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Evaluation of the quality of drinking water distributed by the water distribution authority (REGIDESO) in the DRC: Case of the city of Kananga

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Abstract

The city of Kananga is supplied with drinking water by the water distribution company (REGIDESO), whose mission is to produce water free of impurities and pathogenic microorganisms—in short, water that meets WHO international standards. Therefore, we undertook to evaluate the levels of certain elements identified during the physicochemical analysis of our prepared samples. Following this physicochemical analysis, the following results were obtained and compared to WHO standards. These include: water from the Tshibashi River with a $pH = 5{,}6$conductivity of 62.7, a turbidity of 2.16, and a total calcium carbonate (TCC) value. $(TAC)0{,}52, couleur = 0{,}027, N0_2, \frac{ca^{t2}}{Mg^{2t}} = 1{,}8$, $cut^{t2} = 0{,}9, po_4^{-3} = 3,$

Cro_4^{-2},$Mn^{+2} = 0$; $NO_3^{-} = 2{,}3$

2) Water treated at the plant: pH=5.07, conductivity 120, turbidity 0.2, TAC = 1.23, Cl2= 0.226, colour 7.5 $N0_2^{-2} = 0{,}03, SO_4^{-2} = 8;\ \frac{ca^{t2}}{Mg^{t2}} = 2{,}5;\ cu^{t2} = 0;\ PO_4^{-3} = 0;\ Cro_4^{-2} = 0{,}027;\ NO_3 = 2{,}1;\ Mn^{t2}$

3) Water treated at the mains: pH=5.95; cond=103; Turb=0.366

TAC = 0.33, Cl_2 = 0.225; color = 5.03; NO_2 = 0.027; $\frac{ca^{t2}}{Mg^{t2}} = 2{,}5;\ cu^{t2} = 0$; $Cro_4^{-2} = 0{,}027;\ NO_3^{-} = 2{,}1;\ pb^{t2} = 1{,}5 mg/las$ for the pb^{+} ion content

Y = 0.01558x + 0.37334, the results obtained show two strongly linear lines intersecting at a single point. The titration of pb $^{t2 \text{ with } SO4-2}$ ions is 0.583514 with a standard deviation Sx = 0.002181 and a relative error Er = 0.37%.

The 95% confidence interval is 0.87≤ $\varphi \leq 0{,}999$.

While the Cl- ion concentration decreases over time, as reflected by the slope of the regression curve (-0.01558), the correlation coefficient is not within the acceptable range: -1 indicates ≤ $\varphi \leq 0{,}87$, lower chlorine concentration as the distance increases. In short, of the parameters studied, the other elements either meet WHO standards or, for the most part, do not.

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Methods: It is thanks to these so-called instrumental methods that we were able to prove that this water is unfit for daily consumption, as evidenced by the various results recorded in the different tables presented here.

Keywords: Water; REGIDESO; Physico-chemical Quality Assessment

1. Introduction

The third component of primary health care stemming from the Alma Ata conference in 1978 is the adequate supply of safe water and basic sanitation measures.

Water is considered safe or potable when it meets a number of criteria that make it suitable for human consumption. It is water that poses no health risks to the consumer. This quality implies that the water is suitable for all usual domestic uses, including personal hygiene. It must be chemically free from excessive amounts of organic and mineral matter and biologically free from contamination by pathogenic fecal-oral germs (Bitundu, 2010).

Nevertheless, water in Africa remains a major concern for governments, public health officials, and doctors. It is also the focus of a significant portion of international aid and receives particular attention from Non-Governmental Organizations (NGOs) working in the health sector.

The issue of water affects all age groups, that is, children, adults, and the elderly. Its relationship with health is often presented as a priority, as self-evident by the media, but it has curiously received relatively little attention from researchers, whether they are physicians working on the determinants of health, nutritionists interested in nutritional consequences, or epidemiologists concerned with the complex interaction and infection linked to water.

Although water is available in large quantities throughout the country, Congolese people, like other Africans, face difficulties accessing safe drinking water. Less than half of the Congolese population has access to safe drinking water. This access varies widely between urban centers and rural areas. High rates of urbanization have contributed to focusing national efforts and public policies on providing safe drinking water in urban areas.

Like other major cities in the Democratic Republic of Congo, Kananga, in the Central Kasai Province, receives its drinking water from the national water authority (REGIDESO). REGIDESO boasts a state-of-the-art water intake station and treatment plant, placing it among the largest water production facilities in the DRC. However, the water supply does not reach all segments of society, and the city itself faces numerous challenges, forcing Kananga's residents to regularly fetch water from wells dug using 200-liter drums or from streams that flow through the city's many valleys. In some neighbourhoods, girls and women walk several kilometers in search of water at fountains and springs, carrying buckets, basins, and 20- to 25-liter jerry cans on their heads or shoulders. This traditional way of life is not suited to urban life where water must be collected from the tap (WHO 2017; WORLD BANK 2020; KAYEMBE, JM, TSHIBANDA P and ILUNGA 2023)

Research objectives:

- The overall objective of this study is to assess the quality of water consumed by the population of the city of Kananga.
- This general objective is translated into the following specific objectives:
    - Identify the different sources of water supply for the city;
    - Carry out physico-chemical analyses of the resource;
    - To assess the physico-chemical quality of the water delivered by REGIDESO, the water from the Tshibashi river and the wells used by the population of the city of Kananga.

This assessment of water quality is based on the one hand on the in situ measurement of physico-chemical parameters including temperature, pH and electrical conductivity and on the other hand on the determination of some soluble ions including Na^+, K^+ SO_4^{2-}, NO_3^-, PO_4^{3-} NO_2^- and Pb .

2. Materials and Methods

2.1. Description of the study site

This research was conducted in the city of Kananga, capital of the Central Kasai Province, in the center of the Democratic Republic of Congo. It is one of the country's most important cities, with the following geographical coordinates:

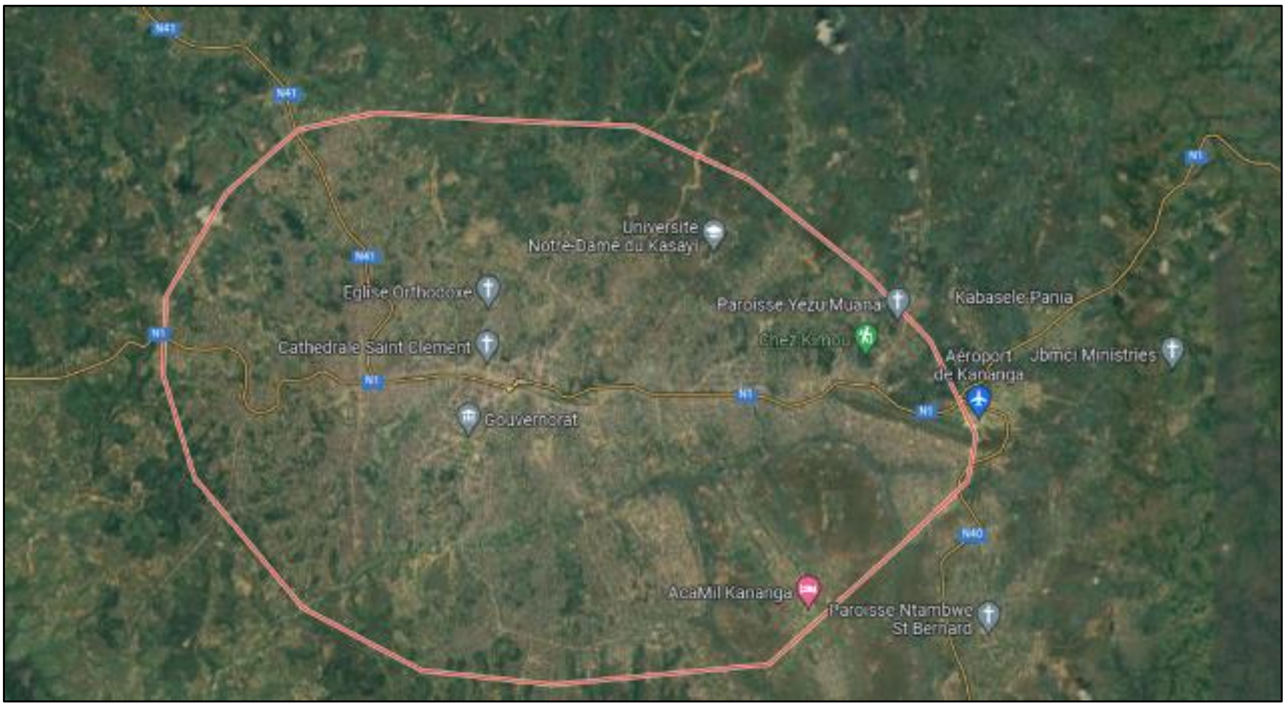
- Altitude: 634 m
- Longitude: 22°25' W'' E
- Latitude: 5° 54' W'' South.

It covers an area of 847 km^2 and has approximately 1,961,181 inhabitants (2015)

The Kananga site consists of a succession of small hills separated from each other by valleys through which flow countless tributaries of the Lulua River, mainly the Tshibashi, the Nganza and the Nkombua.

Despite the presence of several tributaries, two problems are perceived as priorities by the population: the difficulty of accessing drinking water and electrical energy.

These two problems are closely linked. Indeed, electricity currently comes from two thermal power plants, and the cost of water produced by REGIDESO is consequently high (all the inputs necessary for water treatment are twice the price of those in the city of Kinshasa). REGIDESO's service is limited, as its network does not cover the entire city, and the population mainly consumes water from unimproved springs and wells, while many boreholes and small water supply systems recently built with European Union funding are out of service (PAIDEC. K. OCC., 2010). The city of Kananga comprises five communes and 27 neighbourhoods. Our study was conducted in four communes, focusing on several high-concentration sales points such as: the Factory, Hygiene, the Palace Hotel, Batetela, Ndesha, Kamulumba, and Kananga II.



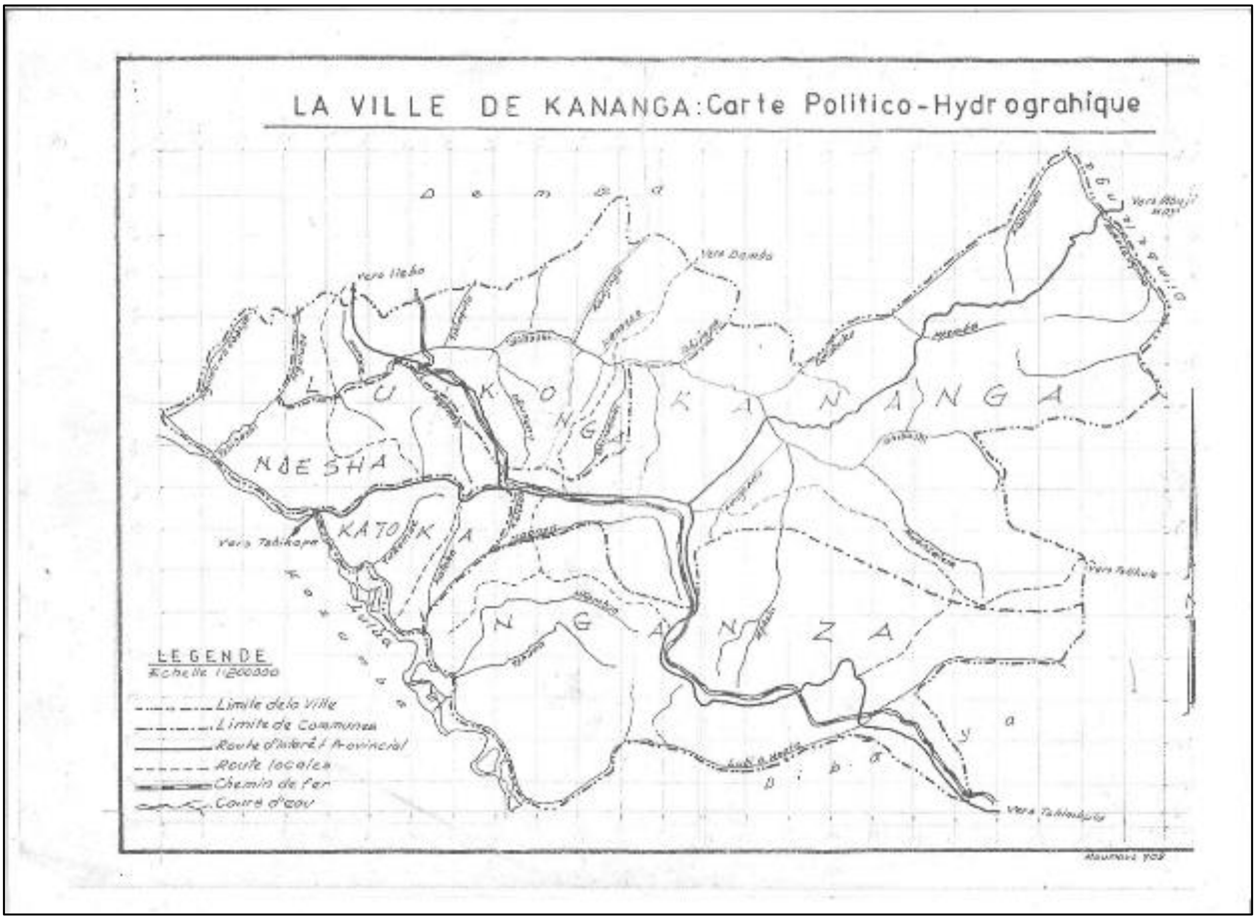


Figure 1 Location map of the study area Kananga city

2.2. Water sampling procedure

2.2.1. Water sampling procedure.

The sampling of water from fountains, the treatment plant and the Tshibashi River was carried out in two phases during the dry season at an interval of 3 months, from May to August 2015 respectively in the communes listed below, and during the rainy season (interval of 3 months 2015 respectively in the communes mentioned above and the samples were labeled differently and according to the day of sampling.

Table 1 GPS coordinates of the communes of the city of Kananga, area, population and type of occupati on

Municipalities	Longitude	latitude	altitude	Population/ Resident	Area	Km 2	Type of space occupation
Kananga	22°24' 26.2'' East	5°54' 15.0'' South	636 m	365,000	300		Primarily urban
Katoka	22°23' 26.3'' East	5°54' 27.9'' South	612 m	225,000	24		Primarily urban
Nganza	22°24' 40.6'' East	5°55' 44.8''	624 m.	234,000	221		Peri-urban
Ndesha	22°21'25.0'' East	5°51'40.9''	630 m	171,000	44		Urban
Lukonga	22°22'26.1''	5°52'42.5''	605 m	168,000	153		Peri-Urban

Source: Kananga City Hall Annual Report 2015, Comment: the positions (altitude, longitude and latitude) of these municipalities where these hydraulic parameters are located were determined on the ground using a GPS: GARMIN 625.

At each point, two types of samples were collected. For physicochemical analyses, the bags used were sterilized at the central offices with the support of SANRU. Certain physicochemical parameters, such as pH, conductivity, temperature, TDS, etc., were measured at the factory and at the site in question using a BHT brand conductivity meter and an ELTh CWP brand digital pH meter, using the analytical method. Other analyses were carried out at the Tshikaji laboratory and the ISP/Kananga laboratory.

We collected two samples from each targeted point at six-day intervals. Each parameter analyzed in the field and in the laboratory underwent two to three consecutive analyses, the average of which is recorded in the results tables. In total, we performed five to ten analyses per parameter. Among the physicochemical parameters analyzed were pH, conductivity, temperature, calcium, nitrates, sulfate, turbidity, total dissolved solids, oxidizable organic matter, lead, chlorine, etc.

2.3. Analysis of physicochemical parameters

The physico-chemical parameters, including temperature (T), pH, dissolved oxygen (O_2) and Electrical Conductivity (EC), were measured in situ or in the Lab using a MU 6100 L Multimeter and BSK "HOMERO" 0 – 50/0.5°C hig.

The concentration of dissolved ions (Na+, K+, PO43-, SO42-, NO3-, NO2-) was measured using ion chromatography (Dionex ICS-3000, Canada) according to the method described by Mavakala et al. (2016). Certified water material (CRM, Ontario-99, Water Research Institute, Canada) was used to verify the instrument's accuracy. The CRM results were within the acceptance range indicated on the CRM certificate.

The Alkalimetric Titration (TA) was measured using the complexiometric method. Two cases are possible: no color develops, TA=0and color develops TA≠0. In the second case, to determine the TA value, the solution is titrated with 0.2 N hydrochloric acid (HCl) until the solution completely changes from pink or red to colorless. Let V₀ be the volume of 0.02 N HCl used to achieve this color change. TA is expressed in French degrees (°F) and is given by TA = V°F.

The Total Alkalinity (TAC) was measured by the method described by RODIER TA=KmlHCl total added (RODIER, J. et al. 2005).

The determination of the water table (WT) was carried out according to the method described by RODIER J., et al, 2005.

Chlorine levels were measured using an ALLDOSE brand spectrometer.

Lead analysis was carried out according to the HACH method and using a conductivity meter (MUSIBONO, 1998; KASEREKA, A & LUMBALA, S 2021; NSUMBU, A & MVITA, L 2020)

2.4. Lead dosage in Regideso water consumed in Kananga

2.4.1. Approach Methods

We applied the instrumental method, namely conductimetry. In this method, we used two techniques:

2.4.2. Direct dosage

-Pre-dosage of P b+2 ions by precipitation in the presence of ions 〖S0〗_4^(-2). The PbSO 4 precipitate at 25°C presents the solubility product (Ps=1.81.10 -8), i.e. a solubility of 1.34586.10 -4 molar.

This gives a concentration of 27.849 Tg/mlof P G+2 . For a SO4 -2 solution of 4.17436.10 -4 Molar, we can detect the P b+2 ions at the limiting concentration of 4.3359.10 -5 molar, i.e. a concentration of the order of 8.975 Tg/ml.

This approach (conductimetry method) allowed us to determine the variation in the conductivity of the solution caused by the dissipation of P b+2 ions and the addition of NH 4 + and SO 4 -2 ions. The (NH_4)_(2) SO_4,point of equivalence is given by the cut of the line 〖X=f(mlNH_4)〗_(2) SO_4).

2.4.3. Dosage by adding doses

This technique was used for verification purposes. It consists of adding known quantities of the ion to be measured, measuring the conductivity at each addition, and establishing a straight line; X=f(ajout);the zero of this curve corresponds to the concentration of the ion to be measured in the samples taken.

To develop this method, we verified on the one hand the correlation between the conductivity of the solution and the variation in the concentration of Pb +2 ions, and on the other hand the empirical correlation factor of the device used in relation to the concentration of Pb +2 ions known with precision.

2.4.4. Pb +2 ion concentration

We took a precise volume of the Pb +2 standard solution (408.13Tg Pb +2 /ml) and dissolved it in 15 ml of solution. The conductivity was read at the solution temperature.

2.4.5. Empirical correction factor of the device

This factor is obtained by titrating a standard solution; it is the ratio between the actual concentration of the standard and the actual concentration of the standard. Therefore, this is the factor that must be multiplied by the experimentally obtained value to find the actual value present in the solution.

To obtain this factor, we used 0.3 mL and 0.31 mL of the standard solution with a concentration of 408.54 Tg/mL, corresponding to a 1.9716 x 10^{-3} molar solution. We titrated this known solution with a solution (NH_4)_(2) SO_4whose concentration of 4.17436 x 10^{-4} molar ions 〖SO_4〗 ^(-2).

2.5. Lead determination

All samples are analyzed under the same conditions. 10 mL of the sample is taken, and volumetric portions of a solution of (NH_4)_(2) SO_4known concentration are added. The conductivity of the solution is measured after each addition. The volume (NH_4)_(2) SO_4corresponding to the cutoff point of the line X =f(ml 〖SO_4〗 ^(-2))is the equivalence point. The equation of the line is calculated statistically.

3. Results and discussion

Based on the results recorded in the tables above, our discussion is centered on 16 parameters.

(Pb^(+2))

Table 2 CorrelationX=f(Pb^(+2)) à 25°C

No.	Standard volume (ml)	Vol. $_{H2O}$ (mL)	Total Volume	Pb content $^{+2}$ µg/ mL	Measured conductivity µScm $^{-}$
01.	0.05	14.95	15	1.3604	7
02.	0.10	14.90	15	2.7208	12
03.	0.15	14.85	15	4.0813	16
04.	0.20	14.80	15	5.4417	17
05.	0.30	14.70	15	8.1626	20
06.	0.40	14.60	15	10.8834	21
07.	0.60	14.40	15	16.3252	26

Table 1 shows the correlation between conductivity and Pb +2 ion concentration . We took a precise volume of the Pb +2 standard solution 408.13 mg/ml which was dissolved in 15 ml of solution and the conductivity was read at the temperature of the solution.

Table 3 Determination of empirical analytical correction factor: X = f (ml SO 4 -2 - in ml)

TESTS	Standard volume	Volume of solution S O_4^{-2}(mL)											
		0	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**3.5**	**4**	**4.5**	**5**	**5.5**
	0.3 mL	21	26	33	40	-	51	54	58	-	66	71	73
	0.3 mL	15	23	28	32	-	-	46	49	53	54	57	-
	0.3 mL	15	19	25	29	34	39	42	46	49	53	-	-
	0.3 mL	14	18	23	27	32	36	40	44	47	51	-	-

The results in this table determine the empirical analytical correction factor:

X = f (volume of SO4 2- solution in ml) are obtained using a few milliliters of the standard solution with a concentration of 4 g/ml, i.e., a y molar solution. We titrated this known solution with the (NH4)SO4 2- solution with a concentration of Z molar in SO4 2 ions (sulfate , see experiment) .

Table 4 Dosage of Pb +2 in tap water in the city of Kananga between 2010 and 2015

No.	Sample	Vol. $SO_4^{-2} ml$	Concentration of Pb $^{+2}$ mg/l	Pb content $^{+2}$ mg/l	Adjusted factors	Ratio between content and standard (0.05mg/l)
01.	Hygiene	1.5	6,261. 10 $^{-5}$	12,974	7,570	151.4
02.	Kananga II	3,154	13,165	27,281	15,918	318.36
03.	Ndesha	2,583	10,782	22,342	13,036	260.72
04.	Kamulumba	2.0208	8,435	17,479	10,199	203.98
05.	Batetela	1.634	6,820	14,133	8,246	164.92
06.	Palace	2,458	10,260	21,260	12,405	248.1
07.	Factory	1,416	5.9108	12,247	7,146	142.9

This table shows that, in the drinking water network of the City of Kananga, the results obtained generally indicate that the water intended for consumption by REGIDESO contains the average lead content found at the different sites. The average lead content is 18.24 mg/L. This bioaccumulative metal presents a permanent medium- and long-term danger to consumers. Observation of the samples reveals that the rainy season is responsible for the large quantity of this metal in the water distribution network. Urban runoff appears to be the main cause. This observation is consistent with studies conducted by Musibono et al. (1999), who found that the lead concentration in the Lukunga and N'djili Rivers was higher during the rainy season than during the dry season. The authors described this season as a "season of high ecological risk."

Because some pipes are made of lead alloys, we are observing a very high level compared to the standards established by the WHO, which are around 0.05 mg/L, and which Health Canada has published its new recommendation for lead in drinking water, which is around 10 µg/L (Health Canada 2019).

Indeed, at a very alkaline pH, lead transforms into lead oxide, which protects the pipe against further corrosion. However, at this acidic pH, lead will be carried to the consumer's tap.

Table 5 Characteristics of the titration lines of the standard solution

TESTS			Curve equation	n	Intersection point a=b	Measured Molecular Concentration of Pb^{+2}	Correction factor	Noticed
No.	Standard volume	Content						
01	0.3ml	Molar Concentration	$y = 12,8X + 20,4$ $y = 7,715X + 31,304$	0.997 0.997	ml $SO4^{2-}$ = 2.1140	$29.83 .10^{-4}$	$\frac{conc.mesured}{conc.real}$	An absurd measure.
02	0.3ml	$19.74.10^{-4}$	a $y = 11,2X + 16,1$ b $y = 5,4X + 30,2$	0.986 0.987	2,431	$33.81 .10^{-4}$	0.582	OK.
03	0.3ml		a $y = 9,602X + 14,798$ b $y = 7X + 21,3$	0.998 0.998	2,498	$33.64 .10^{-4}$	0.585	OK.
04	0.3ml		a $y = 9,002X + 13,798$ b $y = 7,4X + 17,7$	0.999 0.998	2,435	33.89×10^{-4}	0.581	OK.

(Alloway, BJ (2013). Fawell, J., & Nieuwenhuijsen, MJ (2003). Jaishankar, M., Tseten, T(2014). Kumar, M., & Puri, A. (2012) Rehman, K., Fatima, (2018). Sánchez-Camazano, M (1994). Tchounwou, PB, (2012). Wang, W. (2008)

The results obtained for each trial (Table 4, see Appendix 1) show two strongly linear lines intersecting at a single point. This point of intersection represents the equivalence point of the titration of Pb^{+2-} with SO_4^{2-} ions, i.e., ΔS = 0.583514 with a standard deviation ΔS = 0.002181 and a relative error ΔEr = 0.37%. The confidence interval at the 95% precision level is [missing value]. The correlation coefficient is within the confidence interval, i.e., 0.87 ≤ ϑ0.999.

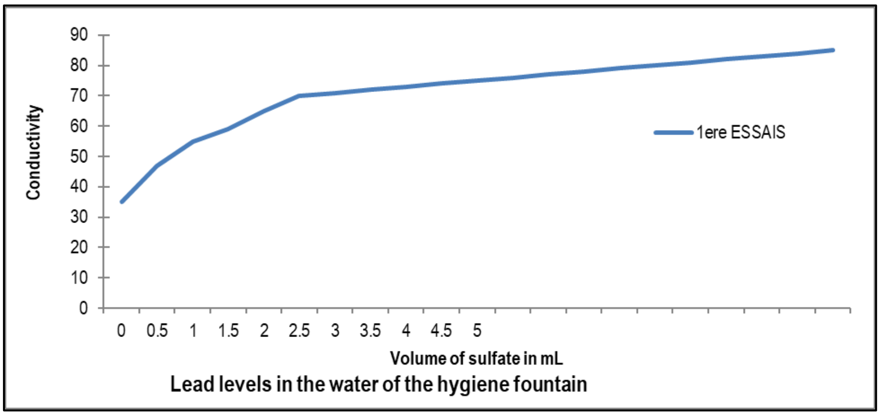


Figure 2 Lead (Pb) levels in the water from the Kananga hygiene fountain between 2010 and 2015

+2 titration line as a function of conductivity and the volume of sulfate expressed in mL in the waters of the hygiene fountain.

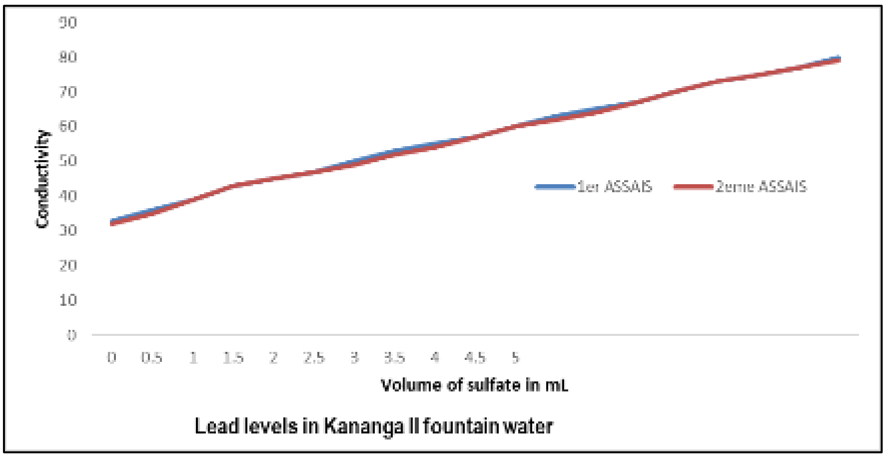


Figure 3 Lead levels in Kananga II fountain water between 2010 and 2015

This graph shows the shape and slope of the Pb +2 titration line in relation to conductivity and sulfate volume in ml in the Kananga II fountain water

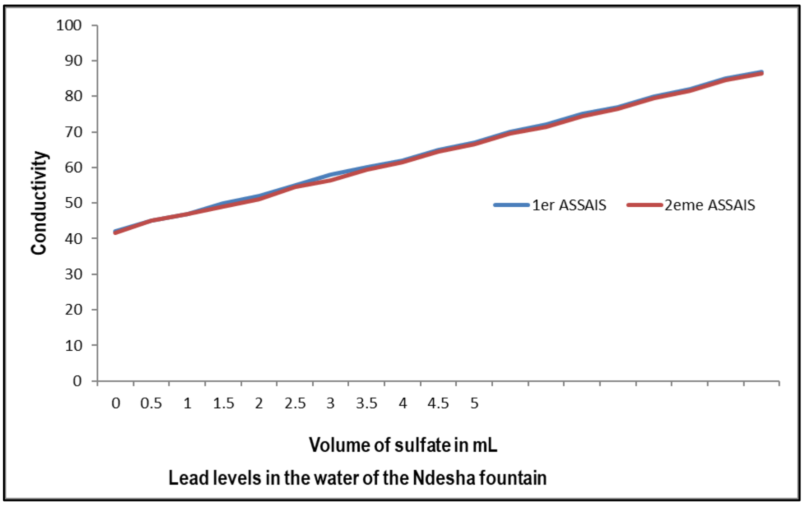


Figure 4 Lead concentration in the water of the Ndesha fountain

+2 titration curve as a function of conductivity and the precise volume of sulfate in the waters of the Ndesha spring

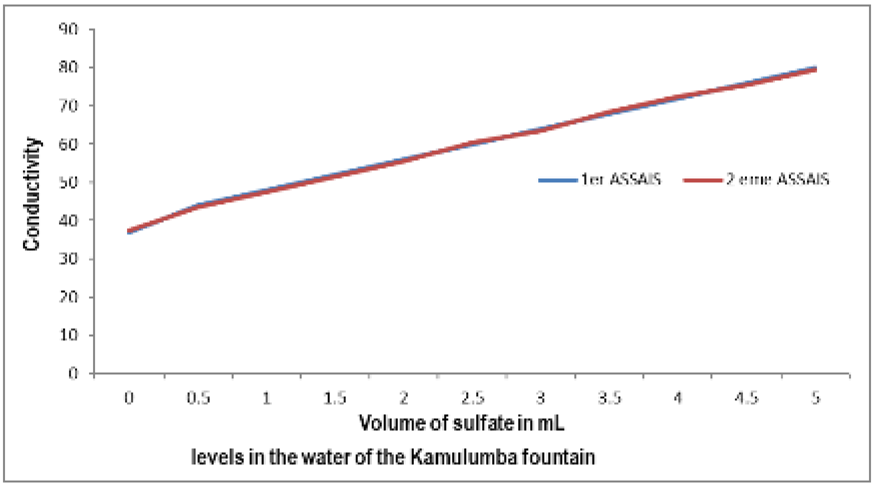


Figure 5 Lead concentration in the water of the Kamulumba fountain

+2 dosage curve as a function of conductivity and sulfate in the waters of the Kamulumba fountain.

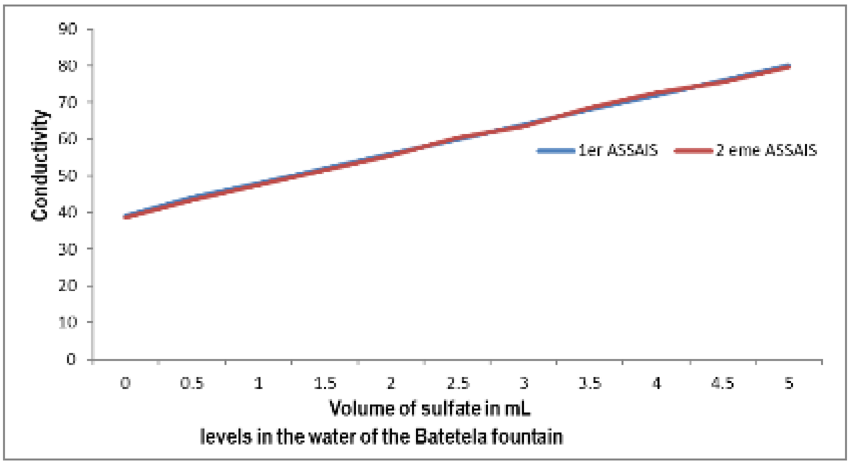


Figure 6 Lead content in the water of the Batetela fountain

+2 dosage curve in the water of the Batetela fountain as a function of conductivity and sulfate.

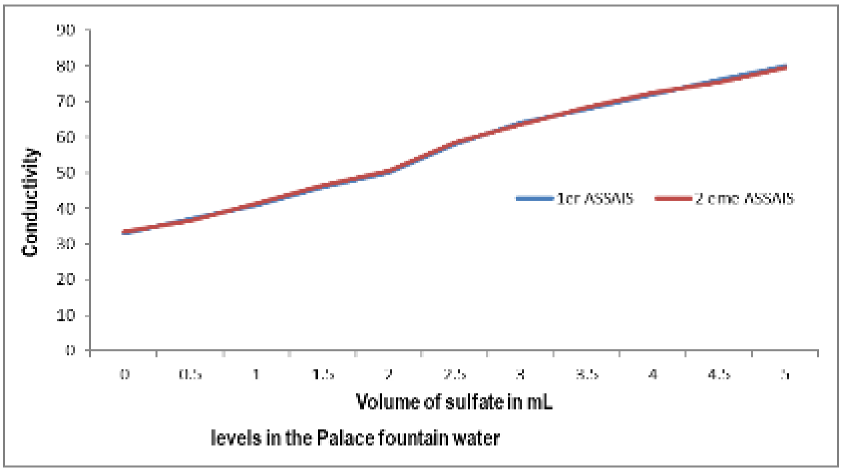


Figure 7 Lead concentration in the Palace fountain water

This graph shows the variation in the Pb +2 dosage curve in the Palace fountain water

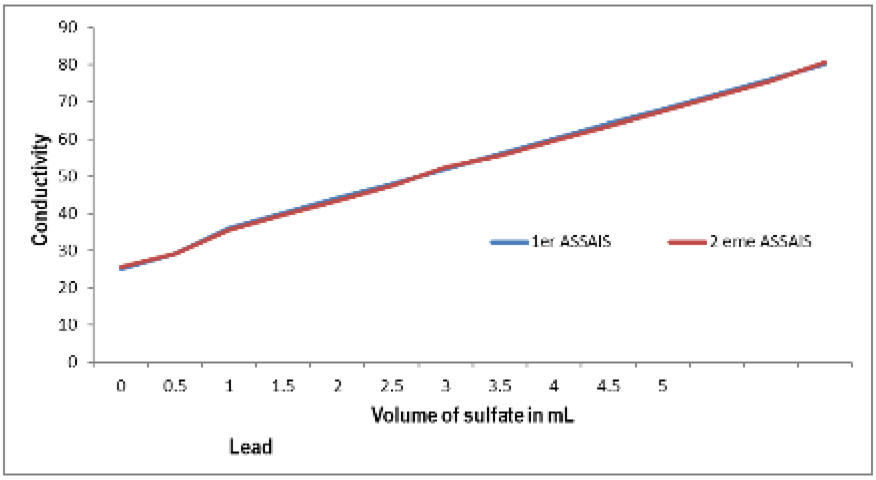


Figure 8 Lead concentration in the water from the Factory Fountain

This curve shows the slope of the line on the Pb +2 dosage in the factory water

Table 6 Analysis results in the production area

Time of collection	Content in cl in mg/l						Average value	Standard deviation	Relative error
	1st J.	2nd J.	3rd J.	4th J.	5th J.	6th J.			
10	-	-	0.2	0.2	0.1	0.2	0.175	0.043	24.5%
11	0.2	-	0.2	0.2	0.2	0.3	0.220	0.040	18.1%
12	0.1	-	0.2	-	0.3	0.3	0.225	0.095	42.5%
13	0.1	-	-	-	0.3	-	0.200	0.10	50%
14	0.1	0.1	-	0.15	-	-	0.116	0.023	20%
15	-	0.1	-	0.2	-	-	0.150	0.050	33%
16	-	0.1	-	0.5	-	-	0.125	0.025	20%
17	-	0.1	-	0.1	-	-	0.100	0.000	0.00%

This table shows that the chlorine level (mg/l) at the factory is not constant, it varies from 10 a.m. (0.175 mg/l) up to 0.100 mg/l at 5 p.m., with a standard deviation of 0.043 for a relative error of 24.5% against a standard deviation of 0.000 for a relative error of 0.00%.

Table 7 Comparison of results

Hour	Factory rate	Kananga ECH I	Ndesha ECH III	Nganza ECH II
10	0.175	0.125	-	0.100
11	0.220	0.100	0.166	0.200
12	0.225	0.175	0.133	0.162
13	0.200	0.100	0.200	0.283
14	0.116	0.030	0.200	0.266
15	0.150	-	-	-

16	0.125	0.013	-	-
17	0.100	0.010	-	-

Regarding chlorine, the concentration is not constant. It varies over time and from one distribution area to another. Our analytical results show an average of 0.163 mg/L with a standard deviation of 0.045 mg/L. Statistical tests demonstrate the homogeneity between the waters of Nganza and Ndesha and the waters from the treatment plant, while the waters of Kananga are not homogeneous with the plant waters. The difference between these samples and the plant waters is not statistically significant. The characteristics of the chlorine concentration are identical, which is confirmed by the null hypothesis and the analysis of variance.

Regression curve of Cl- ion content = f (time) with Y = 0.01558X + 0.37334^(-2)

Table 8 Chi- square test

cl-$\frac{mh}{l}$	F	K	Pi	n.Pi	X ²
0.175	0.1	0	0.19	6,192	4,939
0.220	1	1	0.130	1.104	0.0097
0.225	1	2	0.0112	0.0869	4,250
0.200	1	3	0.0006	0.0046	206,330
0.116	1	4	0.00002	0.00016	
0.150	1	5	0.0000006	0.0000064	
0.125	1	6	0.00000022	0.000000176	
0.100	1	7	0.00117	0.00936	

This table reflects the shape of the regression curve below in relation to the variation of chlorine content, as a function of time and distance.

Cl- = f (time) the line will be Y = 0.01558X + 0.3733 x 10 -2

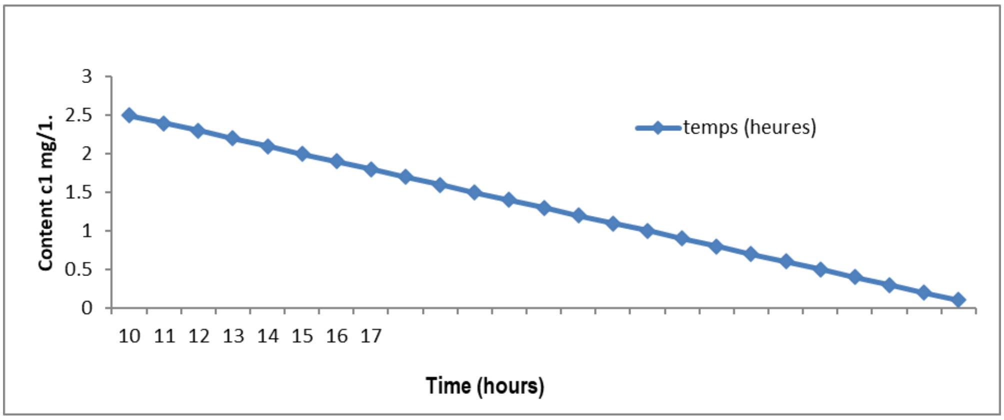


Figure 9 Variation of residual chlorine concentration as a function of time in the distribution network

The test at the production plant reveals that in distribution areas, chlorine levels decrease over time and with distance… this explains the negative slope of the regression curve: -0.01558. The relationship between variation in chlorine levels and time is not actually real because the correlation coefficient is not within the acceptable range: -1≤ϑ≤-0,87.In short, the greater the distance, the lower the chlorine concentration.

Table 9 Physico-chemical parameters 3rd Sampling of 26.01.2015

Setting	Raw water	Flocculent water	Decanted water	Filtered water	Water treated at the factory	Water treated for distribution
pH	5.97	4.17	4.19	5.74	5.02	5.23
Conductivity	0.63	149	148	0.74	108	98
Turbidity	2.7	1.7	0.1	0.2	0.1	-
YOUR	0	0	0	0	0	0
TAC	0.2	0.2	0.2	0.2	0.1	0.1
Color	80	80	80	5	5	5
TH	0	0	0	0	0	0

Contains the concentrations of physicochemical parameters recorded at different sampling sites studied during the 3rd sampling on 26.01.2015

Table 10 Physico-chemical parameters 4th Sampling of 26.01.2015

Raw Water

Hour	T°	Color	Turbidity	pH	Flocculent water			Treated water	
					pH	pH	Color	Turbidity	No. 2
9am	24°C	90	10	6.2	5.8	6.2	10	3.5	0.02
10am	24°C	80	10	6.2	5.8	6.3	10	3.2	0.02
11am	25°C	80	10	6.2	5.8	6.4	10	3.2	0.02
12pm	25°C	80	10	6.2	5.3	6.6	10	1.9	0.02
1 p.m.	26°C	80	10	6.2	5.3	6.8	10	2	0.02
2 p.m.	26°C	90	10	6.2	5.3	6.8	10	2.1	0.02
3 p.m.	26°C	80	10	6.2	5.3	6.8	10	2.3	0.02

Contains the concentrations of physico-chemical parameters recorded at different sampling sites studied during the 4th sampling on the afternoon of 26.01.2015.

Table 11 Compilation of results

Samples	pH	Cond.	Turb.	YOUR	TAC	Cl_2	Color	TH	No_2^-	So_4^{-2}	$\frac{Ca^{+2}}{Mg^{+2}}$	Cu^{+2}	PO_4^{-3}	CrO_4^{-2}	NO_3^-	Mn^{+2}
Raw Water	5.6	62.7	2.16	0	0.52	0	86	0	0.027	0	1.8	0.9	3	0.14	2.3	0
Water treated at the factory	5.07	120	0.2	0	1.23	0.226	7.5	0	0.03	8	2.5	0	0	0.027	2.1	0
Water treated for distribution	5.95	103	0.366	0	0.33	0.225	5.03	0	0.027	8	2.5	0	0	0.027	2.1	0
WHO standards	7-8.5	400	5-10		50°F	0.2-0.5	15		Absent $< 0,1$	400mg	$< 7,5$ $< \frac{20mg}{l}$	0.5	0-2.5	0.05	0.525<	5

This table compiles the minerals analyzed using the methods mentioned above.

pH analyses of the water revealed that the water treated at the plant has an average pH of 5.07, while the water treated at the mains has an average pH of 5.95. All these values indicate a slightly acidic environment. Therefore, the water treated at the plant is neutral or slightly alkaline. Regarding the color of the water treated at the plant and the water treated at the mains, a color temperature of 15 was observed, which is acceptable.

International standards recommend a conductivity of 400. Analyses performed on the treated water at the plant yielded 119.66 and 110.33 for the treated water in the distribution network. This water has a relative error of 5.9%, but for the other waters, this error is well over 10%.

The alkalinity level is zero, which implies that OH- and Co ions are absent in the REGIDESO water, while in this HCo, the bicarbonate ion is present but at levels below the standards, namely 0.52 mg/l for treated mains water. Statistical analysis of all these results shows an error of over 100%. This raises serious questions about the method used by REGIDESO for its analyses.

For all samples, the hydrometry is zero, which suggests that free Ca^{2+} and Mg^{2+} ions are not present in the Regideso water. However, colorimetric analysis proves the presence of detectable quantities of magnesium (Mg^{2+}) and Ca^{2+} ions . The ratio (Ca^{2+} /Mg^{2+}) is as follows: [≫2,5,Cellular] = 1.8 for water treated at the plant, [Cellular] = 1.8 for water treated at the network. ≫2,5. These ratios are quite high compared to international standards, which Ca/mg=7,5/20=0,375.require a [Ca/Mg] ratio of [Ca/Mg] <0,375for drinking water.

Table 12 Statistical assessment of results

Samples	**Raw Water**								**Water treated at the factory**						**Water treated for distribution**							
Measures	**1st**	**2nd**	**3rd**	**4th**	**5th**	$\bar{X}$	**δ**	**Er.**	**1st**	**2nd**	**3rd**	$\bar{X}$	**δ**	**Er.**	**1st**	**2nd**	**3rd**	**4th**	**5th**	$\bar{X}$	**δ**	**Er.**
pH	5.51	5.82	5.97	6.2	4.5	5.6	0.66	11.86	4.86	5.34	5.02	5.07	0.24	4.8	5.48	5.37	5.23	6.5	7.2	5.95	0.85	14.3
Conductivity	42	0.83	0.63			62.66	20.5	32.7	139	11.2	108	119.66	16.86	14.09	102	110	98			102.3	6.11	5.91
Turbidity	23	1.6	2.7			2.16	0.61	28.20	0.2	0.2	0.2	0.2	0	0	0.8	0.2	0.1			0.366	0.37	10.1
YOUR	0	0	0			0			0	0	0	0	0	0	0		0					
TAC	0.2	1.7	0.2			0.52	0.56	107	0.1	3.5		1.23	1.96	15.9	0.1	0.8	0.1			0.33	0.4	12.1
Cl 2									0.4	0.2	0.2	0.266	0.115	43.3	0.2	0.2	0.2		0.3	0.22	0.05	22.2
Color		90	80	84	90	86	4.89	5.69		10		7.5	3.53	47.1			5	5.51	5	5.3	0.057	1.14
TH		0	0							0	0	0	0	0		0	0	0		0	0	0
NO 2 -																		0.03	0.02	0.05	0.007	28.25

Turbidity indicates that the REGIDESO water has the following values:

Raw water, turbidity 2.16 ± 0.61, treated water at the plant 0.2 ± 0 and network water 0.36 plus or minus 0.378. The turbimetric measurements show an error far exceeding 10%.

As for the calorimetric analysis, it allowed us to systematically determine the dissolved Cro, Mn, Cu, No, Po, and Cl ions. These ions have values below international standards, except for calcium and magnesium, whose ratio exceeds the standards, and the Cu and Cro ions, whose levels exceed the standards in the raw water of the Tshibashi River.

4. Conclusion

Access to safe and sufficient drinking water is a fundamental human right. REGIDESO, the water treatment and distribution company in Kananga, operates a network over half a century old that has never been maintained or renewed. The network is composed of cast iron and PVC (polyvinyl chloride) pipes. As water travels through the distribution system, it undergoes physicochemical reactions that alter its quality. These reactions occur not only within the water itself but also at the water-pipe interface. They also depend on flow conditions, pH, temperature, the water's chemical composition, and the type of pipe material. A thorough understanding of these phenomena is essential for effectively controlling the quality of drinking water.

REGIDESO's water treatment process typically uses products such as aluminum sulfate (flocculant) and calcium hypochlorite as disinfectants, as well as lime as a pH adjuster. All these products react with the water and interact with each other to achieve the desired results, but they can also generate water treatment byproducts such as trichloroethane, which is sometimes toxic and carcinogenic.

This study on the state of REGIDESO water consumption in the City of Kananga from 2010 to 2015 allowed us to first determine certain parameters, the content of which is as follows:

Pb+2 content) The level is very high. Therefore, the plant's water treatment system and the distribution network must be reviewed. The high lead content in all the drinking fountains can be explained by a large number of lead pipes receiving water that can dissolve lead. Indeed, water with a pH below 7 contains a high concentration of dissolved oxygen and aggressive carbon dioxide. This can lead to more than 50% of the total supply and presents a risk of contamination. To limit this damage, we use VPVC (hard plastic) piping, the tolerable level of which is 0.05mg/l and can exceed this content and reach values of around 1.5mg/l. Special and appropriate measures must be applied to reduce the risk of contamination, for example: in children, acute lead poisoning is characterized by anorexia, vomiting, behavioral disorders and irritability (HOMAN and BROGAN, 1993; Roujast F, Sorkine M, 1990; MUNYEMBA, E; & KAPEPULA, K (2022) in adults, metallic taste, constipation and abdominal pain.

Upon examining these chlorine results, we can make the following considerations:

Only the Commune of Kananga has a low rate compared to the factory (0.079 - <0.169 mg/l), while Nganza and Ndesha have higher rates than the factory (0.202 and 0.175 - >0.169 mg/l). All these figures are far below the international standards set by the WHO, namely a content of 0.25 to 0.5 mg/l (WHO 2001).

Indeed, studies show that effective virus destruction requires pre-chlorination at a concentration of 0.3 to 0.4 mg/L of residual free chlorine in the water, followed by settling and filtration, and finally post-chlorination at doses producing 0.2 to 0.3 mg/L of free chlorine in the water, for an average of 0.25 mg/L. In short, tap water in Kananga is not sufficiently disinfected and is likely to cause and perpetuate waterborne diseases.

The pH of drinking water varies from 7 to 8.5, according to the WHO. To bring the pH of raw water within drinking water standards, treatment is essential. Since the water in the city of Kananga is intended not only for the population but also for its infrastructure, the pH must be adjusted towards neutrality or alkalinity using lime to satisfy all users before the water is distributed through the network. However, we must point out that the treatment methods used by REGIDESO to correct the pH remain ineffective, which explains the acidic pH values of the treated water at the plant and in the network (see the summary table). This is why we strongly recommend using sufficient quantities of lime to obtain the appropriate pH.

The discoloration of the raw water is due to metallic salts and, above all, to organic matter and other substances present, dissolved or suspended. The raw water of the Tshibashi River is generally colored surface water. The bleaching carried out by Régidéso could be effective, considering the resulting color. In this case, the treated water remains within acceptable limits.

Compared to that of treated, flocculated, decanted, filtered water, the conductivity of raw water is low; this can be explained as follows:

- The raw water of the Tshibashi River contains elements in low concentrations as ions. It is a low-mineralized water with a predominantly non-ionized component content; the treated water contains more calcium, magnesium, and sulfate than the raw water. This is due to the ions introduced by quicklime and aluminum sulfate during treatment, respectively, which increases the conductivity of the treated water. Conversely, the decrease in copper ions, phosphates, and chromates is due to precipitation reactions that occur within the treatment process.
- The alkalinity (TA) of both the raw and treated water is zero, indicating the absence of OH and CO ions. However, the total hardness (TH) of both the raw and treated water shows the presence of significant amounts of calcium and magnesium ions. Both the raw and treated water samples exhibit a Ca^{2+}/Mg^{2+} ratio exceeding the standards, resulting in varying degrees of hardness. This hardness leads to soap consumption and reduced lather due to the increased calcium and magnesium content, resulting from a relatively high concentration of calcium and magnesium salts in the limestone soil through which the Tshibashi River flows.

Compared to that of treated water, the turbidity of raw and flocculated water is higher than that of water at other stages.

In summary, REGIDESO Kananga is not only facing the problem of the quality and quantity of water to be supplied to the population under its jurisdiction, but also, and above all, difficulties of the following nature:

- Lack of a permanent energy source, aging equipment, financial difficulties, the country's economic crisis, and urban expansion. Low capacity and insufficient drinking water reservoirs, subscriber insolvency, and a weak water distribution network.

Given the above, we recommend that Regideso use the appropriate chemical reagents precisely and provide ongoing training for its staff to master operating procedures and state-of-the-art analytical techniques in order to minimize errors and achieve the required drinking water standards that the population of the city of Kananga is forced to consume against its will.

For this work, we believe we have done the essentials and we hope that it will be complemented by other researchers who will undertake other studies either on the bacteriological analysis of these waters and on the measurement of dissolved oxygen.

Compliance with ethical standards

Disclosure of conflict of interest

No competing interests are declared

Authors' contributions

This work was carried out in collaboration between all authors. Authors JP KK, AKK, and HBN and designed the study, wrote the methodology and wrote the first draft of the manuscript. Author JP KK managed the literature searches. All authors read and approved the final manuscript.

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Appendices

DRILLING WATER

NDESHA WATER TOWER

Unimproved well