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Evaluation of the Degree of Pollution in Trace Metal Elements (TME) of the Dam in the Rural Commune of Korsimoro, Burkina Faso

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The objective of this study was to evaluate the level of pollution in trace metal elements from the dam in the rural commune of Korsimoro. Thus, nine (9) water samples were taken at different points of the dam and analyzed at the laboratory of the Bureau of Mines and Geology of Burkina (BU.MI.GE.B). A total of eight (8) metallic trace elements including As, Cr, Mo, Mn, Hg, Pb, Se and

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Ni were characterized and quantified using inductively coupled plasma optical emission spectroscopy (ICP/OES). The results reveal that if the contents of certain elements are low in certain samples, others on the other hand have sometimes very high contents of Hg and Se. For Hg, concentrations range from an average of 25.74 µg/kg to a maximum of 148.91 µg/kg against a threshold of 1 µg/kg recommended for water intended for irrigation. As for Se, its concentration ranges from an average of 14.67 µg/kg to a maximum of 37.01 µg/kg against a standard of 20 µg/kg for irrigation. Thus, the high concentrations of Hg and Se in the waters of the Korsimoro dam constitute a public health problem since they strongly contribute to the contamination of market garden products via the soil. Also, the animals which drink there as well as the resources fish (fish, shellfish, etc.) could be contaminated. And, by bioaccumulation and/or by biomagnification, humans at the end of the food chain can in turn be severely contaminated. Thus, it is imperative to find a solution, especially on the Hg pollution of the dam when we know that it constitutes a real public health problem with its excessively high content.

Keywords: Concentration; trace metal elements; pollution; standard.

1. INTRODUCTION

Market gardening is a very important activity which has experienced remarkable development over the last three decades in Burkina Faso. For arid and semi-arid areas where rainfall is variable and sometimes even very low, water reserves (ponds, dams, rivers, streams, wells, etc.) constitute real opportunities for this activity, especially in dry season [1]. In the rural commune of Korsimoro, a locality located approximately 70 km from the city of Ouagadougou, market gardening is booming around the dam which is the main water reservoir with an original capacity of 4.95x106 m3 of water [2]. Apart from the silting and irregular rainfall which threaten the existence of this large water reservoir, gold panning also constitutes a real threat to the quality of the water in the dam. Indeed, open-air mining releases numerous constituents including trace metal elements (TME) or heavy metals which, through drainage or other more complex mechanisms, end up in the dam and threaten the health of populations via market garden products [3-6]. Indeed, studies have regularly established the correlation between the quality of market garden products and their production environment (soil, water, air) [7-13]. And, this contamination of market gardening areas can be natural or anthropogenic [14-16]. Thus, the objective of this study is to evaluate the level of pollution in trace metal elements from the dam in the rural commune of Korsimoro. Also, the results of this work could help make data available in order to contribute to appropriate decision-making by the competent authorities. So, we constituted nine (9) water samples at different points of the dam in order to characterize and quantify, using ICP/OES at the laboratory of the Bureau of Mines and Geology of Burkina (BUMIGEB), the concentrations of eight (8) trace elements: Arsenic (As), chromium (Cr), molybdenum (Mo), manganese (Mn), mercury (Hg), lead (Pb), selenium (Se), and nickel (Ni).

2. MATERIALS AND METHODS

2.1. Study Zone

Korsimoro, capital of the North-Central Region, is a rural commune with an area of 603.40 km2 which has twenty-nine (29) villages. Its dam, completely developed in 1984, is its main water resource for market gardening which occupies approximately 231.8 hectares along the bank [17]. For this study, the nine (9) sampling points are shown in Fig. 1.

2.2. Physico-Chemical Parameters

Nine (9) polypropylene bottles, with a capacity of 1.5 liters, were used for sample collection. Rinsed several times with water from the dam, each bottle was filled and fixed with nitric acid [18]. The physicochemical parameters were measured in situ using an electronic multimeter. These are essentially the temperature (T), the hydrogen potential (pH) and the electrical conductivity (EC) which can affect the mobility and bioavailability of metallic trace elements [19,20].

2.3. Preparation of Samples for Analysis

The water samples were acidified in situ with nitric acid (HNO3). Thus, once in the laboratory, only the necessary quantity of each sample was taken to determine the eight (8) trace metal elements using an ICP/OES.

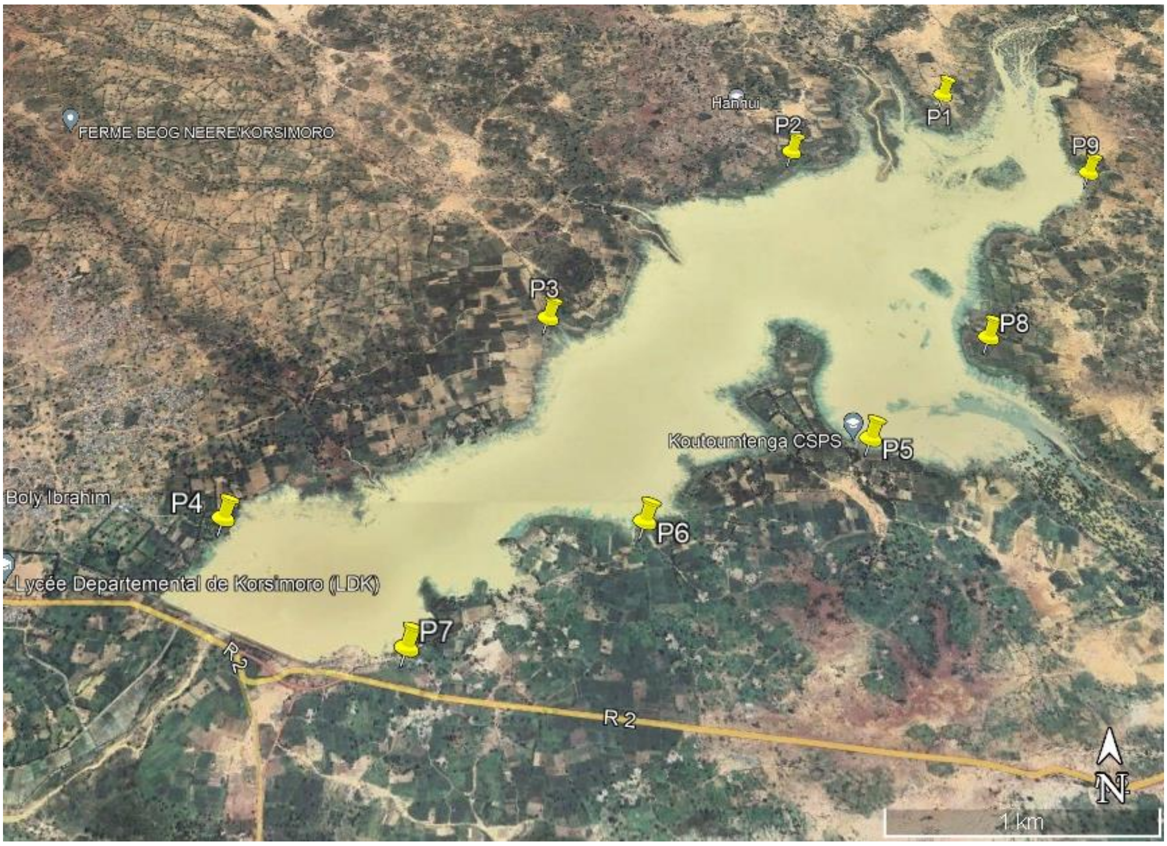

Fig. 1.Study area: Location of sampling points

3. RESULTS AND DISCUSSION

3.1 Assessment of Physicochemical Parameters

In this paragraph, we assess the physicochemical parameters of the water samples taken. Thus, before analyzing the physico-chemical parameters by sampling point, we assess the average physico-chemical parameters such as pHmoy, ECmoy, Tmoy which respectively indicate the average hydrogen potential, the average electrical conductivity and the average temperature of the different measurements. The reference standard used to assess these three parameters is that of Morocco for water resources intended for irrigation [21].

3.1.1 Average physicochemical parameters

The hydrogen potential of the dam water is between 6.69 and 7.15 with an average of 6.90. Thus, this interval complies with the Moroccan standard for irrigation which is 6.5 to 8.4. As for the average electrical conductivity, it is between 37.18 µS and 125.9 µS with an average of 67.37 µS. For temperature, it is between 15°C and 28.6°C with an average of 24.61 which is lower than the standard of 35°C. Thus, the influence of these three water parameters on mobility and bioavailability is less or even negligible.

Table 1. Averages of physicochemical parameters

Parameters	Minimum	Maximum	Average	Standard Deviation	Moroccan standard for irrigation
$\mathbf{pH_{moy}}$	6.69	7.15	6.90	0.16	6.5 à 8.4
$\mathbf{CE_{moy}}$ (µS)	37.18	125.9	67.37	42.59	12 (25°C)
$\mathbf{T_{moy}}$ (°C)	15	28.6	24.61	5.70	35

3.1.2 Physico-chemical parameters for each sampling point

Table 2. Physico-chemical parameters by sampling point

Parameters	P1	P2	P3	P4	P5	P6	P7	P8	P9
pH	6.71	6.81	6.89	6.9	6.97	6.84	7.15	7.13	6.69
CE	39.26	39.98	42.67	37.18	37.61	37.37	125.9	125.1	121.3
T(°C)	28.5	28.5	28.6	28.6	28.2	27.7	18.9	15	17.5

In Table 2, we see that all the hydrogen potential values belong to the standard range which is 6.5 to 8.4. Also, the values of electrical conductivity and temperature comply with the recommended thresholds which are respectively 12µS and 35°C.

3.2 Assessment of Concentrations (µg/kg) in ETM of Samples

In this part, we assess the concentrations of ETMs in the water samples. So, before discussing the concentrations of these elements in each sample, we say a word about the average concentration of each trace element in the dam. The reference standard used to assess these levels of trace elements is that of Morocco for water resources intended for irrigation.

3.2.1 Average concentration of trace metal elements in the dam

It can be seen that mercury is practically present in all samples. We note that its maximum concentration is 148.91 µg/kg with an average of 25.74 µg/kg, or 25 times more than the standard for irrigation water. Also, the minimum value of selenium is zero against a maximum of 37.05 µg/kg with an average of 14.67 µg/kg which is lower than the standard of 20 µg/kg for irrigation water. Moreover, the average concentrations of As, Cr, Mn, Pb, Se and Ni are below the recommended thresholds for each trace element. Finally, the maximum concentrations of ETM in the nine sampling points show that, with the exception of Hg and Se, the Korsimoro dam is not polluted in As, Cr, Mn, Pb, and Ni.

Table 3. Extrema of concentrations of metallic trace elements and standards (µg/kg)

Heavy metal	As	Cr	Mo	Mn	Hg	Pb	Se	Ni
Average	4.45	5.26	73.96	67.86	25.74	11.52	14.67	7.02
Minimum	0	1.08	0	44.49	0	0	0	1.67
Maximum	34.24	8.04	314.37	103.21	148.91	34.01	37.05	14.52
Standard Deviation	11.33	2.57	112.23	24.18	47.47	14.24	14.4	4.81
Standard [21-24]	100	100	-	200	1	5000	20	200

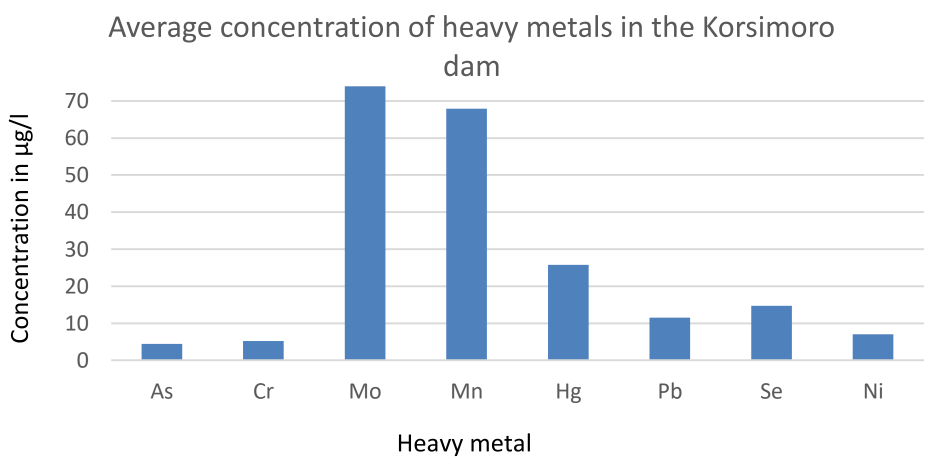

Fig. 2. Average concentrations of metallic trace elements in the Korsimoro dam

Fig. 2 below shows that the level of contamination of the dam by metallic trace elements is not uniform. Indeed, we note that As has the lowest average concentration of 4.45 µg/kg compared to a maximum concentration of Mo of 73.96 µg/kg. Thus, the order of contamination in metallic trace elements of the Korsimoro dam is as follows: Mo>Mn>Hg>Se>Pb>Ni>Cr>As.

3.2.2 Concentrations of trace metal elements per sample

The histograms below highlight the content of each trace metal element in the nine samples. Indeed, Figs. 3 to 10 allow us to better understand the level of pollution in ETM of the Korsimoro dam.

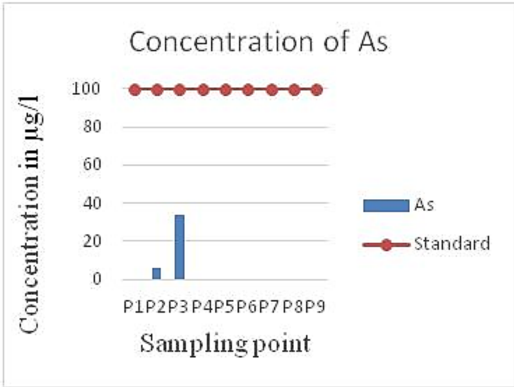

Fig. 3. Arsenic concentration by sampling point

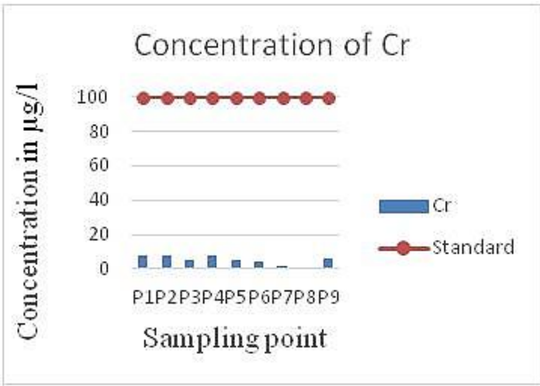

Fig. 4. Chromium concentration by sampling point

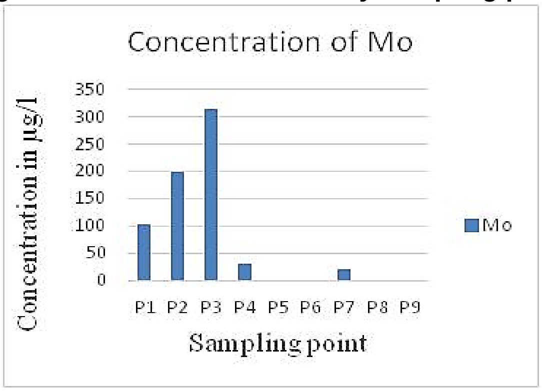

Fig. 5. Molybdenum concentration by sampling point

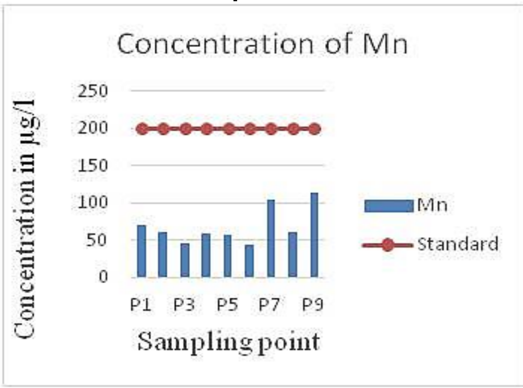

Fig. 6. Manganese concentration by sampling point

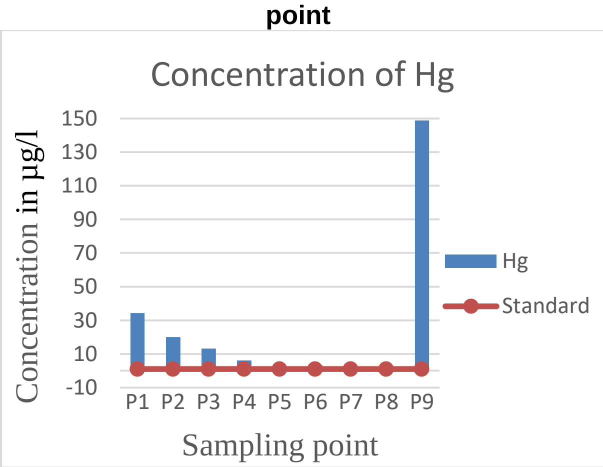

Fig. 7. Mercury concentration by sampling point

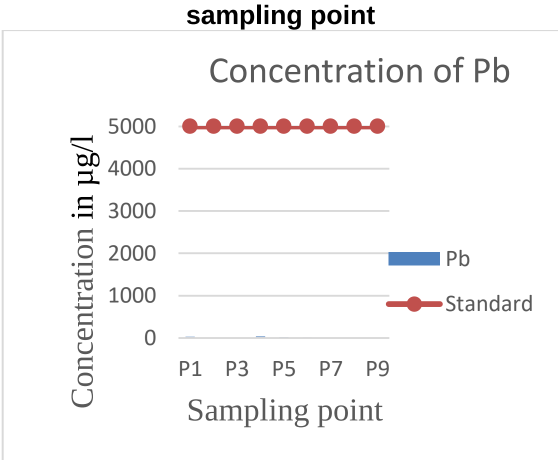

Fig. 8. Lead concentration by sampling point

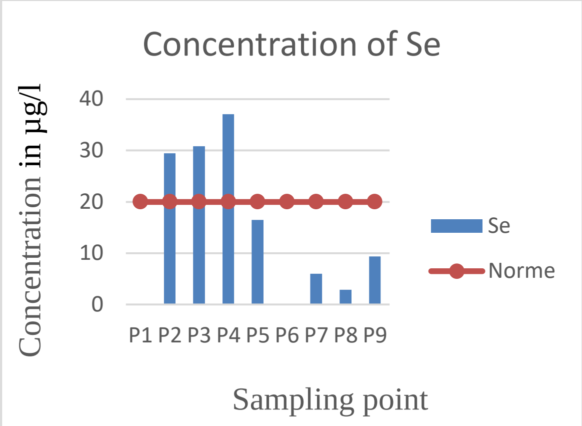

Fig. 9. Selenium concentration by sampling point

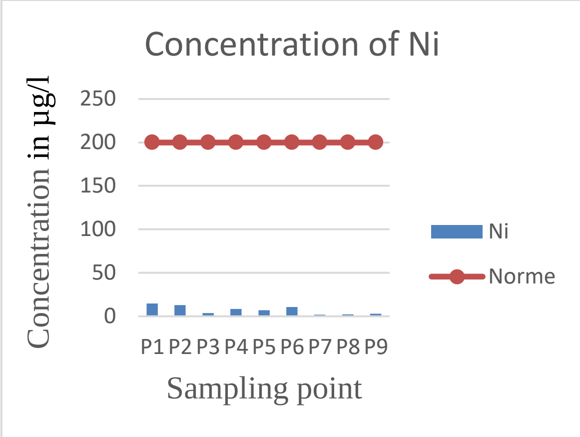

Fig. 10. Nickel concentration by sampling point

Arsenic (As): Apart from points P2 and P3 which have respectively 5.81 µg/kg and 34.24 µg/kg of As, the seven (7) other water samples from the dam have zero contents of this element. Thus, the concentration of As is not uniform throughout the dam. Better, these As levels observed in samples P2 and P3 are lower than the recommended standard for water intended for irrigation which is 100 µg/kg.

Chromium (Cr): Cr is present in all water samples analyzed at fairly low concentrations. Its minimum content is observed at point P8 and the maximum at point P1 with values of 1.08 µg/kg and 8.04 µg/kg respectively. Despite the presence of this element in the nine samples, its concentration is well below that recommended for water intended for irrigation, which is 100 µg/kg. Thus, a study of the sediments and environment around the dam could provide a more plausible explanation for the origin of Cr in Korsimoro Dam. In total, the order of contamination of the Cr dam is as follows: P1>P2>P4>P9>P5>P3>P6>P7>P8.

Molybdenum (Mo): The concentration of Mo is zero in samples P5, P6, P8 and P9. The maximum content is observed at the P3 sampling point of the dam with a value of 314.37 µg/kg. Also, samples P1, P2, P4 and P7 have respectively 103.16 µg/kg, 197.97 µg/kg, 30.96 µg/kg and 19.16 µg/kg as molybdenum concentrations.

Manganese (Mn): We see that Mn is present in all the samples measured. Its minimum content being 44.49 µg/kg for sample P6 compared to a maximum of 112.92 µg/kg for sample P9. However, all samples have levels that are below the threshold of 200 µg/kg. In summary, the order of contamination of the analyzed samples is as follows: P9>P7>P1>P8>P2> P4>P5>P3>P6.

Mercury (Hg): With the exception of P7 which has a zero concentration of Hg, its content in the eight (8) other water samples taken from the Korsimoro dam turns out to be very high. Indeed, the concentrations of Hg in samples P1, P2, P3, P4, P5, P6, P8 and P9 are respectively 34.25 µg/kg, 20.08 µg/kg, 13.28 µg/kg, 6, 08 µg/kg, 2.70 µg/kg, 3.36 µg/kg, 2.99 µg/kg and 148.91 µg/kg. All these concentrations are above the recommended standard for water resources intended for irrigation which is 1 µg/kg. The maximum concentration is observed at sampling point P9 with a value of 148.91 µg/kg, almost 148 times more than the recommended standard. In summary, the order of mercury pollution in the dam is as follows: P9>P1>P2>P3>P4>P6>P8>P5; with an average of 25.74 µg/kg. Thus, the water from the Korsimoro dam turns out to be polluted with mercury. These excessive levels of Hg in the dam constitute a real threat to the health of populations when we know that market garden products (vegetables, leaves, fruits) are contaminated via the soil. Volatile as it is, once on the ground, this metal can be inhaled by market gardeners and cause serious health problems, especially for children and pregnant women. Indeed, in its vapor form, the toxicity of Hg is first expressed via the respiratory tract, then dissolves in the plasma, blood and hemoglobin in order to attack the kidneys, the brain and the nervous system. The abundant presence of Hg in the dam can be justified by the fact that it is widely used by gold miners to search for the precious metal in the locality without precaution.

Lead (Pb): With the exception of samples P7, P8 and P9, lead is present in all water samples analyzed. Thus, the presence of this metal in the Korsimoro dam is in places with concentrations well below the recommended threshold for water intended for irrigation which is 5000 µg/kg. The maximum lead concentration is observed at sampling point P4 with a value of 34.01 µg/kg. Which means that the lead contamination of the Korsimoro dam is low and localized. However, with the help of the phenomenon of bioaccumulation, the presence of this element in the soil, through irrigation, can in the long run constitute a health problem through market garden products and also a threat to children who have pica. Ultimately, the order of lead contamination in the dam is as follows: P4>P3>P5>P6>P2>P3.

Selenium (Se): The Se content was zero in samples P1 and P6. We note that it is sample P4 which has the highest concentration of 37.01 µg/kg. Also, 29.48 µg/kg, 30.83 µg/kg, 16.50 µg/kg, 5.97 µg/kg, 2.86 µg/kg and 9.34 µg/kg were respectively the concentrations of Se for sampling points P2, P3, P5, P7, P8 and P9. Thus, we note that samples P2, P3 and P4 have concentrations higher than the recommended standard for irrigation which is 20 µg/kg. Thus, samples P2, P3 and P4 had concentrations higher than the recommended standard for irrigation which is 20 µg/kg. In places, the Korsimoro dam was polluted with selenium with concentrations up to 1.54 times normal. The use of this water can affect the quality of market garden products and thus the health of consumers. The order of selenium pollution of the Korsimoro dam was: P4>P3>P2>P5>P9>P7>P2.

Nickel (Ni): This element was present in all samples analysed with relatively low concentrations which varied between 1.67 µg/kg and 14.53 µg/kg. Thus, all concentrations were lower than the recommended standard which is 200 µg/kg. However, the presence of this element in the nine (9) sampling points with a low concentration suggested that it was a diffuse contamination. A study of the sediments and the environment of the dam could better determine the origin of this contamination. In total, the order of Ni contamination in the Korsimoro dam was as follows: P1>P2>P6>P4>P5>P3>P9>P8>P7.

4. CONCLUSION

The results of this study reveal that the average physicochemical parameters (pH, electrical conductivity and temperature) and per sampling point comply with Moroccan standards for water intended for irrigation. Also, with the exception of Hg, we note that the average concentrations of As, Cr, Mn, Pb, Se and Ni are lower than the recommended standards for water intended for irrigation. In fact, the average concentration of Hg is 25.74 µg/kg, or 25 times more than normal. In addition, the diagnosis of the contents of all the nine (9) sampling points shows that apart from P7, the other points are highly polluted in Hg; are respectively 34.25 µg/kg, 20.08 µg/kg, 13.28 µg/kg, 6.08 µg/kg, 2.70 µg/kg, 3.36 µg/kg, 2.99 µg/kg and 148.91 µg/kg for sampling points P1, P2, P3, P4, P5, P6, P8 and P9 of the dam. In addition, points P2, P3 and P4 are polluted in Se with respectively 29.48 µg/kg, 30.83 µg/kg and 37.01 µg/kg as concentrations against a standard of 20 µg/kg for water 'irrigation. We can conclude from the above that the very high concentrations of Hg and Se in the Korsimoro dam constitute a public health problem since they strongly contribute to the contamination of market garden products via the soil [12,25]. Also, the animals that drink there as well as the fishery resources (fish, shellfish, etc.) could be contaminated [26]. And, by bioaccumulation and/or by biomagnification, humans at the end of the food chain can in turn be severely contaminated [27,26,28,29,11,8]. Thus, it is imperative to find a solution, especially on the Hg pollution of the dam when we know that it constitutes a real public health problem with its excessively high content.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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