHO (2003), Cr is carcinogenic via the inhalation route even if it is considered an essential nutrient.

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Table 2. Heavy trace metal values in roof-harvested and stored rainwater.

Reference		(WHO 2006)	(WHO 2003)	(WHO 2006)	(WHO 2006)	(WHO 2011)	(WHO 2011)	(WHO 2011)	(WHO 2011)	(WHO 2011)	(WHO 2011)	(WHO 2003)	(WHO 2011)	(WHO 2003)
Element Trace		Cadmium	Cobalt	Nickel	Lead	Aluminum	Copper	Iron	Manganese	Zinc	fluoride	Maganezuim	Soduim	Calcuim
Sampling area	Site	(Cd) (mg/L)	(Co) (mg/L)	(Ni) (mg/L)	(Pb) (mg/L)	(Al) (mg/L)	(Cu) (mg/L)	(Fe) (mg/L)	(Mn) (mg/L)	(Zn) (mg/L)	(F) (mg/L)	(Mg) (mg/L)	(Na) (mg/L)	(Ca) (mg/L)
Limit values		0.003	0.005	0.07	0.01	0.2	2	2	0.4	3	1.5	50	20	270
Contrôle sample	A	0	0.001	0	0.0015	0.0011	0.0031	0.4696	0.0033	0.033	0.02	49.7893	55.7522	9.2198
Plastic Tank 01 Week	A	0.001	0.001	0	0.0015	0.0011	0.003	0.5046	0.0032	0.032	0.02	24.2895	22.4266	0.2661
Concrete tank 01Week	A	0	0.0015	0.001	0.0015	0.0011	0.0031	0.6595	0.0031	0.032	0.02	26.2571	64.3456	0.2003
Plastic Tank 03 Week	A	0.0012	0.001	0	0.0015	0.0011	0.003	0.4946	0.003	0.032	0.02	25.3072	95.9944	0.0756
Concrete tank 03Week	A	0	0.0027	0.001	0.0013	0.0011	0.0032	0.5995	0.0032	0.035	0.031	24.5609	31.02	0.0301
Plastic Tank 03 Months	A	0.0013	0.001	0	0.014	0.0011	0.003	0.4943	0.003	0.032	0.02	25.8977	98.7765	0.0723
Concrete tank 03 Months	A	0	0.0031	0.002	0.011	0.001	0.0032	0.56322	0.0032	0.032	0.052	25.8996	24.6675	1.4223
Contrôle sample	B	0	0.001	0	0.0013	0.001	0.003	0.3116	0.0031	0.032	0.02	46.2154	38.4423	7.4425
Plastic Tank 01 Week	B	0	0.001	0	0.0013	0.001	0.003	0.3887	0.0031	0.032	0.02	25.4673	21.9932	0.1918
Concrete tank 01Week	B	0	0.0015	0.001	0.012	0.001	0.0031	0.4312	0.0031	0.033	0.02	26.9867	44.2433	0.1002
Plastic Tank 03 Week	B	0.0014	0.001	0	0.0013	0.001	0.003	0.3821	0.003	0.032	0.02	25.8897	61.3287	0.0544
Concrete tank 03Week	B	0	0.0027	0.001	0.0012	0.001	0.0031	0.4988	0.0031	0.033	0.033	25.6675	20.02	0.0258
Plastic Tank 03 Months	B	0.0013	0.001	0	0.0012	0.001	0.003	0.4953	0.003	0.032	0.02	25.9943	57.1198	0.0599
Concrete tank 03 Months	B	0	0.0028	0.002	0.0011	0.0007	0.0031	0.6713	0.0031	0.034	0.048	26.7756	16.4457	0.9334
Contrôle sample	C	0	0.001	0	0.0013	0.001	0.003	0.3492	0.0031	0.032	0.02	49.1132	37.2124	7.5991
Plastic Tank 01 Week	C	0.0004	0.001	0	0.0013	0.001	0.003	0.3219	0.003	0.032	0.02	24.1398	21.5671	0.2718
Concrete tank 01Week	C	0	0.0015	0.001	0.012	0.001	0.0031	0.4341	0.0031	0.036	0.02	26.4398	42.2591	0.1343
Plastic Tank 03 Week	C	0.001	0.001	0	0.0013	0.001	0.003	0.3988	0.003	0.032	0.02	25.6671	60.8327	0.0534
Concret tank 03Week	C	0	0.0022	0.001	0.0012	0.001	0.0031	0.3861	0.0031	0.036	0.029	24.8879	22.3287	0.0291
Plastic Tank 03 Months	C	0.0016	0.001	0	0.0012	0.001	0.003	0.3412	0.003	0.032	0.02	25.3931	54.98	0.0674
Concret tank 03 Months	C	0	0.0026	0.002	0.0011	0.008	0.0031	0.4113	0.004	0.035	0.053	27.1883	16.4128	0.9987

However, a National Toxicology Program (NTP) study in the U.S.A has shown evidence for carcinogenicity via the oral route at high doses. The maximum permitted amount of Cr in drinking water according to the WHO is 0.05 (mg/l).

Thus, from what has previously been reported and according to most of the literature regarding the origins of: As, Hg, and Cr, this condition explains the absence of their traces in all samples. This absence is significant, even with existing industrial activities.

Second, the origins and impacts of other toxic metals, such as Cd and Pb, are observed. Cadmium is released into the environment through wastewater, and diffuse pollution is caused by its contamination from fertilizers and local air pollution (WHO, 2017); its guidance standard is 0.003 (mg/l) (WHO, 2006). However, no evidence of carcinogenicity by the oral route as well as for the genotoxicity of Cd is obtained. The kidney is the main target organ for Cd toxicity (WHO, 2017).The results indicate different low values in control samples and water stored for different periods in concrete tanks; an insignificant progression is observed in trace values for water stored in plastic tanks for the three sites. This condition was certainly caused by the interaction between the water stored, the plastic material, and the pre-polluted air. The WHO experts (2017) have reported that Pb is used principally in the production of Pb-acid batteries, solder, and alloys. The organo-lead compounds tetraethyl and tetramethyl Pb have also been used extensively as antiknock and lubricating agents in petrol, respectively. Lead is associated with a wide range of effects, including various neuro-developmental effects, mortality (mainly due to cardiovascular diseases), impaired renal function, hypertension, impaired fertility, and adverse pregnancy outcomes. Impaired neurodevelopment in children is generally associated with lower blood Pb concentrations than permissible in drinking water (0.01mg/l; WHO, 2006). The presence of trace Pb in all the samples was due to local atmospheric dust pollution. Possible interactions between water stored in concrete tanks for longer periods explain its decreased doses in those containers.

Table2 shows the low presence of heavy trace metals, such as Co, Ni, and Al, which are metallic trace elements (TME). Their low levels, which are below WHO standards, provide a reason to believe that the water harvested and the atmosphere of the study area is clean (Guebail et al., 2017a). Cobalt is beneficial for humans because it is part of vitamin B12, which is essential for human health. It is used to treat anemia in pregnant women because it stimulates the production of red blood cells; however, high concentrations of Co can damage human health (Khana et al., 2012).The WHO (2006) standard for drinking water is 0.005 (mg/l). Food, rather than water, is the dominant source of Ni exposure in the non-smoking, non-occupationally exposed population. Allergic contact dermatitis is the most prevalent effect of Ni, and its limit value in drinking water is 0.07 (mg/l) (WHO, 2017).

Many silicate minerals including feldspars, micas, and many amphiboles are important sources of Al (Hem, 1985). In drinking water, Al contents greater than 100 mg/l could lead to an increased risk of developing Alzheimer’s disease (Dartigues et al., 2002), and the permissible concentration of Al in drinking water is 0.2 (mg/l) (WHO, 2011).

However, some heavy metals in drinking water are essential trace elements, but they show toxicity in excess (Chaitali et al., 2013). According to the analyses, their referenced level standards are as follows: Cu as 2(mg/l) (WHO, 2011), Fe as 2(mg/l) (WHO, 2011), Mn as 0.4(mg/l) (WHO, 2011), Zn as 3(mg/l) (WHO, 2011), F as 1.5(mg/l) (WHO, 2011), Mg as 50(mg/l) (WHO,2003), Na as 20(mg/l) (WHO, 2011), and Ca as 270 (mg/l) (WHO, 2003). If these subsequent levels are simply under referenced standards, then they are good for human health. The origins of these elements are rocks, sands, air substances by air pollution (Santé Canada, 2016), (Wanélus, 2016), (Guebail et al., 2017a), or W.S.N pipes with other accessories by corrosive actions (WHO, 2017; Wanélus, 2016). This finding is different from the result of the study, thereby explaining the acceptable results with poor doses of trace metals for all the samples tested except for Mg and Na in the control samples for site A. This condition could be due to some industrial activities, but the introduction of water harvested into concrete tanks for longer periods allowed a regular mutation of the levels to be observed

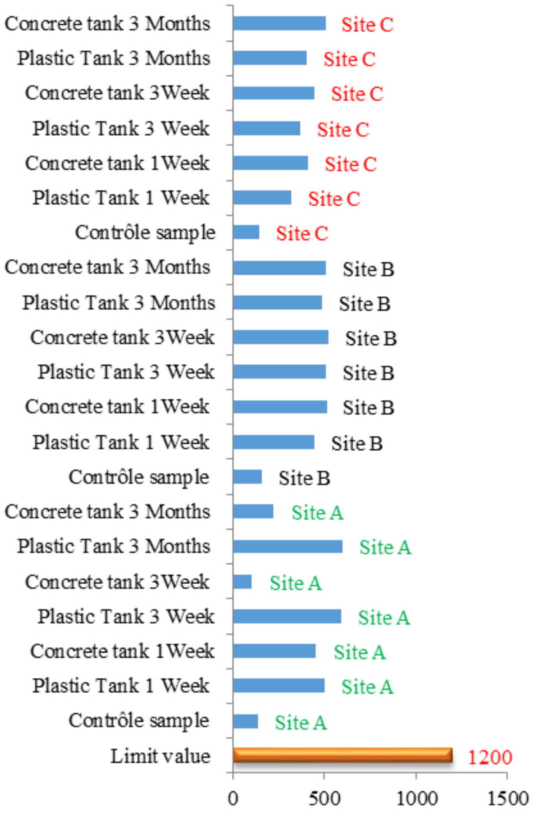

Figure 2. pH results of sample analyses (2020).

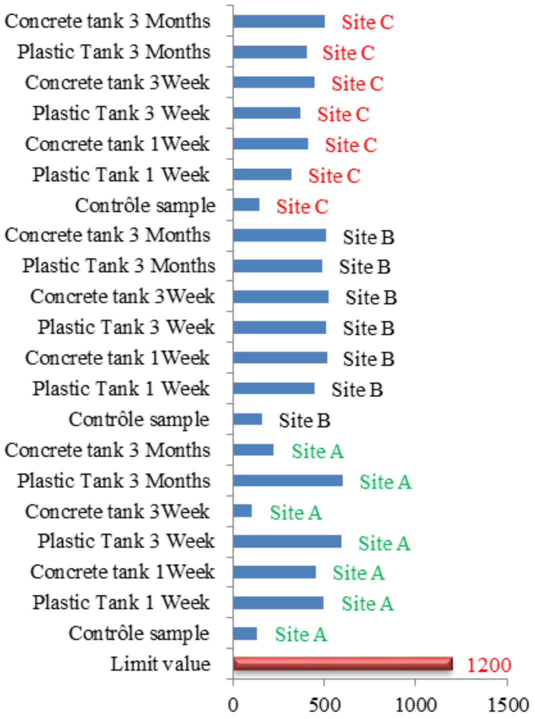

Figure 3. EC20 °C (µ/cm) results of sample analyses (2020).

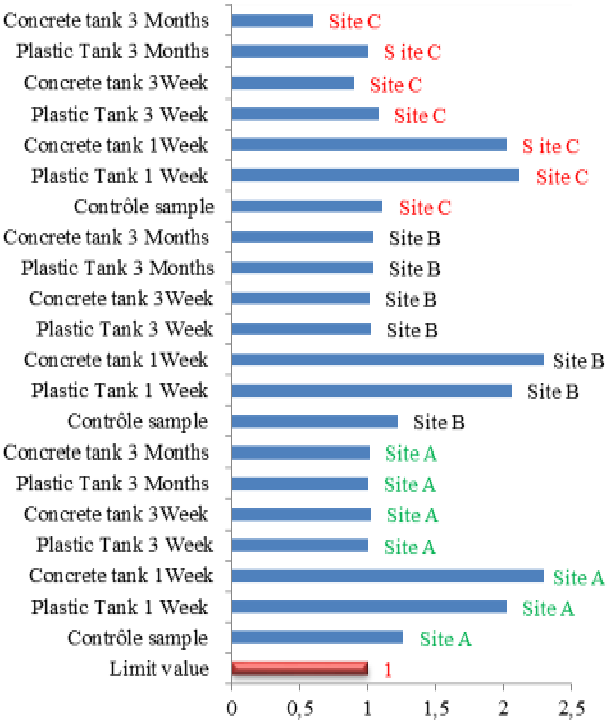

Figure 4. Turbidity (NTU) results of sample analyses (2020).

A majority of experts on water drinking qualities are interested in measuring other physic-chemical parameters with their standard values of pH between 6.5 and 8.5 (WHO, 2011), EC at 20 °C as 1200 (µ/cm) (WHO, 2000), and turbidity of 01 (NTU) (WHO, 2011) to attest if the types of water targeted are viable for drinking or require further treatments and especial dispositive. The results in Figure.2 show the pH of the samples tested; high values are observed for concrete tank samples (Guebail et al., 2017b), but a basic environment is observed for plastic tanks. The clearly variable low results observed for EC testing shown in Figure 3 are due to the poor mineralization subsistence of rainwater harvesting, which confirms the results for Ca, Na, and Mg. However, the high values observed concerning the turbidity parameter (Figure.4) are probably caused by substances of particles in the water with a surprising regularity for the results obtained from water stored in concrete tanks. This finding is perhaps due to the interaction between water and the composite concrete materials; in addition, turbidity values in drinking water exceeding 5 (NTU) are not dangerous to human health (WHO,2017).

Finally, all samples tested were without taste, color, or smell; this pure form devoid of substances harmful to human consumption confirms that the water harvested and stored can be used for the most advanced domestic needs with certain changes in regulations related to drinking water

Conclusions

These samples were collected from different rainwater harvesting systems and analyzed. Pathogens, such as salmonella, yeast, mold spores, fecal coliforms, and streptococci, were undetected in rainwater, but aerobic germs were detected in all tanks. The concrete tanks recorded the best conditions, where 99.7% of the germs were removed; the opposite effect was noted in the third month. The plastic tanks showed no resistance to germ growth; from the first week to the third month, the germs increased by 61%.

The physic-chemical parameter results especially for water stored in concrete tanks, such as pH and turbidity, were evaluated in their referenced norms. Toxic elements, such as: As, Hg, and Pb, were undetected in any of the rainwater samples. Except for Na, the results in rainwater demonstrate poor but acceptable and healthy doses in all samples of essential nutrients, such as Fe, Cu,Mg, F, Zn, and Ca.

However, some recommendations are necessary, as follows:

Concrete tanks are recommended to store harvested water;

The size of the tanks must not be extremely large to store the water harvested to optimize their use during a short period (< three weeks);

The tanks must be equipped with a low-cost filter (a traditional one must be made of textile material) to decrease the turbidity in the stored water;

The user must be aware of the probability of rain (weather forecasts) to wash the tanks before storing water;

The rain collected over the first five minutes should not be stored because this period of rainfall can contain undesirable substances;

Periodic analyses should be conducted in every area by enveloping most of the important parameters for clean water.

Finally, this study should be completed and enriched by other studies that used water harvested treatments and stored at a low cost to acquire essential nutrients. To avoid undesirable interactions between composite tank materials and the stored water, concrete tanks could be replaced with tanks made of a choice of materials including aggregates of non-mining origin, sea sands, and other non-harmful materials.

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Author contributions

AbdelKrim GUEBAIL contributed to study conception, design, data collection, analysis and interpretation of results
Sofiane BOUKHARI : contributed to the writing of the manuscript

Lotfi ZEGHADNIA : contributed to the writing of the manuscript and correction and improvement of English
Ahmed Salah ARAIBIA : contributed to the interpretation of results.
Saliha BOURANENE : contributed to interpretation of chemical analyses

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