Biological and Physicochemical Indicators of Water Quality in Libreville and its Surroundings

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Abstract:- According to the WHO, 88% of diarrheal diseases are due to the use of unsafe water, sanitation and hygiene problems. The quality of water depends on the quality of ecosystems and the survival of species. Water pollution therefore has an impact on human health, the survival of ecosystems and an economic cost. For nearly a decade, the distribution of drinking water in Libreville and its surroundings has been disrupted. Many households use rainwater, water from rivers or water from wells to meet daily domestic needs. In order to assess the quality of drinking water resources in Libreville and its surroundings, certain biological and physicochemical parameters are essential. Samples from surface water and wells are shown, pollution of industrial and faecal origin in the waters of the Alinakiri, Ondongo and Ogombie rivers and in the wells of the villages of Kango. In conclusion, the identification of a large number of colonies, staphylococci, clostridium coliforms, the concentration of nitrate and ammonium ions above the values recommended by the WHO confirms this contamination. Water is a component of the environment most vulnerable to various contaminations. Due to the growing demand, the pressure on water resources has now become a global strategic issue. Its management must imperatively be integrated into a political perspective of sustainable development. For this, the protection and safeguard, in the medium and long term, of the quality of this resource is essential.

Keywords:- *water; indicator; pollution; sustainable development.*

I. INTRODUCTION

Water is essential to life, for this reason it must be protected. This is why the Earth Summit in Rio de Janeiro 1992 dedicates March 23 of each year as World Water Day. Water is established as a universal value, it appears to be the most important good on the planet. Being a very important commodity for vital and industrial functions, a supply in quality and quantity must be ensured (Bignoumba, 2007). Protecting aquatic areas and groundwater is the best way to ensure water safety. Indeed, water is essential for the survival of all living beings. However, it can also contain contaminants and parasites responsible for the transmission of waterborne diseases (Minko mi-Etoua, 2008). It is a vital resource that forms an essential part of biological life. Water performs many essential physiological functions such as digestion, absorption, thermoregulation and waste disposal (Obuebie et al, 2006). Drinking water intended for human consumption must not contain any dangerous chemical substances or pathogenic germs harmful to the health of individuals (John P.H. and Donald A.K, 2010; WHO, 2003). However, as soon as a potentially dangerous situation is known, the health risks must be taken into account. Man discovered the role of water in the transmission of agents of certain diseases such as cholera, typhoid fever. In Africa, villages and informal settlements are particularly exposed to sanitation problems. Households resort to the street, the courtyard, plots and vacant lots to evacuate wastewater (Balloy Mwanza, 2019).

With the advent of industry, the development of cities has increased, the degradation of nature is accelerating dangerously. The increase in population leads to increased needs for basic services and in particular for the sanitation of solid and liquid waste. Uncontrolled dumping of household waste in the streets, the situation of gutters, waterways and green spaces reveal high levels of insalubrity. The delay in the construction of infrastructure is becoming a major concern for the authorities, who must now mobilize more material, human and financial resources to deal with it in the short, medium and long term (ESMP, 2018). The delay in the construction of drinking water supply infrastructure in sub-Saharan cities multiplies the risks incurred by the population (ESMP, 2018).

We note that the degradation of nature is accelerating dangerously with the development of human activity and industry, causing an increase in pollution (Hounsounou, 2016; Amoussou, 2016). Indeed, the industrial revolution gave birth to a variety of factories that transform many products from agriculture and the subsoil, causing changes in the terrestrial and aquatic ecosystem. The modifications of the terrestrial and aquatic ecosystem, generated by these different processes disturb and threaten the biodiversity of disappearance (Renou, 2016). The quality of water depends on the quality of ecosystems and the survival of species. In addition to its impact on the survival of ecosystems, water pollution has a cost on human health and the economy. According to WHO 2004, 88% of diarrheal diseases are due to lack of sanitation, hygiene and the use of unsafe water (Wethé et al, 2003; Sy, 2017). Many factors such as urban growth, the rural exodus, the lack of drinking water, the increase in housing needs, transport difficulties, the absence of an urban planning policy, handicap the development of Libreville and its surroundings (ESMP, 2018). It is therefore a city that faces the degradation of the socio-economic conditions of the populations, the insalubrity and the destruction of the surrounding nature (mangroves, rivers). In the environment, certain organisms are bioindicators of the chemical and ecological quality of water (Bonnin, 2015). The collection of these organisms makes it possible to deduce the state of health of the ecosystem and the type of pollution that affects it (Ngoay-Kossy, 2018), thus determining the quality of water.

This study aims to determine the quality of water from rivers and wells used in Libreville and its surroundings. The identification of biological and physico-chemical indicators of pollution can enable actors from various backgrounds to act for the preservation of resources with a view to sustainable development. This study is of great interest for health education services which must implement preventive and curative policies in order to avoid possible serious health risks. Indeed, in this time of COVID 19, decision-makers must put in place Information, Education, Communication and Awareness (IECS) policies and programs aimed at the rationalization, preservation and enhancement of our water resources while aligning themselves with the recommendations of the sustainable development (El Ouali-Lalami et al, 2014).

II. MATERIALS AND METHODS

A. *Material*

The water of the Alinakiri, Ondogo, Ogombie, Ngomatou rivers and that of the Wells of Kango served as support for the study of the various parameters observed. All these rivers are located in Libreville and its surroundings. This study, which took place in several stages using the following equipment: Fishing net, one-litre jars, magnifying glass, pliers, watch glass, oximeter, filtration ramp, ovens, bunsen burner, butane gas, cooler, pH meter, Petri dish, spectrophotometer, conductivity meter, turbidimeter, chemicals, culture medium.

B. *Methodologies*

The purpose of the parasitology and microbiological analyzes was to find and count the germs existing in the samples to be analyzed. The count was made on revivable flora (yeast or mold bacteria capable of forming colonies in specific media) at 22°C and 37°C on different culture media.

The search for coliforms was done on lactose agar with TTT7 (Triphenyltetrazolium with tergitol 7). Streptococcus was isolated on Slanet and Bartley medium. Chapman's and Baird Parker's (BP) media were used for coagulase-positive Staphylococci. Plate Count Agar (PCA); m-TEC agar for Escherichia Coli; Salmonella-Shigella Agar (SS Agar), Xylose-Lysine Deoxycholate Agar (SS Agar) for Salmonella spp. The spores of Clostridium sp were isolated on a meat-liver medium in the presence of iron ammoniacal citrate and sodium sulphite.

The identification of the bacteria was carried out by Gram staining and the Api Gallery. Protozoa and helminths were observed under the microscope, this study was completed by the method of biotic indices based on the inventory of living animals on the bottom of a watercourse or under the shelter of aquatic plants.

The determination of the physico-chemical parameters was carried out by the measurements carried out using the thermometer, the PH-meter, the conductimeter, the turbidimeter, the BOD-meter.

The chemical analysis made it possible to determine, by different dosages, the undissolved matter (MES), the alkalimetric title (TA, TAC), the Total hydrometric title (THT) and various ions (Chlorides, nitrates, Sulphates, silica, ferric calcium, potassium, sodium magnesium). The dosage of metals such as lead, copper, manganese and zinc is also carried out.

For the bacteriological analyses, the samples required great precautions under rigorous aseptic conditions. In the wells, the samples were taken at 0.50 meter above the bottom, not touching the bottom and the edges. At the level of the rivers, the samples were taken upstream and downstream from the chosen point. In order to preserve their integrity, the samples were transported in a cooler containing eutectic plates at 4°C.

III. RESULTS AND DISCUSSION

The different sites D, F, C, E (Figure 1) correspond respectively to the upstream of the Alinakiri river (site D), to the waters of SOBRAGA, an industrial beverage production site (site F), to the meeting place of the waters from the river to those of SOBRAGA (site C), downstream of the Alinakiri river (site E). Upstream, the Calcium and Magnesium ions are in lower proportion compared to the reference values of the WHO, 2004. Downstream, the rate of these elements is greatly exacerbated. The content of metals, iron (Fe), aluminum (Al) is high upstream of the river, probably due to the nature of the terrain. The BOD5, that is to say the biochemical oxygen demand for five days (BOD5) also expressed in milligrams of oxygen per liter of water makes it possible to evaluate the concentration of biodegradable organic matter. It represents the quantity of oxygen necessary to degrade the organic matter present for five days.

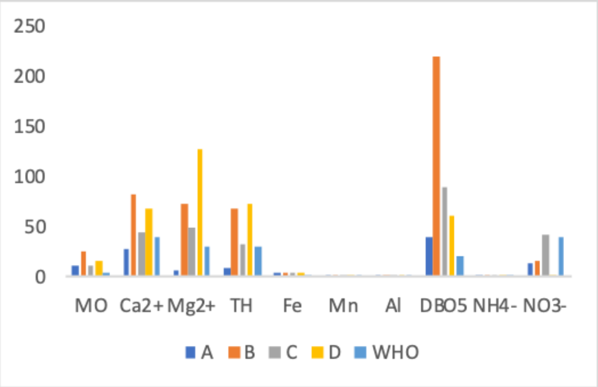

Fig. 1: Chemical analysis of the waters (in mg/L)

The COD difference (chemical oxygen demand BOD5) determines the load of organic matter that is difficult to biodegrade. It is low upstream at site D, i.e. 40 mg/L, high downstream (60 mg/L) and five times higher (220 mg/ L) at site F (SOBRAGA) These results are comparable to those of MPAKAM et al, 2019. The "natural" concentration of nitrates in the atmosphere, in the soil and in water in the absence of fertilization, the nitrates in groundwater is estimated at a maximum of 15 mg/L. It is estimated that too high a nitrate content in the aquatic environment induces toxicity on its fauna and flora, modifies the environment (eutrophication) and harms biodiversity The eutrophication of water promotes phenomena such as the proliferation of green algae. In this case, the concentration of nitrates upstream is 13.04mg/L and 0.83mg/L downstream. WHO 2017, has set the limit value for the concentration of nitrates in water at 50mg/L, considering that beyond that it pre felt health risks. Chlorination oxidizes nitrites (NO2) rapidly to nitrates (NO3-) (Maoudombaye et al, 2015). The presence of nitrate ions bound to agricultural residues constitutes a pollution factor (Gilliam et al, 1986). In 2017, the WHO recommends a value of 0.5 mg/L for drinking water. The values we observe are slightly higher than the WHO value. Lagnika et al, (2014) and Mickael et al, (2010) reported averages of 0.193±0.28 and 39.8±13.31 respectively. Abdoulaye et al, (2013) obtained ammonium ion contents ranging from 0.02 mg/L to 1.29 mg/L in November and 0.03 mg/l to 0.36 mg/L in July in the water on the right bank of the Senegal River. Downstream, the rate of these elements is greatly exacerbated. The content of metals, iron (Fe), aluminum (Al) is high upstream of the river, probably due to the nature of the terrain. Organic nitrogenous matter is low upstream and downstream, however the values of mineralized matter (nitrate) are higher upstream (13.04 mg/L) and very low downstream (0.83 mg/L) and mineralized.

Sampling sites	pH	T °C	TA° (F°)	TAC° (°F)	TH$_T$ (°F)	MES (g/L)	Conductivity (µS/cm)	Turbidity NTU	Chloride Mg/L
A	7.65	24.20	0	12.50	7.20	0.311	580	155.20	>150
B	7.88	24.5	0	19.15	16.50	0.164	470	11.40	48.99
C	7.70	24.2	0	18.50	41.10	0.141	29671	12.89	13.49
WHO	7.00	25.00	2.50	2.50	15	15	400<C<600	5	<150

Table 2: chemical analysis of the waters of the ONDONGO river

A, B, C sample collection site

The turbidity values in Table 2 greatly exceed the WHO (NTU) standard. This cloudy appearance of the water is due to the presence of suspended solids. These suspended solids are responsible for the proliferation of phytoplankton which can cause eutrophication.

Sampling sites	O$_2$ content	Beads	Short-lived	Limnea	Planorb	Gammarus	trout
S1	12.90	8	12	25	0	0	77
S2	9.50	0	0	471	3	14	14
S3	11.50	1	4	4	0	1	16

Table 3: Biological analysis of Ogombie River water

S1, S2, S3 sample collection site

Table 3 presents the data collected on the Ogombie River. Site 1 corresponds to the upstream of the river, site 3 to the downstream and site 2 to the waste dumping area. In the dumping area, there are garages and factories that dump waste oil, effluents from the mattress manufacturing industry and various kinds of garbage. The distribution of invertebrates is uneven between the three sites. On this site 2, the significant biological factor is the very significant presence of limnae gastropods and crustaceans of the genus Gammareae (Ngoay-Kossy, 2018). This last species is distinguished by its great sensitivity to toxic micropollutants and its ability to accumulate contaminants. These properties of accumulating contaminants and sensitivity to pollutants make it possible to diagnose the level of contamination and the toxicity of aquatic environments (Geffard et al, 2013). These invertebrates show, their importance on the natural balance on the one hand and the contribution of aquatic flora, fauna in the phenomenon of self-purification therefore of the protection and maintenance of the quality of river water on the other hand. At the physico-chemical level, we note that the oxygen content is lower compared to that of sites 1 and 3 (Pourcher et al, 2010).

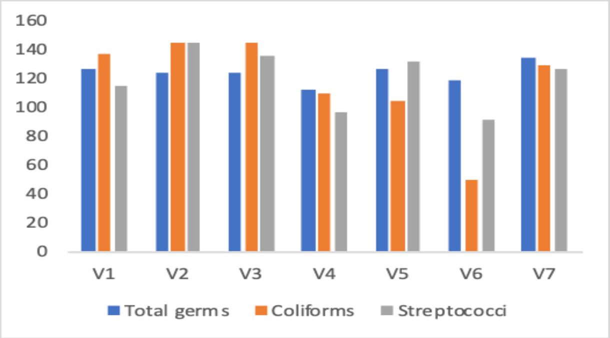

Fig. 2: Biological analysis of water from the villages of Kango (number/volume 50/mL)

The samples in the wells of the villages of Kango show after analysis of each sample the presence of total germs in all the wells. The number of coliforms is greater in wells V2 and V3. A greater number of colonies of staphylococci is identified in the Then V2, V3, V5 and V7. Large colonie of Clostridium in wells V1 and V7. Observation of the samples with the naked eye, with a magnifying glass and under a microscope made it possible to identify in many wells tadpoles, paramecia, filaments of spirogyre, chlamydomonas, chlorella, brown and green algae, diatoms, mayfly and eristalid larvae, bloodworms or chironomids, ringed or tubifex worms, hydra-mites, etc. (Ajeagah et al, 2013). Protozoa are the group of pathogens least susceptible to inactivation by chemical disinfection. Protozoa are medium-sized organisms that can be eliminated by physical means. They can survive in water for long periods of time. They have moderate species specificity (WHO, 2017).

Total coliforms constitute a heterogeneous group of bacteria of faecal and environmental origin (Verhille, 2013). The presence of total coliforms in water does not always indicate faecal contamination or a health risk (Makoutode et al, 1999). Indeed, most species of total coliforms can be found naturally in soil and vegetation." This may be a deterioration in the bacterial quality of the water linked to the infiltration of surface water into the well, or the gradual development of a layer of bacteria on the walls (Schoeller, 1971). The analysis of total coliforms makes it possible in particular to obtain information on the possible vulnerability of a well to surface pollution (WHO, 2017).

	Village 1	Village 2	Village 3	Village 4	Village 5	Village 6	Village 7
Temperature (ºC)	22.60	22.60	22.90	23.40	23.90	24.30	24.70
Conductivity	142	147	32	33	70	82	468
Alkalinity TAC	6.50	5.50	3	2	4.5	4	9.40
Alkalinity TAC$_E$	26.50	20.50	18	24	12.5	13.50	36.50
Turbidity	7.86	2.11	6.18	49.2	20.20	2.74	61.7
pH	6.80	6.17	6.33	5.45	5.97	6.41	6.17
WHO							

Table 4: Physical properties of well water from KANGO villages

Faecal streptococci or enterococci are essentially intestinal bacteria, but, as noted earlier, they are less numerous in feces than coli bacteria, although virtually all members of the enterococcus group are found there. In water, enterococci which do not multiply disappear more or less quickly like E. coli, in any case more quickly than other coliforms; therefore, the characterization of enterococcus in a water sample is a sure sign of recent faecal pollution (Vernozy-Rozandcet al, 2002). When enterococcus is encountered, it is very rare that E. coli is not present at the same time; generally, the ratio of enterococci present and coliforms present is between 1 to 2 and 1 to 10. It is accepted that drinking water should not contain any enterococci in 100 millilitres. In fact, the enterococcus is an insensitive control and its research can in no way replace that of E. Coli. On the other hand, the characterization of the enterococcus constitutes an excellent confirmation of faecal soiling (Lièvre et al, 1992; Balloy Mwanza et al, 2019).

Table 4 shows that the temperatures measured on the well waters show moderately low values, given the sampling period (January and February). They vary between 22.6°C and 24.7°C. These temperatures are slightly lower than those obtained by Nwala et al, 2007) and by Dégbey et al, 2010), Lagnika et al, 2014), which obtain temperatures between 27.6°C and 28.7°C.

The pH of the water in the wells in the different villages varies between 5.45 and 6.41.6 (Table 4) these values volve in the acid zone. This could be explained by the presence of free CO2 at the time of measurement. However, these pH values are in accordance with the drinking water standards of the WHO since they are included in a drinking water range of 6.5 to 9.

The measured values of the conductivity (Table 4) indicate a very high mineralization for the village wells V1, V2 and V7 because they are respectively 142, 147 and 468. Note that this primary salinity can be of geological origin (coastal zone). But it would tend to increase due to poor exploitation of wells, be aggravated by pollution of anthropogenic origin (Makoutode et al, 1999; Achour et al, 2008).

The TAC values show that the well waters contain carbonates and bicarbonates. Suspended solids in the water cause physical contamination. Indeed, these materials are very fine particles in suspension (sand, clay, particles of polluting products, etc.), which give a cloudy appearance to the water (CPEPESC, 2014). The turbidity values observed do not meet the standards of WHO, 2004.

Physico-chemical parameters influence potability, and organoleptic character, they are an indicator of health risk. Regarding metals except copper which is found in trace form, iron, zinc and manganese are found in relatively high quantities in villages V7 and V4, i.e. 087 mg/l and 2.01 mg/l and 210 mg/l respectively. The WHO standards are 0.3 mg/l for iron, 1 mg/l for copper, 3 mg/l for zinc and 0.1 mg/l for manganese. Lead, a toxic substance whose recommended standard is 0.01 mg/l, is found much more in villages V3 and V5 at concentrations of 6.37 mg/l and 2.3 mg/l respectively. With regard to ions, the quantity of sulphate ions, their quantity is very high in wells V7, i.e. 56.32 mg/l and V2, i.e. 9.89 mg/l against values between 1.27 mg/l and 4, 54 mg/l in all other wells. The cations, calcium, magnesium, sodium and potassium present an unequal distribution in the various wells. Calcium has very high concentrations in well V7, i.e. 47.4 mg/l, lower in wells V3 and V4, i.e. 1.96 and 2.33 mg/ml, while wells V1 and V2 have concentrations whose values are close that of the WHO, i.e. 16.6 mg/L and 18 mg/L. Magnesium is in excess in wells V1 and V7, ie 3.2 mg/L and 4.4 mg/L. In wells V6 and V2, the values are close to WHO standards, i.e. 2.96 and 3.2 mg/L. Sodium and potassium have high concentrations in well V7, ie 31.3 and 20.7mg/L. The analyzes on anions show that the chlorides are absent from the wells V5, V6, V7 in the other wells this concentration is low and conforms to the WHO standards. The amount of silicon exceeds the standards required in the V4 pit. Nitrates, the tolerated threshold of which is 50 mg/L, are in less quantity in all the wells except in well V1 where the quantity is 26.89 mg/L. Ammonium values are all below 0.38mg/L in all wells. Chen, Wu and Qian (2016) show the link between digestive cancer and nitrate absorption. Methemoglobinemia or blue baby disease has also been shown to be caused by the presence of nitrates in drinking water. This disease is characterized by the weakness of the blood to transport oxygen due to the decrease in the levels of normal hemoglobin 4. It is a rare disease that particularly affects infants fed with bottles and well water (WHO, 2017). The concentration of organic matter is determined in an acid medium for that of vegetable nature and basic for that of animal origin. The vegetable origin of the organic matter is detected in the wells V2 and V4 on the other hand in the wells V1, V3, V4 it seems to be of animal nature.

	Village 1	Village 2	Village 3	Village 4	Village 5	Village 6	Village 7
NH4	0.38	0.15	0.13	0.04	0.80	0.17	0.10
MatOrg/acid	0.90	4.80	1.80	2.10	1.10	1.00	1.20
MatOrg/basic	3.60	9.80	2.30	7.60	7.50	3.10	9.80
NO_3^- mg/mL	26.89	2.09	2.59	1.75	2.40	2.95	2.93
Nitrites mg/mL	0.03	0.01	-	0.04	-	-	-
Pb mg/mL	0.01	0.01	6.37	0.01	2.30	0.01	0.01
Cl^- mg/mL	0.70	1	0.40	0.40	-	-	-
SiO_4^{4-} mg/mL	6.94	2.83	5.45	13.24	9.96	1.06	2.46
K^+ mg/mL	2.90	2.10	0.05	0.78	0.51	0.31	20.70
Na^+ mg/mL	5.20	3.40	1.48	97.00	2.08	11.58	31.30
Ca^{2+} mg/mL	16.60	18	1.96	2.33	10.06	8.12	47.40
Mg^{2+} mg/mL	4	3.20	0.66	0.65	1.28	2.96	4.40
SO_4^{2-} mg/mL	1.98	9.89	1.27	4.54	2.78	2.02	56.32
Cu mg/mL	Trace	Trace	Trace	Trace	Trace	Trace	Trace
Zinc mg/L	1.85	1.93	1.91	0.01	1.91	1.93	2.01
Mn m/L		0.30	0.31	0.32	210.00	27.00	0.28

Table 5: Chemical analysis of well water from KANGO villages

The values observed are different from the references recommended by the World Health Organization (2011). The water from the wells in the villages of Kango is therefore unfit for human consumption. The results of work carried out by Kisanguka in 2013 showed that well water is 83% microbiologically polluted. These results corroborated those of Malangu 1983 as well as those obtained by Mulungulungu in 2007, according to which the water of the rivers and wells of Lubumbashi was polluted at 90%. The latter had found that the water in the rivers of the Lubumbashi hinterland was 100% polluted and that of the wells 86.5%. According to Hounsounou, 2016, the practical assessment of the microbiological quality of water is done on the basis of so-called “indicator” organisms (Festy et al, 2003: Servais et al, 2009); choice resulting from the technical difficulties or impossibility of detecting the full diversity of microorganisms (Givord and Dorioz, 2010). The most appropriate indicator bacteria for faecal contamination are the coliforms known as Escherichia coli and faecal or intestinal Enterococci (Rodier et al, 2009).

IV. CONCLUSION

The physico-chemical parameters can be divided into four groups: those which influence potability, which present a risk to health, those which are toxic and those which determine pollution.

The analysis carried out on the various sites shows that the quality of the water is influenced by several factors. The waters of rivers and wells present a wide range of microorganisms, staphylococci, bloodworms or chironomids, ringed worms or tubifex, hydra-mites which can be responsible for pollution. The strong anthropogenic activity observed has major repercussions on water quality.

High conductivities indicate strong mineralization. In these waters the dominant anions are chlorides and sulphates, the dominant cations are sodium, calcium and magnesium.

Regarding the pollution parameters, an excess concentration of nitrates was noted in the industrial areas as well as significant levels of ammonia. Abnormally high levels of metals such as manganese and copper were found. All these elements seem to indicate that the waters of the Libreville region are exposed to various types of pollution, both of agricultural and industrial origin. It is therefore essential to focus on:

The establishment of a normative framework, water quality control and risk management, especially for wells, which are the most used type of water point in Africa although presenting a health risk not negligible.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

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