World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

Maximum, minimum and typical concentration of copper, iron, lead and zinc that can be leached in tap water

Bachir MIJITABA SAHIROU *, Mahaman Sani LAOUALI, Abdoulkadri AYOUBA MAHAMANE and Awali ABDOUL BARI IDI

Departement of Chemistry, Faculty of Sciences and Technology, Abdou Moumouni University, Niamey, Niger

World Journal of Advanced Research and Reviews, 2022, 14(01), 419–426

Publication history: Received on 14 March 2022; revised on 19 April 2022; accepted on 21 April 2022

Article DOI: https://doi.org/10.30574/wjarr.2022.14.1.0341

Abstract

Lead, copper and iron are the contaminants whose concentrations are most likely to exceed the recommended values due to the corrosion of drinking water distribution system materials. This work studies the maximum, minimum and typical concentration of copper, iron, lead and zinc that can be leached in public tap water in Niamey (Niger). Thus, water samples were taken at the outlet of twelve taps after water stagnation for six hours and after water stagnation for six hours followed by a five-minute drain at maximum flow. For the evaluation of typical concentrations, two half-liters of water are sampled randomly during the day without stagnation or prior emptying. The samples of the first liters taken after a stagnation of 6 hours are more concentrated in metals (from 1 to 12 times) than the samples taken after a draining of 5 minutes. Concentrations of iron and lead generally exceed WHO guideline values. The evaluation of the typical concentration of Cu, Fe, Pb and Zn showed that 91.66% and 16.66% of the analyzed samples exceeded the respective guide values for Pb and Fe. The typical concentrations of Zn and Cu in water taken from the same taps are in line with WHO guideline values.

Keywords: Tap Water; Maximum Concentration; Typical Concentration; Metals Contaminants; Niamey

1. Introduction

On leaving the treatment plant, public water supply generally has a low concentration of metallic trace elements. However, the metallic elements can end up at the outlet of the faucet by leaching from the plumbing elements that contain them, such as galvanized pipes, brazed joints and piping accessories [1]. It is reported that lead, copper and iron are the contaminants whose concentrations are most likely to exceed the recommended values due to the corrosion of drinking water distribution system materials [2-5]. In addition, the intermittent use of tap water promotes its stagnation [6-7].

In addition, various other studies have shown that the concentrations of trace metals measured in samples of tap water taken after a period of stagnation can reach values higher than those recommended [7-9]. The degree of leaching depends on the chemical nature of the water, the hydraulic regime, the stagnation time and the temperature of the water. Thus, studying the impact of stagnation time on the amount of metal released into the water supply is important in several respects. In this sense, a systematic model to describe the concentration of metals as a function of stagnation time would be useful in order to predict human exposure with more precision. Thus, random sampling and sampling after a period of stagnation, are able to assess typical metal exposure, including possible exposure to particulate metals, and can therefore be used for residential sites. These protocols are appropriate for identifying priority locations for

* Corresponding author: Bachir MIJITABA SAHIROU
Departement of Chemistry, Faculty of Sciences and Technology, Abdou Moumouni University, Niamey, Niger.

action to reduce lead levels and for assessing compliance [1]. The objective of this work is thus to determine exposure to copper, iron, lead and zinc in tap water from the public water supply network in Niamey.

2. Material and methods

2.1. Analytical procedure

Sampling after controlled stagnation makes it possible to determine the maximum quantity of metallic trace elements from the piping but also it makes it possible to detect leaching of a given metal at a certain distance or at the outlet of the valve. The protocol is as follows

2.2. Evaluation of the maximum concentration of Cu, Fe, Pb and Zn

In a residence, school or health center, the list of all water outlets is drawn up. After water stagnation for 6 hours (from 12:00 a.m. to 6:00 a.m.), for each water outlet:

- A sample of 1 liter at the first flow (i.e. no prior emptying) is taken. The water flow is normal (medium flow);
- Then, a 1-litre sample is taken after a 5-minutes flow of water at maximum flow.

The taking of the second 1 liter sample makes it possible to know if the content of the metallic element comes from individual service pipes or from the water network (service pipes and arteries). In other words, it makes it possible to know the contribution of the individual connection pipe and accessories on the leaching of metallic trace elements in the water at the outlet of the tap.

2.3. Evaluation of the maximum concentration of Cu, Fe, Pb and Zn

In each of the previous 12 taps two 500 mL samples are collected. To better correspond to the normal use of consumers, the samples were taken randomly during the day without prior emptying; no stagnation period is prescribed. The water had an average flow. The concentration of metallic elements at each water outlet corresponds to the average of the results of the two samples. The analyzes where carried out by using atomic absorption spectrophotometry as descrived by [10].

For the collection of tap water samples, new and sterile 1 liter high density polyethylene bottles were used. During sampling, parameters such as electrical conductivity, dissolved oxygen and pH of the water were measured at the sampling site. A total of 48 water samples from twelve taps were taken. The sampling points were located using a GARMIN brand GPS device.

The sample bottles are previously washed with 1.5 M nitric acid and rinsed with distilled water. All the samples are acidified at 0.5% (v/v) with 65-68% nitric acid just after the measurements of the parameters at the sampling site. A WTW multimeter was used to measure the parameters at the sampling site.

3. Results

3.1. Some characteristics of the water samples taken

3.1.1. pH

pH is one of the most important operational parameters of water quality [11]. Although it has no direct effects on the health of consumers, its monitoring is necessary for drinking water. The pH measurement results show that all samples have a pH between the WHO recommended values of 6.5 to 8.5. This pH shown in Figure 1 varies from 6.54 to 7.74. Furthermore, a pH lower than this range could explain a risk of corrosion of the water pipes. And, at extreme pH values (5 ≤ pH or pH ≥ 11) water can cause skin and eye irritation (figure 1) [12].

3.2. Electrical conductivity

Electrical conductivity is one of the parameters that should, if possible, be regularly monitored for drinking water. It indicates the ability of water to conduct electricity. The electrical conductivity is low for all tap water samples taken. It varies from 75.2 to 101.5 µS.cm-1 (Figure 2). This could be due to the low mineralization of the water of the Niger River which is the source of public water supply in Niamey and to the treatment methods applied at the Société des Exploitations des Eaux du Niger (figure 2) [13].

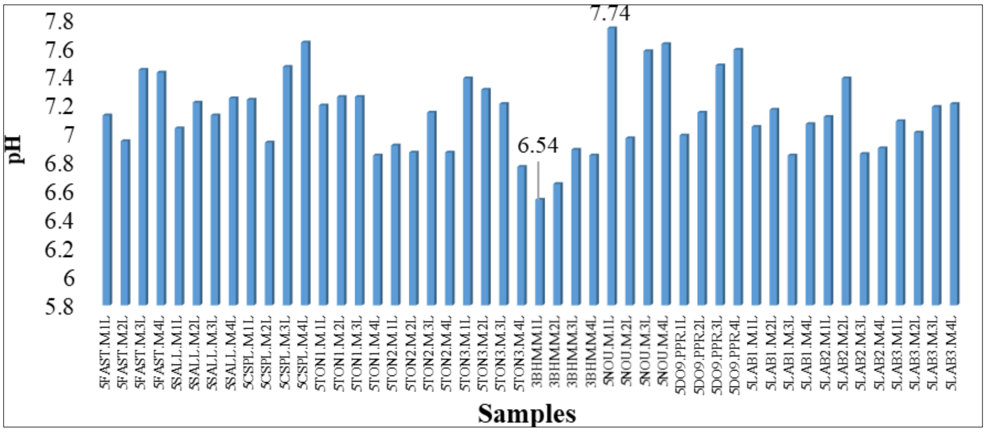

Figure 1 PH of water samples taken from taps

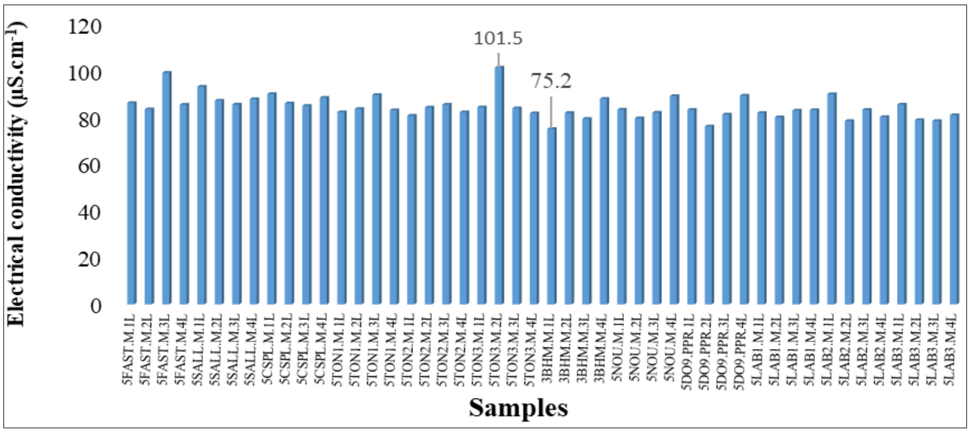

Figure 2 Electrical conductivity of water samples taken from taps

3.3. Dissolved oxygen

The concentration of dissolved oxygen in the tap water samples studied oscillates between 3.81 and 9.51 mg.L^{-1} (Figure 3). Initially, the water from these taps is surface water, it then contains a relatively high quantity of dissolved oxygen, close to saturation (≤ 9 mg.L^{-1}). Nevertheless, the low values obtained may be due to the transformation of dissolved oxygen within the distribution network [14].

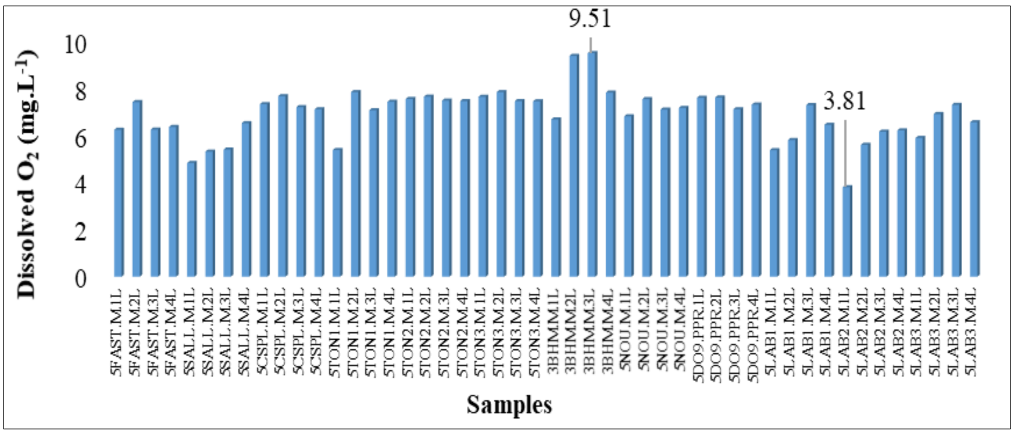

Figure 3 Dissolved oxygen content of water samples taken from taps

3.3.1. Maximum, minimum and typical concentrations of copper in tap water

A maximum acceptable concentration of 2 mg.L^{-1} is proposed for total copper in drinking water. An aesthetic objective of 1 mg.L^{-1} is also proposed for total copper in drinking water [5].

Figure 4 presents the maximum, minimum and typical concentrations of copper in tap water samples collected in the city of Niamey. For each faucet where there is copper, the sample taken immediately after the water has stagnated for 6 hours has the highest copper concentration. These concentrations vary from 0.000 to 0.049 mg.L^{-1}. The copper concentrations in the samples taken after stagnation of the water for 6 hours followed by a 5-minute drain vary from 0.000 to 0.002 mg.L^{-1}. All these copper contents are very low compared to the acceptable limit value of 2 mg.L^{-1}.

Taking the two water samples at each of the previous taps randomly during the day (e.g. one at 12 p.m. and the other at 5 p.m.) made it possible to assess the typical concentrations of copper at which consumers can be exposed. These concentrations vary from 0.001 to 0.022 mg.L^{-1}. They are very low compared to 1 mg.L^{-1} concentration limit for aesthetic purposes and much lower than 2 mg.L^{-1}, concentration limit set by [5] for health reasons.

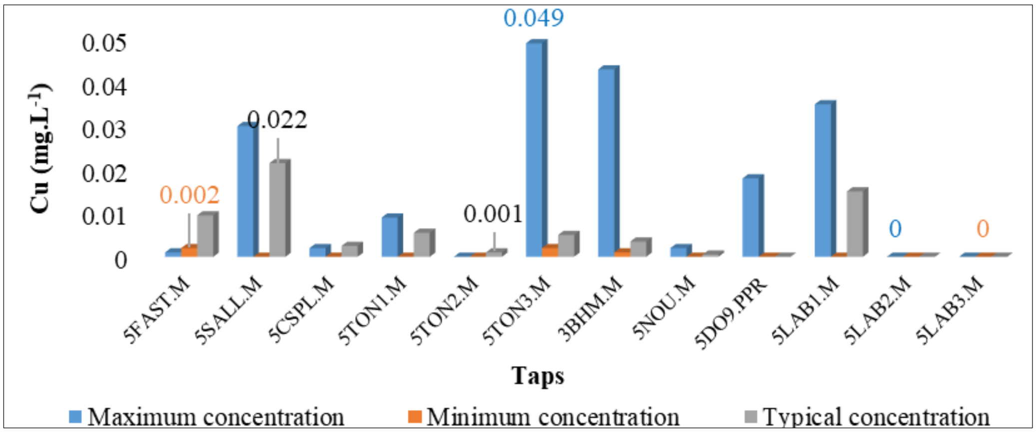

Figure 4 Maximum, minimum and typical concentrations of Cu in tap water

3.3.2. Maximum, minimum and typical concentrations of iron in tap water

According to the [11] no guideline value based on health arguments has been proposed for iron. However, its presence stimulates the growth of iron-hungry bacteria and also affects the color and odor of the water when its content exceeds the guideline value of 0.3 mg.L^{-1}.

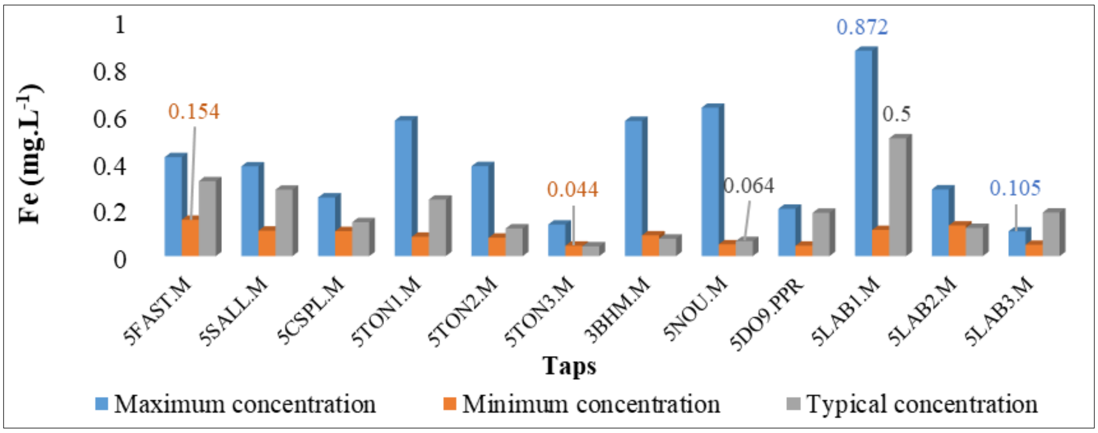

Figure 5 Maximum, minimum and typical concentrations of Fe in tap water

The maximum concentrations of iron to which the population can be exposed in tap water was assessed by sampling after water stagnation for 6 hours. Figure 5 shows the concentrations of Fe in water from different taps varying from 0.105 to 0.872 mg.L^{-1}. Thus, 7 out of 12 taps, i.e. 58.33%, have levels above the guideline value of 0.3 mg.L^{-1} set for aesthetic reasons.

The sampling of one liter after running the water for 5 minutes at each tap made it possible to obtain much lower iron concentrations (about 2 to 12 times lower) than in the cases where the sampling is not preceded by any purge. These concentrations vary from 0.044 to 0.154 mg.L^{-1}. They are all below the guide value. Therefore, the minimum concentration of Fe that can be found in tap water is of the order of 0.044 mg.L^{-1} when water stagnation for 6 hours is followed by a 5-minutes emptying at flow rate maximum.

3.3.3. Maximum, minimum and typical concentrations of lead in tap water

Lead is usually present in drinking water due to its leaching by the elements of the distribution system or the plumbing. In the past, lead was frequently used in service lines, solders, and fittings, making its presence in drinking water more likely in older homes and neighborhoods. A maximum acceptable concentration of 0.005 mg.L^{-1} (5 µg.L^{-1}) is proposed by [3] for total lead in drinking water, measured in a tap water sample and according to the appropriate sampling protocol for the type of building. The WHO proposes a guide value of 0.010 mg.L^{-1}.

The maximum concentration of lead that can be leached in tap water was assessed by taking samples after water stagnation for 6 hours in domestic pipes. The concentrations found vary from 0.023 to 0.063 mg.L^{-1} (Figure 6). All the samples show lead levels exceeding 0.010 mg.L^{-1}. Sampling after water stagnation for 6 hours followed by a 5-minutes drain at maximum flow rate found lead concentrations in tap water ranging from 0 to 0.061 mg.L^{-1}. These concentrations are lower at 91.66% of the taps compared to those found in the case where the sample is taken without purging (the case where the 5TON2.M sample, on the other hand, has a high lead content, after purge, means the lead source is some distance from the valve).

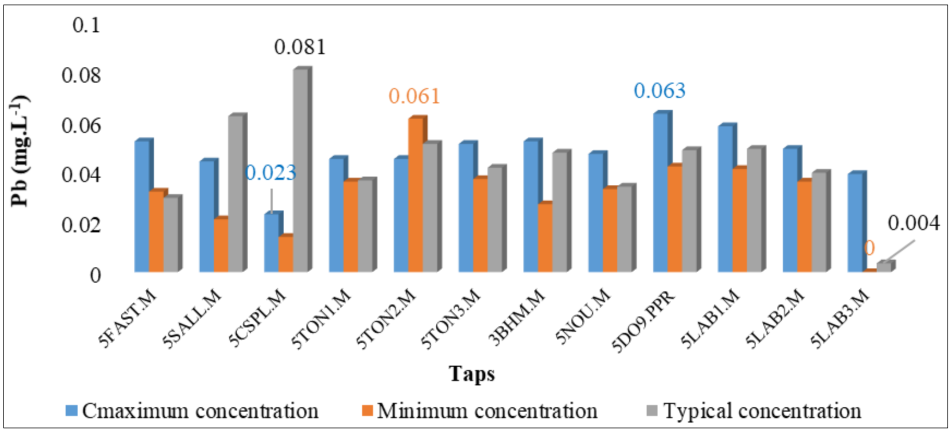

Figure 6 Maximum, minimum and typical Pb concentrations in tap water

3.3.4. Maximum, minimum and typical concentrations of zinc in tap water

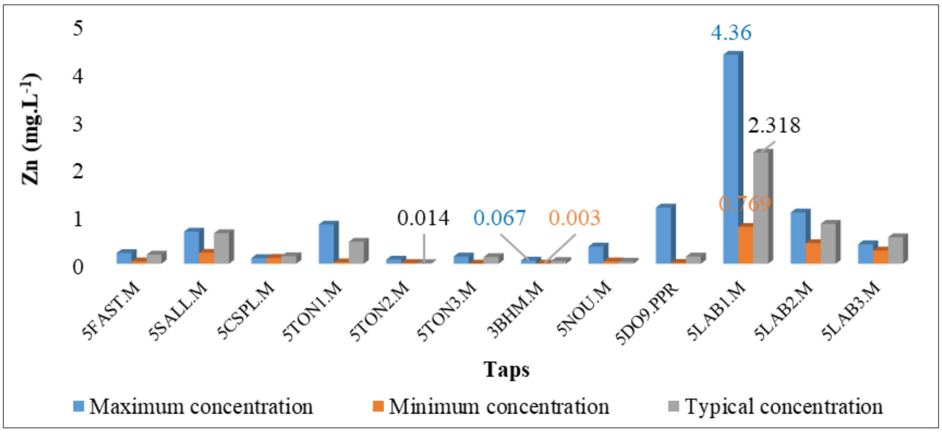

Figure 7 Maximum, minimum and typical concentrations of Zn in tap water

Although drinking water rarely contains zinc in concentrations above 0.1 $mg.L^{-1}$, levels in tap water can be significantly higher due to zinc present in older galvanized materials used in plumbing [11]. The aesthetic quality objective for zinc is ≤ 5.0 $mg.L^{-1}$ and the guideline value is set at 3 $mg.L^{-1}$ [15].

The maximum concentrations of zinc found after water stagnation for 6 hours, shown in Figure 7, vary from 0.067 to 4.360 $mg.L^{-1}$. The so-called minimum concentrations obtained after stagnation of the water for 6 hours followed by emptying for 5 minutes at maximum flow oscillate between 0.003 and 0.769 $mg.L^{-1}$. Typical Zn concentrations in water taken from the same taps range from 0.014 to 2.318 $mg.L^{-1}$. Concentrations are below the guideline value of 3 $mg.L^{-1}$. They are generally between the maximum concentrations and the minimum concentrations.

4. Discussion

The low concentrations of copper would be due to the nature of the individual branch pipes; to incrustations which would form poorly soluble deposits within the pipes and to the nature of the water, in particular the pH (6.54-7.74). These results show that the stagnation of water in the pipes for 6 hours favors the dissolution of copper and draining the water for at least 5 minutes makes it possible to considerably reduce the concentration of copper at the outlet of the tap. However, the second liters (from two taps: 5FAST.M and 5TON3.M) taken after 5 minutes flow showing higher copper concentrations than the first liter after 6 h stagnation means that the copper source is at a certain distance (because the water must be evacuated for 5 minutes, at maximum flow, so that the water with a higher Cu content can reach the tap).

The analysis results, presented in figure 5, showed that the total iron varies from 0.064 to 0.500 $mg.L^{-1}$. Some of the samples then contain iron at levels exceeding the guideline value of 0.300 $mg.L^{-1}$. These results thus show that the stagnation of water in domestic installations favors the dissolution of iron at relatively high concentrations (58.33% of the samples exceed 0.3 $mg.L^{-1}$ of Fe). When a 5-minutes flush is performed just after water stagnation, iron concentrations are lowered to lower values but do not cancel each other out. The estimate of the typical concentration showed that 16.66% of the samples exceed 0.3 $mg.L^{-1}$ of Fe. Consumer exposure concentration. Because, sampling after stagnation without purging and sampling after stagnation followed by purging can respectively overestimate and underestimate the concentration of iron in tap water.

The evaluation of the typical exposure of the population to lead showed lead concentrations varying between 0.004 and 0.081 $mg.L^{-1}$. Thus, several samples (91.66%) greatly exceed the guide value of 0.010 $mg.L^{-1}$ of Pb. This excess is due to the pH values of the water in the samples taken, which range between 6.54 and 7.74. Because the estimation of the dissolution potential of Pb showed an order of magnitude of predictable average Pb contents of 0.025 to 0.050 $mg.L^{-1}$ when the pH is between 7.0 and 7.5 [16]. In addition, the Pb concentration can be greater than 0.050 $mg.L^{-1}$ when the pH is less than 7 [16]. Furthermore, similar concentrations of Pb, in this study, were found in water of pH 7.04 stagnated in different pipes when the aging of these pipes ranged from 28 to 90 days.

Lead in tap water mainly comes from lead solders as they typically contain 50 to 60% lead [17]. Lead is thus detached in water mainly by phenomena of galvanic corrosion. Indeed, a solder behaves like an electrochemical cell in which copper plays the role of the cathode (the most noble metal), lead the role of the anode and water the role of the electrolytic solution. Thus, the lead contained in the solder dissolves in the water and can, as in the case of lead service entrances, play a passivating role by forming a protective film on the surface of the solder [17].

Also, the zinc used for galvanizing steel pipes contains lead in a content of up to 1%. Because the presence of lead is necessary to obtain a good adhesion of zinc on steel.

Brass and bronze plumbing fixtures and fittings also contribute to lead levels in tap water. Thus, the main phenomenon governing the release of lead from brass/bronze alloys is galvanic corrosion. These alloys are made up of a mixture of copper, zinc, tin and lead. Zinc, mainly, and copper, on a smaller scale, dissolve in the alloy and reveal the lead inclusions. Exposure of these inclusions to lead makes them prone to corrosion or detachment, and therefore to increased lead concentrations in tap water [4 ;17]. This problem is of particular concern in schools and large buildings due to the very large number of brass elements and the sometimes prolonged stagnation times compared to a house.

Consequently, recent studies on humans have made it possible to highlight the effects due to a blood lead level of the order of 0.015 to 0.020 $mg.L^{-1}$. These are long-term neurological, renal and cardiovascular effects. Furthermore, it has been reported that lead has no known physiological role, which leads to considering that it has non-threshold toxicity [9]. In addition, [2] showed that the association between the concentration of lead in tap water and the blood lead level

(PbS) is positive and statistically significant. Letting the water run for 5 minutes before consumption would reduce by about 40% the proportion of children expected to have a PbS ≥ 5 $\mu g.L^{-1}$ during the hot months.

The Zn concentrations, in the first liter after stagnation followed by draining for 5 minutes, are 1 to 5 times lower than those obtained in the first liter after stagnation without draining. Therefore, the emptying of the water at the tap made it possible to considerably reduce the concentration of Zn in the tap water. Typical Zn concentrations in water taken from the same taps are generally between the maximum and minimum concentrations. It appears here that the maximum and minimum concentrations could respectively overestimate and underestimate the human exposure to zinc in tap water.

5. Conclusion

The study of the maximum and typical level of Cu, Fe, Pb and Zn made it possible to show that the concentrations of these different elements could vary according to the type of sample. The samples of the first liters taken after a stagnation of 6 hours contain more metals than the samples taken after a draining of 5 min. This is explained by the important role played by stagnation in the release of these metals. Thus, the concentrations of Cu, Fe, Pb and Zn obtained by random sampling without stagnation or prior purging could better correspond to the consumer exposure concentrations. Indeed, sampling after stagnation without purging and sampling after stagnation followed by purging can respectively overestimate and underestimate the concentrations of these metallic trace elements in tap water. It should be noted that the evaluation of the typical concentration of Cu, Fe, Pb and Zn showed that 91.66% and 16.66% of the analyzed samples exceed the respective guide values for Pb and Fe. The typical concentrations of Zn and Cu in the water taken from the same taps comply with the guide values.

Compliance with ethical standards

Acknowledgments

The authors would like to thank the Materials-Waters-Environment Laboratories of the Faculty of Science and Technology and the Laboratory for Chemical Analysis and Process Improvement of the Société des Mines de l'Aïr (SOMAÏR) in Niger where the analyzes were carried out.

Disclosure of conflict of interest

The authors stated that they have no competing interests.

References

[1] Gauthier V. Particles in drinking water networks: characterization and impact on the quality of the distributed water [Ph.D. Thesis]. France: Henri Poincaré University - Nancy I; 1998.

[2] Jumeni GN. Impact of lead concentrations in tap water on blood lead levels in children aged 1 to 5 years, and estimation of the modifying role of nutritional and socio-demographic factors [Ph.D. Thesis]. Canada: LAVAL University. 2015.

[3] Health Canada. Lead in drinking water. Canada: Federal-Provincial-Territorial Committee on Drinking Water; 2017.

[4] Deshommes E. Particulate lead in tap water: source, occurrence, removal and bioaccessibility [Ph.D. Thesis]. France: University of Montreal; 2012.

[5] Health Canada. Copper in drinking water. Canada: Federal-Provincial-Territorial Committee on Drinking Water; 2018.

[6] Lytle DA, Schock MR. Impact of stagnation time on metal dissolution from plumbing materials in drinking water. Journal of Water Supply: Research and Technology-AQUA. 2000; 49(5): 243-257.

[7] Barn P, Nicol AM, Ma L. Measuring lead in school drinking water summary of sampling protocols. British Columbia: National Collaborating Center for Environmental Health; 2019.

[8] Ajuste C, Berland JM, Celerier JL. Rehabilitation / replacement of drinking water networks in rural areas. France: National Fund for the Development of Water Supply; 2004.

[9] INERIS. Lead and its inorganic derivatives. Toxicological and environmental data sheet for chemical substances. Version N° 4.1-2016. France: INERIS; 2016.

[10] AFNOR. Water quality: determination of eight metallic elements (Mn, Fe, Co, Ni, Cu, Zn, Ag and Pb) by flame atomic absorption spectrometry. 1st draw, Classification index T90-112. France: AFNOR; 1998.

[11] WHO. Health safety and water quality. 4th edition. Geneva: CC BY-NC-SA 3.0 IGO; 2017.

[12] Adamou H, Ibrahim B, Salack S, Adamou R, Sanfo S, Liersch S. Physico-chemical and bacteriological quality of groundwater in a rural area of Western Niger: a case study of Bonkoukou. Journal of Water and Health. 2020; 18(1): 77-90.

[13] Alhou B, Micha JC, Dodo A. Study of the physico-chemical and biological quality of the waters of the Niger River in Niamey. Int. J. Biol. Chem. Sci. 2009; 3(2): 240-254.

[14] Rodier J, Legube B, Merlet N. Water analysis: Natural water, waste water, sea water. 9th edition. Paris: Dunod Edition; 2009.

[15] UNEP. Global drinking water quality index development and sensitivity analysis report. Canada: National Water Research Institute; 2007.

[16] Austruy E. Lowering of the quality limit for lead in water intended for human consumption. Technical, social and legal assessment. Case of the city of Paris [Dissertation, Sanitary engineering]. France: School of high studies in public health; 2014.

[17] Riblet C. Assessment of exposure to lead from drinking water through the implementation of proportional valves. [Master of Applied Sciences]. France: University of Montreal, Polytechnic School of Montreal; 2018.