Physico-Chemical and Microbiological Assessments of Water Wells Consumed in Tshamilemba and Kabetsha Quarters, Lubumbashi Suburb in the Democratic Republic of Congo

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Abstract: ***The Tshamilemba and Kabetsha quarters are located in industrial area and are experiencing environmental degradation, reflected by the appearance of whitish substances perceptible on the walls of houses and on the floors. The degradation of the air and water of domestic wells as well as that of the gardens vegetables is observed every day. Due to a lack of a treated water supply system, many residents resort to water from wells to meet their household needs. The present study aims to evaluate the physico-chemical and bacteriological parameters of this water. It is based on the dosage of metallic elements in well's water and by making clearly the Escherichia coli. The dosage of the chemicals elements was done by inductively coupled plasma (ICP). Escherichia coli have been realized by innoculation in liquid culture medium. The mean aluminum concentrations were found to be statistically above the average reference value in eight wells; the same for seven wells concerning manganese; six for cobalt and nickel, three for lead and one for copper. In contrast, only three Kabetsha's wells gave statistically higher mean aluminum concentrations. The search for Escherichia coli was positive in 36% of the wells studied in Tshamilemba. It was 100% in Kabetsha. Since Escherichia coli circulate through the negligence of the population, the inhabitants of the two neighborhoods would be partly responsible for the microbiological fails of the water of the wells they use.***

Keywords: Water wells, mining, emanations, metallic elements, Escherichia coli, pollution, environmental, Tshamilemba, Kabetsha, Lubumbashi

1. Introduction

Water is a natural resource essential to any living organism. Having it at our disposal in sufficient quantity and in required quality contributes to the maintenance of health. However, water can also be a source of diseases, due to its pollution by industrial discharges, household or agricultural waste, excrement etc. (Scanlon et *al*., 2005; El-Naqa et *al*., 2007 ; Eblin et *al*., 2014).

According to the World Health Organization (WHO), 2.1 billion people do not have access to safely managed water services and 423 million people use well water and unprotected sources. More than 2 million people, mostly children under five in developing countries with poor hygiene and sanitation, die each year from water-related diseases (WHO, 2019). Water has now become a global strategic issue, the management of which must imperatively be integrated into a political perspective of sustainable development (Servais and *al*., 2009). Thus, the supply of drinking water to the populations in sufficient quantity in all seasons remains one of the major concerns of the various governments (Hawa, 2002).

However, the Democratic Republic of Congo contains 52% of the total surface water reserves of the African continent and abundant easily exploitable groundwater throughout the national territory. Some of these aquifers are the subject of drilling and abstraction for the supply of fresh water in both urban and rural areas. Unfortunately, the mining and metallurgical industries expose humans and the rest of biodiversity to the risk of poisoning, due to the irresponsible management of the freshwater ecosystems available to the country (Banza, 2012).

Toxic waste resulting from mining and metallurgical activities, particularly in the mining region of Haut-Katanga, is massively discharged into watercourses. They cause pollution of these rivers as well as the water tables. The consequence of this phenomenon is the significant human exposure to metallic elements depending on the living areas. Indeed, people living near factories would be the most affected. This is the case for residents of the Tshamilemba and Kabetsha neighbourhoods who find themselves in the middle of the area. Signs of environmental pollution are, in fact, visible in this industrial area. These include the appearance of perceptible whitish substances on the walls of houses and on the floors, the deterioration of the quality of air and water from domestic wells and the deterioration of the vegetation of vegetable gardens (Banza, 2012).

In addition, it was noted that, due to insufficient supply of treated water, several inhabitants of the Tshamilemba and Kabetsha districts have wells to supply water. This is how this study, sequenced in two phases, will first tackle the assessment of the quality of well water in these two districts.

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To achieve this, we will proceed by the determination of the metallic elements in the well water and their bacteriological analysis. This analysis will consist in demonstrating the presence of Escherichia coli, normal host of the digestive tract of humans and warm-blooded animals. Indeed, the presence of this germ in water is indicative of a possible presence of enteropathogenic agents following faecal contamination (Dellaras, 2010).

The assay of the chemical elements will be by atomic emission spectrophotometry using an inductive plasma generator, while the detection of Escherichia coli will be carried out by the method of seeding in liquid medium (Rodier and *al*., 2009; Girard, 2011; Cardot & Gilles, 2013).

2. Methodology

2.1 Presentation of the Research Environment

The Kabetsha and Tshamilemba districts, located in the Kampemba commune, city of Lubumbashi, Haut-Katanga province in the Democratic Republic of the Congo, were chosen as the study environment.

These two districts are located not far from the mining companies involved in the metallurgical processing of copper ores, cobalt and other rare metals (Banza, 2012).

2.2 Methods

Sampling

A comprehensive survey in the two districts was carried out to identify the wells. The non-probabilistic method was used for sampling because the wells were chosen so as to have a global view. To constitute a representative sample, the 2012 version of the Accounting / petium 2 software made it possible to take the sample size which was 11 wells for the Kabetsha district, and 3 wells for Tshamilemba. Since these are results to be compared, the sample size for Tshamilemba district was reduced to 11, making a total of 22 wells.

Five samples per well were taken for chemical analyzes and 2 samples per well for microbiological studies, making a total of 154 samples.

The samples were taken using a small bucket or an appropriate device. The taking of a sample is a delicate operation to which one must be very attentive because it conditions the analytical results and the interpretation which will be given. Thus for a chemical analysis, according to the recommendations of Rodier (2009), polyethylene bottles were used, they were rinsed with 55% nitric acid, and at the time of sampling, they were again rinsed three times. times in water to be analyzed then filled to the brim and the caps were correctly placed.

For the microbiological analysis, the same types of flasks were used, but here the samples were taken under strict hygienic conditions in order to avoid contamination of the samples by the sampler. Thus, it was avoided for example to touch the inside of the vial, and to draw water to a volume of 100 to 200ml, leaving an air volume of about 1/10 of the volume of the bottle, then close immediately the vial. As soon as the sample was taken, each container was carefully, clearly and precisely labelled to identify it (McNabb & Mallard, 1984 ; Azadpour-Keeley, 2000; Alégoët, 2006, Centre d'expertise en analyse environnementale du Québec, 2009). And it was agreed that after sampling, the analysis of samples is done as quickly as possible. Otherwise, the samples were stored in the refrigerator between 1 ° C and 10 ° C, in order to suppress any microbial activity (Berho, 2008; Fondation Nationale de la Santé, 2013).

2.2.1 Plasma atomic emission spectrophotometry for chemical analysis

Emission spectrophotometry using an inductive plasma generator is generally called ICP (Inductively Coupled Plasma). This technique offers interesting possibilities: a sensitivity generally superior to atomic absorption spectrophotometry with flame, little interference, the simultaneous determination of many elements (Rodier and *al.*, 2009).

2.2.2 Seeding in liquid medium for the detection of Escherichia coli

a) First step: presumption

The bacteriological examination of water in a liquid culture medium begins with a presumption test. It consists in inoculating the water sample to be analyzed in a suitable liquid culture medium, in test-tubes which are then incubated at 37 ° C and examined after 48 hours (Dellaras, 2010).

b) Second step: confirmation by Mackensie test

Indeed, the presumption test will be supplemented by a test to confirm the presence of coliforms. The most convenient method is to transplant the contents of each positive tube in the presumption test into two tubes, one containing brilliant breen bile broth and the other containing indole-free peptone water; they will then be incubated at 44 ± 0.5 ° C for 48 hours (Dellaras, 2010).

Read the gas test on the brilliant breen bile broth tube and the indole test on the peptone water tube using Kovacs reagent; the presence of *Escherichia coli* is reflected in the formation of a red ring above the broth, and the presence of gas in the broth of brilliant breen bile broth.

3. Presentation of Results and Discussion

The well census in the two districts gave 34 wells for the Tshamilemba district and 107 for the Kabetsha district. As mentioned above, the sample size was 22 wells due to 11 wells per district.

Presentation and discussion of the results of chemical analysis

For the discussion of the results, the Graph Pad software allowed us to use the Student test as a statistical test (with $\alpha = 0.05$).

The results obtained at the end of the dosage of the metallic elements are presented in Tables I and II.

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Table I: Concentration of metallic elements in the Tshamilemba wells

		Concentration of chemical elements (in µg / l) (n = 5)								
		Aluminium	Barium	Chromium	Cobalt	Copper	Lead	Manganese	Nickel	Zinc
RLV (WHO, 2006 ; Rodier, 2009)		200	700	50	1000	2000	10	400	70	3000
Wells	P_1T	785±63	13,2±0,8	4±1,6	13,6±3	3,4±1,14	0	114,4±11,9	2,8±0,4	4,4±0,9
	P_2T	2818,8±214,6	62,8±3,9	1,8±0,83	10,6±1,51	0	4,4±1,14	34,6±7	13,6±0,5	20,8±0,83
	P_3T	340±47,9	10	13,6±2,6	10168±378,5	1293,2±156,3	7±1,73	3501±111,4	99±7,1	1636±73
	P_4T	401,4±71,3	12,2±0,4	19,2±2,5	16854±367,7	638,2±38,15	9,2±2,16	4984±89,9	107±9	1776±31,8
	P_5T	4882,2±382,9	15±2,5	26,2±10	10944±681,18	1239,4±116,3	16,8±2,8	4819±412,5	170±15,6	984,8±37,06
	P_6T	187,6±34,18	11,8±3,5	55,4±13,7	877,8±62,35	37,8±8,34	2,8±0,83	414,8±61,65	6,6±1,52	24,4±7,82
	P_7T	342±90,22	10,6±0,89	54,2±16,7	428,4±114,42	51±15,083	2,6±0,55	2885±237	2,6±0,55	40,2±7,8
	P_8T	114,8±12,25	13,2±2,86	9,8±2,5	26,4±4	5,8±2,04	6,8±1,3	90±19,5	3,4±1,14	13,2±3,27
	P_9T	4627±179	172,2±1	14±0,7	3392±89	145,8±9,28	165,4±6,3	3258±41	71,4±0,9	147,2±13,4
	$P_{10}T$	1843,8±97	11,2±1,3	9±1,2	11462±121,5	5497,2±239,32	44,2±11,73	4159±48	95,2±1,3	1353,2±41
	$P_{11}T$	183,4±11	20,2±4	8±1	4603,4±57,2	38,4±9,5	5,8±1,3	3805±35	192,4±0,5	337,2±6,2

RLV: Reference Limit Value

Table II: Concentration of metallic elements in the Kabetsha wells

		Concentration of chemical elements (in µg / l) (n = 5)								
		Aluminum	Barium	Chromium	Cobalt	Copper	Lead	Manganese	Nickel	Zinc
RLV (WHO, 2006 ; Rodier, 2009)		200	700	50	1000	2000		10	70	3000
wells	P_1K	101±14,4	41,2±3,3	5,2±2,5	9,4±2,2	8,8±5,5	0	29±2	5,6±1,1	22±4,2
	P_2K	88,2±2,5	62,8±4	1,8±0,83	9,4±2,6	0	4,2±0,83	34,6±7	13,6±0,5	21±1
	P_3K	154,4±5,17	46,2±1,5	0	6,8±1,3	7,4±1,14	4,4±0,55	28,4±2,19	5,2±0,83	17±3
	P_4K	394±51,4	158,2±6,2	3,6±0,89	21,8±4	0	5±1	94,2±3,11	14,2±2,8	26,2±5,2
	P_5K	90,4±12,9	157±4,4	4,2±0,83	9,6±0,5	5,7±0,7	0	43,4±8,79	9±1	11,6±0,54
	P_6K	129,8±16,57	156,8±20,1	8,2±0,83	4±0,7	0	0	10,8±0,83	2,4±0,54	4,6±0,9
	P_7K	138,8±3,11	111,8±4,9	5,8±0,83	9,6±1,14	0	0	7±1, 7	0	7,4±1,14
	P_8K	69,4±11,58	68,6±11,5	8,6±1,6	5,2±0,83	0	0	97,4±5,32	0	11,4±0,9
	P_9K	56,8±13,6	142±14,2	3,2±1,3	4,8±0,83	13,8±2,7	1,8±0,83	83,2±11,77	1,4±0,54	7,4±1,52
	$P_{10}K$	1307,6±54,3	263,2±4,6	10,6±0,5	7±0,7	20,4±0,8	0	62,4±1,14	1,2±0,4	13,4±0,54
	$P_{11}K$	314,6±24,4	307,4±13,5	9,6±0,5	2,2±1	7±1,7	4,1±1	32±1,22	0	8,4±1,14

It appears from Table I that the chemical analyzes carried out on the water samples from the wells taken in the Tshamilemba district have made it possible to highlight concentrations of nine metallic elements: Aluminum (Al), Barium (Ba), Chromium (Cr), Cobalt (Co), Copper (Cu), Manganese (Mn), Nickel (Ni), Lead (Pb) and Zinc (Zn). It should be noted that concentrations above the reference limit values are colored red.

Among these elements, barium and zinc are at normal concentrations, that is to say, not exceeding the maximum reference limits. Indeed, for barium, the limit is 700 µg / l, but the well with a higher concentration is P9T with 172.2 ± 1 µg / l as the value; for zinc, the reference limit value is 3000 µg / l, but the well P4T gave the highest concentration which was 1776 ± 31.8 µg / l.

As for the other 6 metallic elements, the situation is as follows:

The aluminum and manganese contaminations were the most remarkable. For aluminum, among the 11 wells studied, only 3 showed concentrations below the reference limit (200 µg / l). The other 8 wells including P1T, P2T, P3T, P4T, P5T, P7T, P9T and P10T (i.e. 72.72%) showed concentrations ranging from 340 ± 47.9 µg / l for P3T to 4882.2 ± 382, 9 µg / l for P5T. These values are statistically higher than the reference limit value ($P<0.0001$ for P1T, P2T, P5T, P9T and P10T; $P<0.0028$ P3T; $P<0.0032$ for P4T and $P<0.0245$). Indeed, this high concentration of aluminum exposes the population of the neighborhood to Alzheimer's disease (Harrisson, 2002).

With regard to manganese, the P3T, P4T, P5T, P6T, P7T, P9T, P10T and P11T wells showed concentrations greater than 400 µg / l, value fixed as limit. These concentrations range from 414.8 ± 61.65 µg / l for P6T to 4984 ± 89.9 µg / l for P4T. The values statistically higher than the reference limit value range from 2885 ± 237 µg / l for P7T to 4984 ± 89.9 µg / l for P4T, $P<0.0001$ for P3T, P4T, P5T, P7T, P9T, P10T and P11T. But for P6T, the concentration is 414.8 ± 61.65 µg / l and $P<0.6199$; so this is a high value but not statistically significant. These concentrations expose the population to Parkinson's disease (Rodier and *al*, 2009; Bismuth, 2000).

Cobalt and nickel contaminations were high in 6 wells, or 54.54%. It should be noted that these were the same wells including P3T, P4T, P5T, P9T, P10T and P11T.

With regard to cobalt, the directives of the Council of the European Communities (CEC) and the WHO do not give a limit value for cobalt. A level of 1000 µg / l in water intended for human consumption could be considered as the limit concentration; this value was, moreover, that adopted by the former USSR (Rodier and *al*, 2009). The high concentrations in the wells studied range from 3392 ± 89 µg / l for P9T to 16854 µg / l for P4T. These concentrations are

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statistically higher than the reference limit value (P<0.0001 for the six wells). Consumers of these waters are then exposed to dermatitis irritation, respiratory pathologies (rhinitis and asthma), cardiomyopathies and polycythemia (Bismuth, 2000).

For nickel, the reference limit value is fixed at 70 µg / l. The higher concentrations range from 71.4 ± 0.9 µg / l for P9T to 192.4 ± 0.5 µg / l for P11T. These concentrations are statistically higher than the reference value (P<0,0001 for P5T, P10T and P11T; P<0,0008 for P3T and P4T; P<0,0249 for P9T). Consumers of water from these wells are then exposed to the risks of respiratory tract cancers, kidney damage and allergic dermatitis (Rodier et al., 2009; Bismuth, 2000).

With regard to lead, only 3 wells (27.27%): P5T, P9T and P10T gave concentrations higher than the limit concentration which is 10 µg / l. These concentrations range from 16.8 ± 2.8 µg / l for P5T to 165.4 ± 6.3 µg / l for P9T.

Indeed, these values are statistically higher than the reference value (P<0.0054 for P5T; P<0.0001 for P9T and P<0.0029) and expose consumers to digestive disorders, encephalopathy, damage kidney, high blood pressure, hyperuricemia, hematological effects (disorders of heme synthesis, anaemia, and jaundice), cancers and reproductive disorders (Bismuth, 2000; Reichel, 2009).

The high chromium values were demonstrated in wells P6T and P7T which gave concentrations of 55.4 ± 13.7µg / l and 54.2 ± 16.7µg / l, respectively. These values are not statistically higher (P<0.433 for P6T and P<0.4468) than the reference limit value fixed at 50 µg / l. Nevertheless, consumers of this water would be exposed to skin and mucosal lesions with respiratory system damage (bronchitis, asthma, bronchopulmonary cancer) and a gastric ulcer (Rodier and *al*., 2009; Bismuth, 2000).

Finally, the high copper values were found in well P10T (i.e. 9.09%), which gave a concentration of 5497.2 ± 239.32 µg / l, statistically higher value (P<0.0001) at the reference value fixed at 2000 µg / l. Indeed, consumers of water from this well are exposed to irritation of the ocular and respiratory mucous membranes, allergic dermatitis, bronchopulmonary cancer and liver damage (Bismuth, 2000).

All of these results show that the quality of well water consumed in this district does not meet the quality standards of good water with regard to metallic elements. These results are similar for some elements to those found by a study carried out by Banza in 2012 on the waste water and runoff discharged by the mining industries surrounding the district. This study showed that the concentrations of manganese, cobalt, copper, nickel and lead greatly exceeded the reference values; so that this waste water and runoff can easily seep into the wells from the soil surface and cause pollution of well water; because it is from the soil surface that pollutants pass through runoff before passing into the hydrosphere (Kaller, 2009).

As for the Kabetsha district, it appears from Table II that only 3 out of 11 wells or 27.27% gave higher values in aluminum (P<0.0011 for P4K; P<0,0001 for P10K and P<0,0005 for P11K) at the reference limit value, the rest of the chemical elements in the wells studied gave average concentrations lower than the values fixed by the WHO. This would be due to the position of this district in relation to the mining industries, making it that the district does not receive the waste water coming from these although being close.

4. Results and Discussion of Microbiological Analysis

The following graph clearly illustrates the pollution situation of the wells studied in the Tshamilemba district.

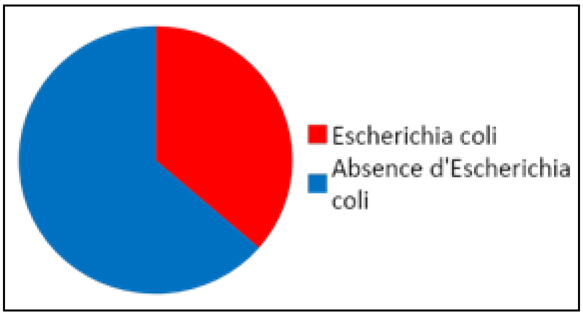

Figure 1: Presence of *Escherichia coli* in Tshamilemba wells

For the Kabetsha district, all the wells studied demonstrated the presence of gas and the appearance of the medium was cloudy at 37 ° C, which resulted in the presence of total coliforms. It was then necessary to make a transplant at 44.5° C in order to search for the presence of thermotolerant coliforms and to highlight Escherichia coli.

Of the 11 wells analyzed in the Tshamilemba district, 4 (36.36%) showed faecal pollution. However, these wells are apparently found in the same states as those of Kabetsha, and therefore susceptible to contamination by *Escherichia coli*. But the majority are exempt; this would come from toxic effects that the excessive concentrations of chemical elements would exert on these organisms.

As for the Kabetsha district, of the 11 wells studied, all of them gave a positive reaction to the detection of *Escherichia coli*, which indicates a probable presence of pathogenic enterobacteria. This situation would be due to the exposure of their water to significant sources of pollution such as the distance between the wells and the latrines which is minimized, the state of the wall of the wells which is not cemented. Thus, bacteria immobilized by adsorption at the well wall can live for long periods in moist soil. As a result of heavy precipitation, the walls of the wells collapse, favoring the passage of bacteria into the water. Note also the condition of the roof covering which is in plank for some wells, in sheet metal, brick or tire for others, and sometimes there was no roofing. These different states would easily promote the infiltration of waste water, household or biological waste.

Our results are similar to those obtained by Kassim (2005) in a study carried out in 45 wells in Bamako and found that all of them were contaminated with Escherichia coli.

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Likewise, Belghiti and *al*. (2013) highlighted the presence of this germ in all 14 wells studied, in the Merkès region of Morocco.

5. Conclusion

The present study focused on the determination of cationic chemical elements and the detection of *Escherichia coli* in well water consumed in the Tshamilemba and Kabetsha districts.

The assay of the chemical elements was carried out on atomic emission spectroscopy using an ICP atomic emission spectrophotometer while the detection of *Escherichia coli* was carried out by seeding the samples in liquid media: broth of brilliant breen bile broth and peptone water.

The average aluminum concentrations were found to be statistically higher than the reference limit value in 8 wells; for manganese, 7 wells gave statistically higher concentrations than the reference limit value. Six wells produced statistically high average cobalt and nickel concentrations; 3 for lead and 1 for copper. In contrast, only 3 Kabetsha wells gave statistically higher average aluminum concentrations.

As for the demonstration of *Escherichia coli*, it was found that 36.36% of the wells studied in the Tshamilemba district knew contamination by this germ, and therefore, a probable presence of pathogenic enterobacteria; in addition, all the wells in the Kabetsha district studied (ie 100%) were known to be contaminated with *Escherichia coli*.

The results obtained show that the chemical pollution of the wells is due to the fumes from the mining activities of the surrounding industries, and that the population of the two districts is partly responsible for the poor microbiological quality of the water from the wells they use.

However, the study of other factors such as the physicochemical parameters, the assay of anions, the detection of pathogenic germs, is essential for the optimization of the evaluation of the contamination of the water of the wells of these two. neighborhoods; and a study on the health of the inhabitants of these districts would correlate these factors to the health of the population of said districts. Finally, a possibility of combating this pollution while releasing its possibility into the water is best envisaged.

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