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RESEARCH ARTICLE

HEALTH RISKS LINKED TO THE CONSUMPTION OF WATER FROM SHALLOW AQUIFERS IN THE CITY OF DALOA (CENTRAL-WESTERN IVORY COAST)

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Abstract

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The water provided by the public network in the city ofDaloa is rejected by residents because of the disagreeable organoleptic characteristics. This situation has pushed a large, proportion of the population to exploit the water from resurgent springs and traditional wells. However, these waters tap into alterite aquifers, which are the first reservoir to receive seepage water that is often highly laden with impurities. As a result, these waters could be contaminated by domestic and industrial effluents, deteriorating their quality and impacting consumer health. Hence the need to evaluate the health risk from these waters. To this end, seasonal analyses of physico-chemical parameters on 40 waters points have been carried out. Methodological approach consisted of using the water quality index and the probabilistic risk method. As a result, these waters are rich in heavy metals whatever the season, and the quality varies from very poor to good for wells and from poor to good for springs. Thus, the chromium VI-related health risk for these waters in both seasons has a hazard quotient greater than 1. The level of carcinogenic risk is also very high, with a value greater than 10^{-4}. People are therefore exposed to gastrointestinal risks and can contract cancer when they consume untreated well and spring water.

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Introduction:-

The problem of human health, in different parts of the world, is closely associated with environmental and groundwater pollution (Adimalla et al., 2018 ; Babuji et al., 2023). Speaking of groundwater contamination by physicochemical substances, it is a very important concern in the current century (Babuji et al., 2023 ; Rajan et al., 2024). These concerns are widespread throughout the world, because water pollution affects people's health and well-being. In fact, ingesting contaminated water causes serious problems for human health (Ramos et al., 2023). This is the case for metals, which have various impacts on health, such as cancers, respiratory diseases, gastrointestinal disorders and skin allergies (Mawari et al., 2022). And, according to the WHO (2017), more than 1,1 million children under the age of 5 and the elderly, who live where hygiene measures and sanitation systems are inadequate, die each year from diarrhoeal diseases, of which 90% are due to the poor quality of the drinking water. This problem affects developing countries enormously, especially urban areas, where rapid population growth, lack of adequate sanitation, industrial operations and climatic variations influence the quality of groundwater resources used for human consumption (Mendieta-Mendoza et al., 2021 ; Babuji et al., 2023). Daloa, the area covered by this

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study, is not exempt from this problem. In Daloa, the presence of uncontrolled household waste dumps, wastewater run-off and faulty septic tanks located less than 15 m from water points make us fear the risk of groundwater contamination and harmful effects on consumer health. However, these water tables, exploited by traditional wells and natural springs, are often used without appropriate treatment by the majority of the population of Daloa. Faced with this situation, it is important to assess the possible health risks to the population so as to avert the appearance of illnesses linked to unsafe water. Thus, this study contributes to points 3 (Good health and well-being) and 6 (Clean water and sanitation) of the Sustainable Development Goals (SDGs).

Material and Methods:-

Presentation of the study site

Daloa is a city in the centre-west of Ivory Coast, covering an area of 97.28 km^2. It is located geographically between 6°22' and 6°29' west longitude and between 6°49' and 6°56' north latitude (Fig 1). It is the third most populous city in Ivory Coast, with an estimated population of 421,879 (INS, 2021). Daloa is governed by an attenuated transitional tropical climate with a rainy season (March - October) and a dry season (November - February). Daloa lies in a single geological domain, namely migmatites on heterogeneous granitoids and there is generally a composite aquifer in this environment composed of fractured layers topped by layers of alterites (Lachassagneet al., 2011). However, alterites are the first to receive infiltration water from rainfall, of which the reserves are tapped by traditional wells and modern wells (Lasmet al., 2004).

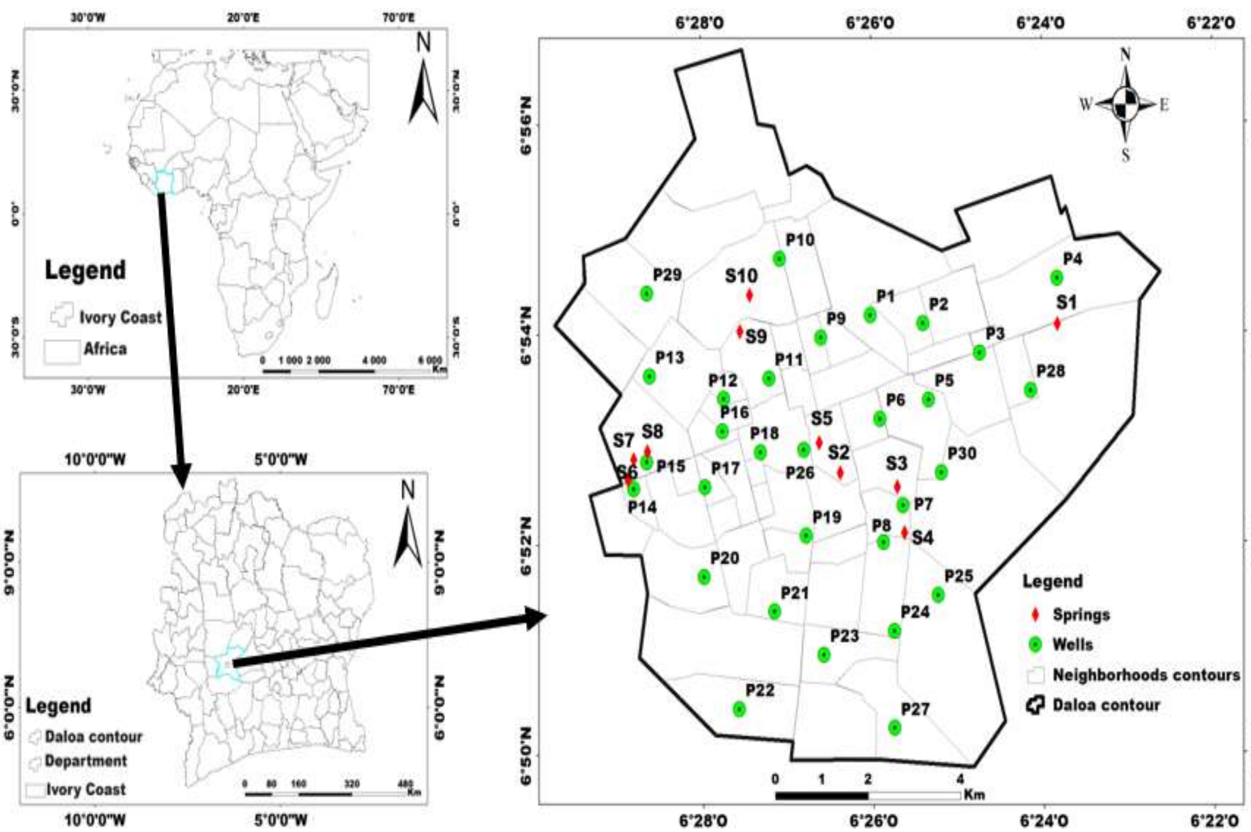

Fig 1:-City map and spatial distribution of sampling points.

Realisation of the survey

A survey was carried out in March 2022, which marks the start of the rainy season, among households in the city of Daloa by means of direct interviews and observations using questionnaires. The survey focused on the use made of well and spring water, the populations consuming it and the method of treatment applied. The sample (households in the city) was selected on the basis of simple random sampling as described by Quivy&Campenhout (1988). Based on this sampling method, the sample size was determined using the equation of Islam (2018) :

$$n = \frac{Z^2 \times p(1-p)}{e^2} \quad (1)$$

With n the sample size ; z the constant resulting from the normal distribution according to a selected confidence level ; p the proportion of the population using well and spring water and e the estimated margin of error.
For the present study, the data used are : z = 1.96 ; p = 70% and e = 0.05. The equation thus becomes :

$$n = \frac{1.96^2 \times 0.7(1-0.7)}{0.05^2} = 322 \quad (2)$$

However, only 200 of the 322 households agreed to be interviewed. The results will therefore concern the 200 households. The details of the households interviewed are given in Table I in the appendices.

Sampling and analyses

This study required sampling campaigns at high water (march 2022) and low water (november 2022). These sampling campaigns were carried out at 30 wells and 10 springs throughout the city of Daloa (Figure 1). Two (2) intakes of water were carried out for each water point in order to determine nutrient salts and heavy metals in the laboratory. The following procedure was adopted for sampling : firstly, Garmin-type GPS (Global Positioning System) was used to locate the water points. Next, the water samples were taken in 1 L bottles that had been sufficiently rinsed with the water to be analysed and labelled. Only water destined for analysis of heavy metals was acidified with nitric acid (60%). The bottles were filled to reflux and hermetically sealed to ensure that there were no air bubbles and that the water was not ejected during transport. Finally, five (5) parameters (temperature, pH, electrical conductivity, dissolved oxygen and redox potential) were measured in situ with the HACH HQ40d multiparameter. The method used is called potentiometry. To do this, deionised water and the water to be analysed were used to rinse the various probes before being immersed in the water. The values are read on the screen once they have stabilised. In the laboratory, nutrient salts, chromium VI and heavy metals were analysed by molecular absorption spectrometry with the addition of specific reagents and X-ray fluorescence using different standards.

Analysis of significant temporal variation

The study of spatio-temporal variation required the application of a univariate statistical test. The parameters were subjected to non-parametric Mann-Whitney test at a significance level of 5 %. This test was applied because the data did not meet the conditions for application (normality of the data, equality of variances, quantitative data, independence of the data and number of data greater than 5) of a parametric test.

Assessment of water quality using the index method

Among the methods used to assess water quality, the index method seems interesting. Thus, the groundwater quality index (IQE) was used to assess the specific quality of each water point. This index is defined as an estimate of water quality based on the influence of many parameters (Ramakrishnaiah *et al*., 2009) and maximum guides values for the different parameters. The calculation was carried out in three (3) steps.

Weighting of parameters

Unit weights wi were assigned to seven parameters that directly influence health (nitrates,nitrites, sulfates, ammonium, nickel, chromium and lead), four acceptability parameters(calcium, magnesium, iron, manganese) and three regulatory parameters (temperature,hydrogen potential and electrical conductivity), taking into account their importance indetermining water quality. Thus, those that have an adverse effect on health have the highest weights on a scale of 1 to 5 (Ramakrishnaiah et al., 2009 ; WHO, 2017) (Table II in appendices).The relative weight is then determined according to Srinivas &Nageswararao (2013) :

$$Wi = \frac{wi}{\sum_{i=1}^{15} wi} \quad (3)$$

Wi : relative weight and wi : unit weight of parameter i.

Parametric index determination (qi)

The parametric index (qi) is an estimation scale calculated for each parameter. It is determined according to the equation below :

$$q_i = 100 \times \frac{C_i}{S_i} \quad (4)$$

Ci :concentration of parameter and Si : maximum guide value of parameter.

Determination of global groundwater quality index

The final calculation of the WQI (Equation 5) consists of summing the products of the parametric index and the relative weights of all the parameters considered :

$$GQI = \sum Wi \times qi \quad (5)$$

A class is then assigned according to the index calculated. According to Ramakrishnaiah et al. (2009), there are 5 classes : excellent (GQI < 50) ; good (50 < GQI < 100) ; poor (100 < GQI < 200) ; very poor (200 < GQI < 300) and inappropriate for consumption (GQI > 300).

Estimation of the carcinogenic or non-carcinogenic risk of chromium VI

Health risk refers to the probability of encountering a hazardous substance likely to cause disease in humans (Babuji et al., 2023). As a result, this risk is based on two factors : hazard and exposure (Guo et al., 2023). Thus, risk assessment comprises four stages :

Hazard identification :

It consisted of inventorying the substances to which people are potentially exposed and identifying their harmful effects, based on criteria such as the type of substance, its concentration and the ailments it causes in children under 5 and adults. Chromium VI was considered in this study. This substance is likely to cause toxic effects on the gastrointestinal tract, liver, development and lower respiratory tract in humans and cancer by oral ingestion (Mohammadi et al., 2019 ; US EPA, 2024).

Chromium exposure assessment:

Exposure was assessed by estimating the minimum and average concentrations and daily dose of chromium capable of causing infection in an individual or a population. To do this, the ingestion of water was considered. The scenarios considered are as follows : exposure of children under 5 and adults with body weights of 10 and 60 kg respectively. The average daily dose (ADD) is calculated based on the Sadler et al. (2016) equation :

$$ADD = C \times \frac{Q}{BW} \quad (6)$$

With ADD : average daily dose (mg/kg/d) ; C : chromium VI concentration (mg/L) ; Q : quantity of water consumed by day (L/d) ; BW : body weight (kg).

The data used to calculate the average daily dose are given in Table III (Appendices).

Dose-response relationship :

The objective of this step is to define the dose capable of causing a harmful effect. For oral exposure, this is the reference dose (RfD) (see Table III in appendices).

Risk characterisation :

It consists of estimating the non-carcinogenic and carcinogenic effects of chromium VI on the gastrointestinal tract. To do this, we determined the hazard quotient (HQ) and the carcinogenic risk (CR) by the oral route.

HQ correspond to the ratio of the average daily dose (ADD) to the reference dose (RfD) (US EPA, 20011) (Equation7). A hazard quotient greater than 1 indicates a significant risk. On the other hand, when the HQ is less than 1, this expresses a lesser risk (Wei *et al*., 2015).

$$HQ = \frac{ADD}{RfD} \quad (7)$$

As for the CR (Equation 8), this involved multiplying the average daily dose by the oral cancer slope factor (OSF) (Sushila et al., 2024 ; US EPA, 2024). The total lifetime exposure OSF established by US EPA (2024) with application of the age-dependent adjustment factors at constant dose (ADAFs) is 0.27 $(mg/kg/day)^{-1}$.

$$CR = ADD \times OCSF \quad (8)$$

A range of acceptable carcinogenic risk values has been established. When the cancer risk is of 10^{-6} to 10^{-4},it is said to be acceptable (WHO 2017 ; Oni et al., 2022). A cancer risk less than or equal to 10^{-6} does not constitute a health problem for consumers. It is negligible. On the other hand

Results and Discussion:-

Results:-

Survey data

Sources of water supply

The survey revealed that people use three principal sources of water supply : well water, spring water and water from the public network. However, the majority use well water (42 %) only for drinking, to the detriment of water from the public network (4 %) and resurgent springs (3 %). On the other hand, 24 % of these households use well and spring water simultaneously ; 18 % consume water in plastic bags and from tanks (water from springs and the public network respectively) and 9 % of households drink water from wells, springs and the public network at the same time (Fig 2).

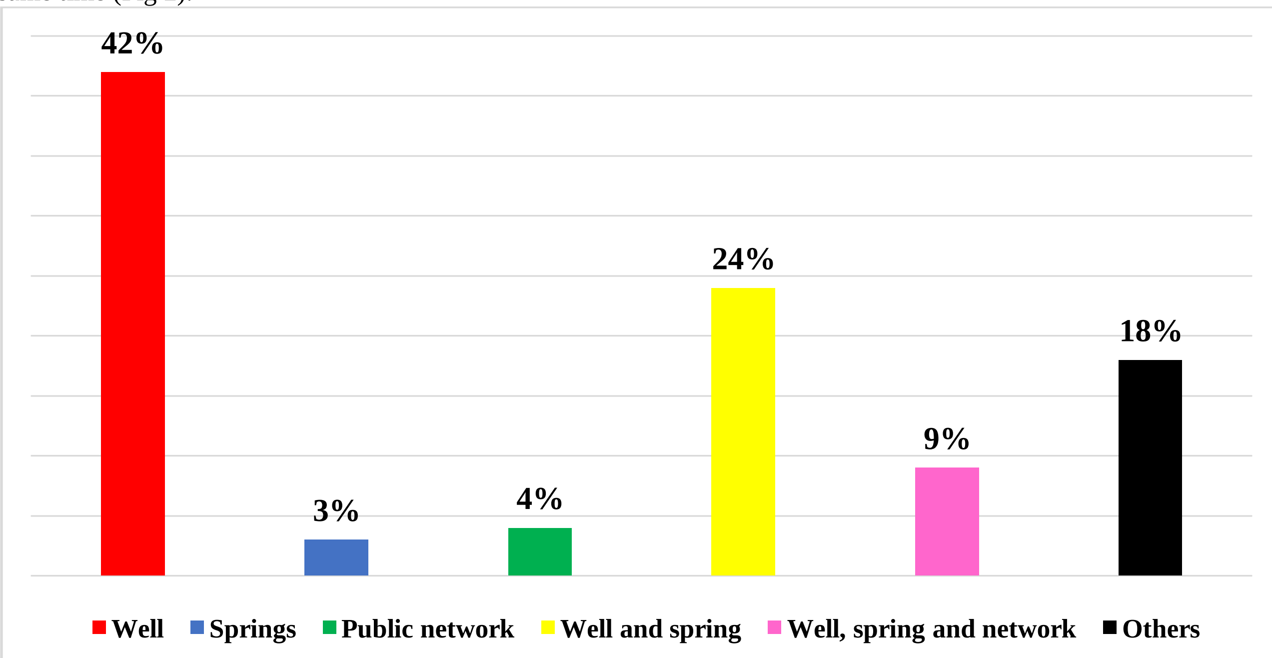

Fig 2:-Distribution of water supply sources in the city of Daloa.

Treatment applied

For all the households that consume well and spring water (78 %), 32 % state that they do not apply any treatment and drink the water directly. On the other hand, 30 % inject calcium hypochlorite, commonly known as bleach, directly into wells and springs. In addition, some households disinfect their water by filtration (13 %), decantation (13 %) and bleach-filtration (12 %) (Fig 3).

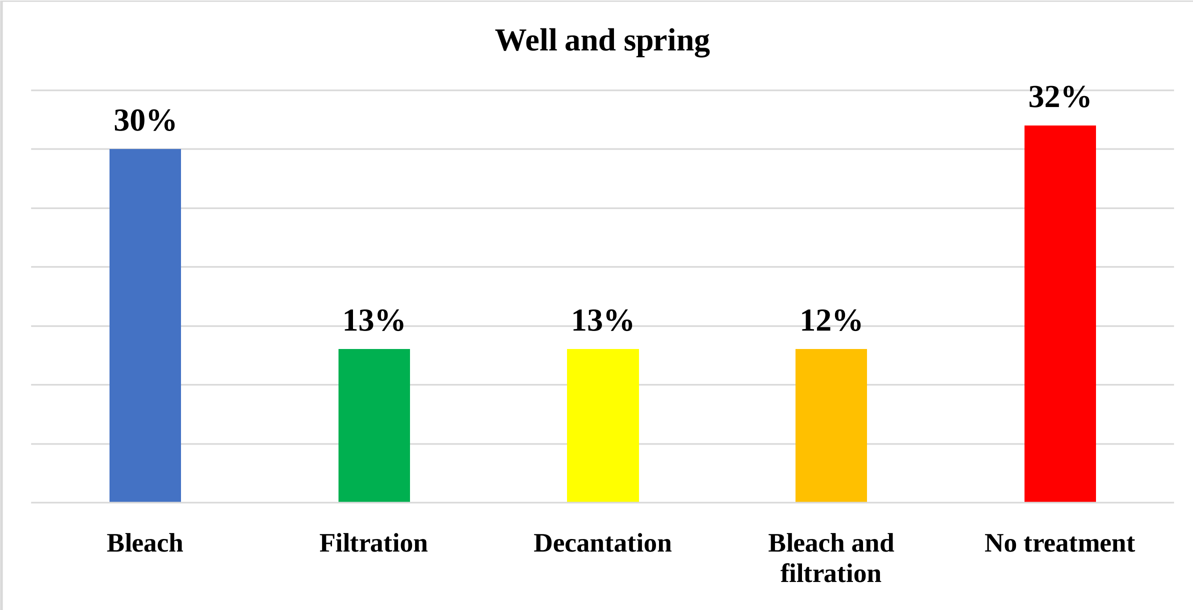

Fig 3:-Treatment method applied mainly to well and spring water.

Diseases detected

Fig 4 shows the various illnesses identified during the direct interviews with households in the city of Daloa. People stated that when they drink well or spring water, they often experience diarrhoea (46%), cholera (19%) and stomach pains (16%).

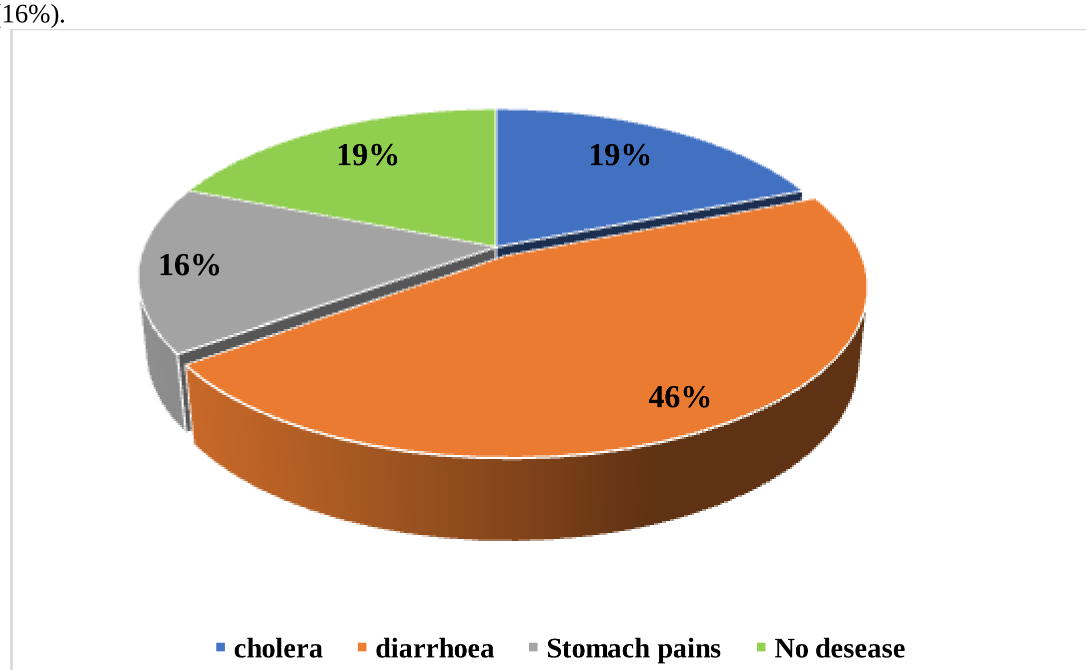

Fig 4:-Diseases encountered following consumption of well and spring water.

Basic physico-chemical characteristics of well and spring water

The table IV present the results of the univariate analysis carried out on the mean values of the fourteen (14) parameters studied (see in Appendices). It highlight the significant temporal variation in the different parameters. A total of eight (8) parameters for wells and seven (7) for springs vary significantly from one season to another. Thus, for wells, we note high values of temperature, sulfates, manganese, calcium and nickel in the rainy season. The opposite is true for nitrates, ammonium and iron, where average concentrations exceed WHO (2017) limit values during the dry season. Regarding the sources, the temperature, sulfates, manganese, calcium, and chromium are high in the rainy season. In the dry season, however, mean nitrate and ammonium concentrations are high.

Chemical quality of well and spring water

Fig 5 shows the chemical quality of well water sampled in the rainy season (histograms above) and in the dry season (histogram below). On the basis of the 14 physico-chemical parameters considered, the GQIs have enabled the well water to be classified into three classes in the rainy season : poor, very poor and inappropriate. The indices obtained are between 126 and 527, which exceeds the limit for good quality water, which is 100. In the dry season, however, the quality of this water passes into good and poor.

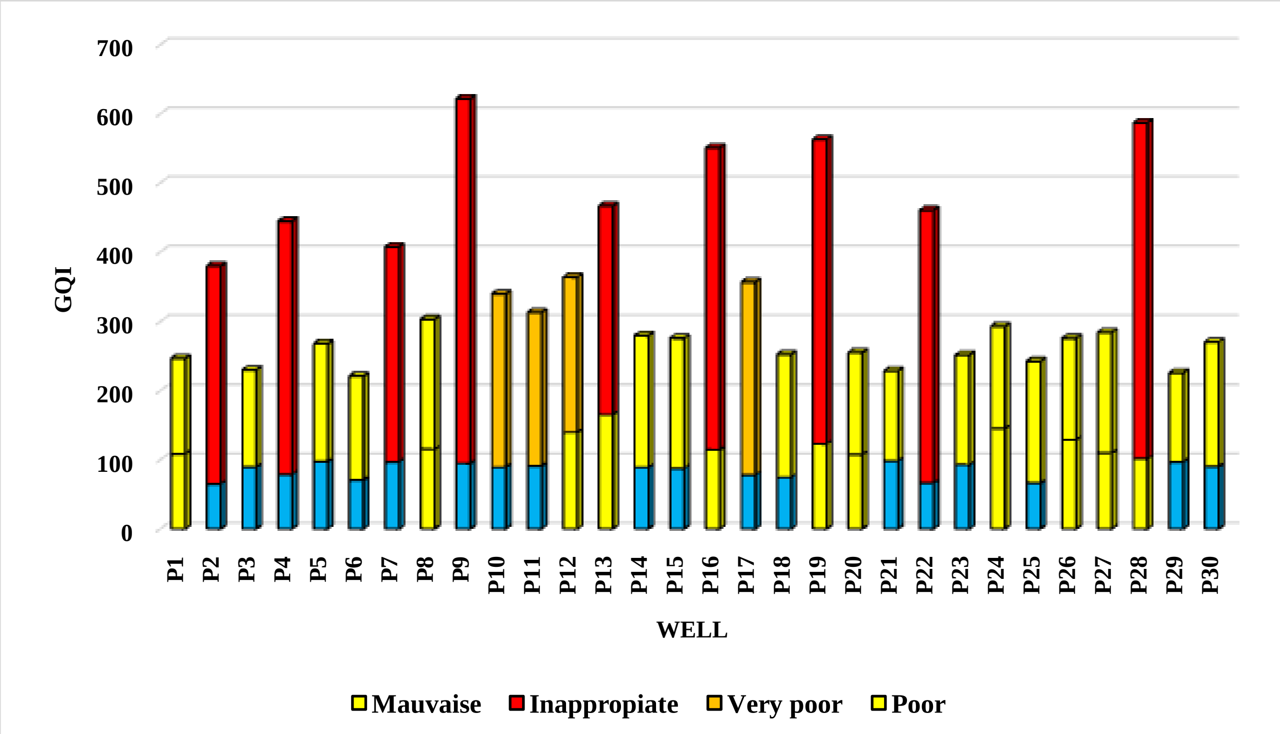

Fig 5:-Chemical quality indexes and classes for well water.

The variation in the chemical quality of spring water according to season is shown in Fig 6. In the rainy season, the quality of spring water remains poor, with indices ranging from 159 to 198. However, it varies from good to poor in the dry season. It should be noted that the quality of springs S1, S3, S6 and S9 remains unchanged, regardless of the season. It was also noted that the S4 spring dried up in the dry season, so the quality was only determined in the rainy season.

Characteristics of the chemical health risk

The health risk results for chromium indicate exposure of adults and children under 5 who consume well and spring water. Indeed, the hazard quotient (HQ) values are vastly greater than 1 for both well water and spring water in all seasons (Tables V and VI). In comparison with the rainy season, the hazard quotients obtained by ingesting water in the dry season decrease for both water sources. In both cases, the probability of the effects appearing in the population is very high. However, this study shows that children under the age of 5 are the most vulnerable when they consume spring water ($5.08 < HQ < 22.13$) and well water ($4.96 < HQ < 5.93$).

Also, this study showed that 0.02 and 0.03 mg/L are the lowest concentrations that have been obtained in drinking water and already indicate the presence of a high risk of gastrointestinal illness in children under 5 and adults respectively (see Table VII in appendices).

Concerning the level of carcinogenic risk linked to ingested chromium VI, the results are presented in Tables V and VI. It can be seen that there is indeed an increased risk of cancer of the gastrointestinal tract in the populations concerned who drink well water and spring water from Daloa. In fact, the CR obtained range from 4.0 x 10^{-4} to 5.4 x 10^{-3}. These are all above the threshold range of 10^{-6} to 10^{-4}. However, this risk decreases in the dry season for both adults and children under 5.

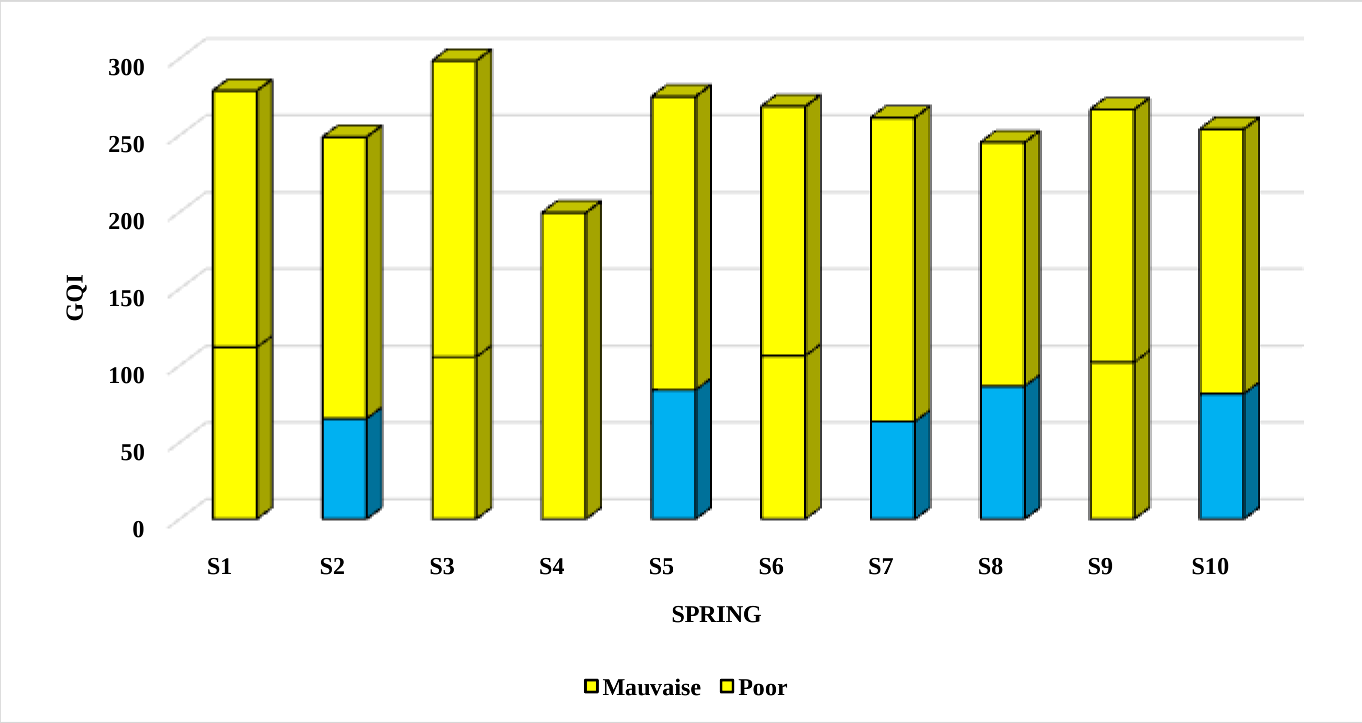

Fig 6:-Chemical quality indexes and classes for well water.

Table V:-Characterization of the chemical risk related to chromium in well water.

Well	Scenarios	C_{means}	ADD_{means}	HQ_{means}	CR
Rainy season	Children under 5 years old	0.05	0.0053	**5.93**	**1.4 x 10^{-3}**
	Adults	0.05	0.0018	**1.97**	**4.8 x 10^{-4}**
Dry season	Children under 5 years old	0.045	0.0045	**4.96**	**1.2 x 10^{-3}**
	Adults	0.045	0.0015	**1.65**	**4.0 x 10^{-4}**

Table VI:-Characterization of the chemical risk related to chromium in spring water.

Spring	Scenarios	C_{means}	ADD_{means}	HQ_{means}	CR
Rainy season	Children under 5 years old	0.199	0.0199	**22.13**	**5.4 x 10^{-3}**
	Adults	0.199	0.0066	**7.37**	**1.8 x 10^{-3}**
Dry season	Children under 5 years old	0.046	0.0045	**5.08**	**1.2 x 10^{-3}**
	Adults	0.046	0.0015	**1.69**	**4.1 x 10^{-4}**

Discussion:-

The survey carried out among households in the city of Daloa enabled us to appreciate the place or proportion that well water and spring water occupy in their daily habits. Indeed, it shows that 42 % of households use well water and 3% resurgent springs. These values could be explained by the fact that the majority of concessions in Daloa have a well. As for springs, these concern the 10 springs found in only a few neighbourhoods. These results corroborate those obtained by Awomon et al. (2018) and by Konan-Waidhet et al. (2020) at Orly (Daloa) and the Lobo catchment respectively.Their work highlighted increased use of well water (79.05 % ; 54.94 %). However, these results differ from those of Kouadio (2021), who conducted a survey of water supply sources in seven (7) cities, including Daloa, which uses around 55 % of water from the public network to the detriment of well water.

Next, these waters are consumed by everyone (adults, young people and children) and are disinfected by 68 % of households using either granulated calcium hypochlorite, filtration or decantation. For them, the use of bleach, especially for treatment, seems to be effective in killing all the microbes in the water. On the other hand, 32 % stated that they did not use any treatment at all, as they felt that the organoleptic quality of their water was better than that of water from the public network. In contrast, the results of Awomon et al. (2018) showed treatment by filtration. This study therefore made it possible to set up the scenarios (adults and children under 5) for assessing health risks. The WHO (2017) stipulates that this is a specific sub-population more exposed than the rest of the population to a given substance in relation to body weight. Following consumption of these waters, illnesses were detected by the population surveyed. Indeed, cases of diarrhoea (46%), cholera (19%) and stomach ache (16%) were reported, compared with 19% of people who had not observed any illnesses. These rates indicate that there are certain toxic or carcinogenic parameters in the water consumed. These results were also highlighted by Traoré (2021) who recorded 52.54% cases of diarrhoea, 15.25% cases of typhoid fever, followed by 11.86% cases of dermatosis in the Balouzonneighbourhood of Daloa.

From the above, 14 parameters were analysed in well and spring water in the city of Daloa. These were temperature, hydrogen potential, electrical conductivity, iron, manganese, calcium, magnesium, lead, chromium, nickel, sulphates, nitrites, nitrates and ammonium. Subsequently, the Mann Whitney test applied revealed that certain parameters varied significantly over time. Thus, for wells, these are temperature, sulfates, manganese, calcium and nickel which present high values in the rainy season. This is the opposite case for nitrates, ammonium and iron where average concentrations exceed limit values during dry season. Regarding the sources, temperature, sulfates, manganese, calcium, and chromium are high in rainy season. In the dry period, however, mean nitrate and ammonium concentrations are high. These parameters are governed by climate, geology and human activity. The variation in these parameters could be explained by the hydrolysis of certain silicate minerals such as quartz, mica, plagioclase and pyrite (geology of the area), but also by the rainfall of contaminants on the surface and their infiltration into groundwater. These results differ from those of Kouadio (2019), who found an increase in Fe, SO_4^{2-}, NO_3^- and a decrease in Ca^{2+} and Mg^{2+} during the main rainy season in all the wells studied. Physico-chemical parameters vary greatly because wells and springs are not very deep, as is the case in Daloa. Indeed, the wells and springs in Daloa are located in the first layer of alterites called alloterite, with depths ranging from 1.04 m to 20.42 m. The depth determines the distance the pollutant has to travel before reaching the water table (Kouadio 2019). The higher the water level, the faster the pollutant could reach the water table (Maqsoom*et al*. 2021 ; Patel *et al*. 2023).

Concerning the physico-chemical quality of well and spring water, it varies from one season to another. Indeed, water of poor, very poor and inappropriate quality is obtained in the rainy season and of good and poor quality in the dry season. This variation in water quality is attributable to the presence of heavy metals, which are present in high concentrations in the water. These results differ from those of Kouadio (2019) and Kamenan (2021), who worked in the same environment. This difference is probably linked to the number and types of parameters considered. In the present study, 14 parameters were used, which is not the case for these authors, who used 12 and 11 parameters respectively.

As a result of the water quality assessment, the people of Daloa are exposed to gastrointestinal diseases. Indeed, the hazard quotient (HQ) values obtained for the different scenarios are very high for both well water and spring water during the rainy and dry seasons, with HQs vastly higher than 1. However, children under the age of 5 are the most vulnerable when they consume spring water ($5.08 < HQ < 22.13$) and well water ($4.96 < HQ < 5.93$).

Therefore, low concentrations of heavy metals have been shown to be just as harmful to humans (Sanou *et al*., 2022). In fact, this study showed that 0.02 and 0.03 mg/L are the lowest concentrations that have been obtained in drinking water and already indicate the presence of a high risk of gastrointestinal illness in children under 5 and adults respectively. It could therefore be said that for concentrations of CrVI (above 7% of total chromium) there is a high risk of gastrointestinal disease. These results differ from those of Adeyemi &Ojekunle (2021), Shi *et al*. (2022) and Below *et al*. (2024) who carried out their research in countries such as Nigeria, China and Ethiopia. They all found HQ values of less than 1. This difference is thought to be linked to the quantity of water, the body weights of adults and children and the RfD. In fact, these authors used ingestion rates ranging from 2 to 2.8 L/d and 70 kg body weight for adults and 0.64 to 1.8 L/d and 10 to 30 kg body weight for children. The RfD used is 0.003 mg/kg/j.
In addition, drinking Daloa water can lead to cancer of the gastrointestinal tract in children and adults with body weights of 10 and 60 kg respectively. In fact, the carcinogenic risk values are all greater than 10^{-4} with a slight decrease in the dry season. This reduction could be explained by the fact that it does not rain enough in the dry season. As a result, rainfall and the infiltration of chromium and chromium VI are limited. This would favour a reduction in the chromium VI content and an increase in Cr III, which is essential for humans, in the water. These results were obtained by Oni *et al*. (2022) who worked on well water in Nigeria. Although they used 0.5 $(mg/kg/d)^-$

[1]as the oral slope factor, they found CR values greater than 10^{-4} (0,000330 and 0,000155 for children and adults respectively). However, this is not what was observed in the work of Saber *et al*. (2024) in Egypt. They obtained CR values that are 9.43528 x10^{-8} and that are below 10^{-6}. This difference is probably linked to the very low concentrations of chromium analysed in spring water.

Conclusion:-

This study aimed to estimate the potential health risk linked to the consumption of well and spring water in Daloa. Therefore, it necessitated first determining the quality of the water and then estimating the health risk associated with chromiumVI using the probabilistic method. To do this, analyses were carried out on 30 well water samples and 10 spring water samples, depending on the season. After analysis, it was found that the well and spring water contained low values of nutrient salts but high contents of metals, particularly total chromium. Most of the chemical quality parameters are below the WHO standard for drinking water, with the exception of heavy metals, and vary from season to season. As a result, the quality index obtained on the basis of the 14 parameters considered revealed seasonal variations in water quality. In fact, during the rainy season, well and spring water quality ranges from poor to inappropriate. In the dry season, the quality becomes good and poor. These waters are therefore subject to natural and man-made pollution. Consequently, the consumption of well and spring water would have harmful effects on the health of children under 5 and adults, because the probability of these effects occurring is very high (HQ > 1). In addition, drinking Daloa water can lead to cancer of the gastrointestinal tract in children and adults with body weights of 10 and 60 kg respectively. In fact, the carcinogenic risk values are all greater than 10^{-4} with a slight decrease in the dry season. Although this study has produced some interesting results, it could be supplemented by other investigations, a microbiological study. The precarious sewage system that exists in Daloa could encourage the infiltration of wastewater containing bacteria into the groundwater.

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Appendices:-

Table I:-Characteristics of households surveyed.

Characteristics	n = 200 households	Percent (%)
Gender		
Femme	108	54
Homme	92	46
Number of residents per household		
< 10	67	33.5
10-30	106	53
> 30	27	13.5
Consumers under 5 years old		
Oui	113	56.5
Non	87	43.5

Table II:-Unit weights and maximum guidelines values.

Parameters	Units weights (wi)	Guidelines values
T	4	30
pH	4	8.5
CE	4	1000
NO_3^-	5	50
NO_2^-	5	3
Cr	5	0.05
Pb^{2+}	5	0.01
Ni^{2+}	5	0.07
SO_4^{2-}	4	250
NH_4^+	4	1.5
Ca^{2+}	2	100
Mg^{2+}	2	50
Fe	3	0.3
Mn^{2+}	3	0.1

Table III:-Chemical risk assessment criteria.

Parameters	Children under 5 years old	Adults	References
Quantity of water ingested by day (Q) (L/d)	1	2	WHO (2017)
Body weight (PC) (kg)	10	60	WHO (2017)
Reference dose of Cr VI (mg/kg/d)	0.0009	0.0009	US EPA (2024)

Table IV:-Significant variation in physico-chemical parameters.

	Well water		Spring water		
	Rainy season	Dry season	Rainy season	Dry season	WHO 2017
T	28.99^a	28.45^b	29.48^a	28.32^b	25
pH	5.62^a	5.44^a	5.33^a	5.13^a	6.5-8.5
CE	222.49^a	246.51^a	74.86^a	79.50^a	

NO_3^-	2.36[b]	23.49[a]	1.330[b]	11.711[a]	50
NO_2^-	0.06[a]	0.13[a]	0.019[a]	0.051[a]	3
NH_4^+	0.43[b]	1.60[a]	0.353[b]	0.703[a]	1.5
SO_4^{2-}	13.37[a]	9.13[b]	9.200[a]	0.889[b]	250
Ni^{2+}	1.38[a]	0.19[b]	0.174[a]	0.178[a]	0.07
Pb^{2+}	0.01[a]	0.01[a]	0.010[b]	0.012[a]	0.01
Cr	0.18[a]	0.15[a]	0.664[a]	0.152[b]	0.05
Fe	0.12[b]	0.53[a]	0.663[a]	0.630[b]	0.3
Mn^{2+}	0.05[a]	0.05[a]	0.050[a]	0.025[b]	0.1
Ca^{2+}	93.35[a]	1.93[b]	88.300[a]	0.881[b]	100
Mg^{2+}	56.71[a]	2.68[b]	8.583[a]	3.114[b]	50

[a]high value ;[b]low value ; [a a]no significant variation ; [a b]significant variation

Table VII:-Concentration values for Cr VI and HQ from different water sources.

	Rainy season			Dry season		
Well/ Springs	CrVI (mg/L)	HQ_Children	HQ_Adults	CrVI (mg/L)	HQ_Children	HQ_Adults
P1	0,04	4,72	1,57	0,09	10,17	3,39
P2	0,03	3,65	1,22	0,01	0,91	0,30
P3	0,04	4,26	1,42	0,04	4,65	1,55
P4	0,02	2,73	0,91	0,02	2,30	0,77
P5	0,05	5,94	1,98	0,05	5,01	1,67
P6	0,04	4,41	1,47	0,01	0,95	0,32
P7	0,07	7,31	2,44	0,07	7,40	2,47
P8	0,06	7,16	2,39	0,08	9,10	3,03
P9	0,05	6,09	2,03	0,02	2,65	0,88
P10	0,05	5,33	1,78	0,05	5,73	1,91
P11	0,05	5,33	1,78	0,00	0,00	0,00
P12	0,04	3,95	1,32	0,06	6,90	2,30
P13	0,04	4,72	1,57	0,11	12,24	4,08
P14	0,05	6,09	2,03	0,03	2,92	0,97
P15	0,06	7,01	2,34	0,04	3,92	1,31
P16	0,06	6,24	2,08	0,01	1,61	0,54
P17	0,05	5,78	1,93	0,03	3,86	1,29
P18	0,06	7,01	2,34	0,00	0,00	0,00
P19	0,07	8,07	2,69	0,06	6,50	2,17
P20	0,05	5,63	1,88	0,05	5,57	1,86
P21	0,06	6,39	2,13	0,06	6,44	2,15
P22	0,05	5,48	1,83	0,00	0,21	0,07
P23	0,07	7,92	2,64	0,04	4,72	1,57
P24	0,08	8,53	2,84	0,08	9,17	3,06
P25	0,05	5,48	1,83	0,02	1,80	0,60
P26	0,07	7,31	2,44	0,10	11,53	3,84
P27	0,05	5,94	1,98	0,08	9,00	3,00
P28	0,05	5,33	1,78	0,06	6,58	2,19
P29	0,05	6,09	2,03	0,03	3,41	1,14
P30	0,07	7,92	2,64	0,03	3,58	1,19
mean	**0.05**	**5.93**	**1.97**	**0.04**	**4.96**	**1.65**
S1	0,18	19,70	6,57	0,09	10,04	3,35
S2	0,22	24,26	8,09	0,02	1,91	0,64
S3	0,21	23,50	7,83	0,04	4,87	1,62
S4	0,21	23,12	7,71	0,03	3,85	1,28
S5	0,21	23,88	7,96			
S6	0,17	19,32	6,44	0,08	8,99	3,00
S7	0,24	26,16	8,72	0,01	0,70	0,23
S8	0,18	20,46	6,82	0,06	6,51	2,17

S9	0,17	19,32	6,44	0,07	7,94	2,65
S10	0,19	21,60	7,20	0,01	0,94	0,31
mean	**0.19**	**22.13**	**7.38**	**0.05**	**5.08**	**1.69**