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Chinche Sylvie Belengfe
Laboratory of Hydrobiology and Environment, Department of Animal Biology and Physiology, Faculty of Science, University of Yaounde I, Cameroon

Zebaze Togouet Serge Hubert
Laboratory of Hydrobiology and Environment, Department of Animal Biology and Physiology, Faculty of Science, University of Yaounde I, Cameroon

Moanono Patrick Georges Thiery
Laboratory of Hydrobiology and Environment, Department of Animal Biology and Physiology, Faculty of Science, University of Yaounde I, Cameroon

Pountougnigni Oumarou F
Laboratory of Hydrobiology and Environment, Department of Animal Biology and Physiology, Faculty of Science, University of Yaounde I, Cameroon

Tuekam Kayo Raoul Polycarpe
Laboratory of Hydrobiology and Environment, Department of Animal Biology and Physiology, Faculty of Science, University of Yaounde I, Cameroon

Fomena Abraham
Laboratory of Parasitology and Ecology, Department of Animal Biology and Physiology, Faculty of Science, University of Yaounde I, Cameroon

Corresponding Author:
Zebaze Togouet Serge Hubert
Laboratory of Hydrobiology and Environment, Department of Animal Biology and Physiology, Faculty of Science, University of Yaounde I, Cameroon

Impact of physicochemical parameters on biodiversity and groundwater quality in Tiko, Cameroon

Chinche Sylvie Belengfe, Zebaze Togouet Serge Hubert, Moanono Patrick Georges Thiery, Pountougnigni Oumarou F, Tuekam Kayo Raoul Polycarpe and Fomena Abraham

Abstract
In order to evaluate the impact of physicochemical variation on biodiversity in ten wells in the town of Tiko, physico-chemical parameters of the well water were analyzed using standard methods while their fauna were collected using a phreatobiological net. The physicochemical analysis showed that, the well water in Tiko had high temperature (27 ± 0.84 °C), slightly acidic pH (6.42 ± 0.45 CU), highly turbid (13.55 ± 8.7 FTU), high orthophosphate levels (0.53 ± 0.45 mg/L), good dissolved oxygen level (59.57 ± 6.48 %), weak mineralization (256.75 ± 104.52 µS/ cm) with high colour content (32.17 ± 13.35 Pt/Co), with all the values being relatively higher in the dry season than in the rainy season except for colour. A total number of 6290 organisms were collected during the study period in the sampling points, belonging to 02 phyla, 09 classes, 29 families and 26 identified genus/or sub families. This community was dominated by Ostracods (46.51%) followed by Copepods (43.3 %) while the least taxa were Hirudinea (0.24 %) and Arachnids (0.35 %). Groundwater was rich in mostly epigean taxa and very poor in groundwater dependent organisms (hypogean taxa) due to the poor management and protection levels of the wells and also due to the relationship between ground water and surface water. A total of 43 stygobites were collected, belonging to the families Asellidae (01), Stenasellidae (20) and Darwinulidae (22). The results obtained showed that the water is not good for consumption by the population without treatments. There is therefore need to sensitize these population on the development of positive habits towards their water points in order to prevent them from water borne diseases that could be caused by the poor physicochemical properties.

Keywords: Cameroon, groundwater, physico-chemical quality, stygobites, Tiko

1. Introduction

Groundwater is water that flows beneath the earth's surface, filling the porous spaces in soil, sediments and rocks. It is the source of water for aquifers, springs and wells. It is the main source of drinking water reservoir on earth, but also a major ecosystem in terms of biological diversity (Leijs *et al*., 2009) [1]. Maintaining groundwater quality and conserving its biodiversity are converging goals towards ensuring healthy wells for the population. Groundwater ecosystems contain many endemic species adapted to live in an environment with no light and limited resources (Lou & Bloomfield, 2012) [2].

Ecological and microbiological exploration of groundwater over the past two decades has identified a diverse range of organisms inhabiting groundwater systems called stygofauna (Asmyhr *et al.,* 2014) [3]. They are made up of many kinds of crustaceans and other invertebrates which are typically well adapted for the subterranean environment with features such as lack of pigments, elongated appendages and reduced or absence of eyes (Humphreys, 2006) [4]. Stygofauna are valued as a biodiversity resource, as indicators of groundwater ecosystem health, and potential providers of ecosystem goods and services (Tomlinson *et al.*, 2007) [5]. Groundwater adapted species provide an important contribution to biodiversity (Lou and Bloomfield, 2012) [2]. In Cameroon, previous work has been done in this domain in the Centre, Littoral and West regions. The results of the physico-chemical parameters of the different stations studied showed that these regions have a high level of organic and chemical pollution and the groundwater habours Stygobites of the genus *Metastenasellus* (Zebaze Togouet, 2006, 2011, Tuekam Kayo, 2013, Nana Nkengmeni, 2015) [6, 7, 8, 9].

The main objective of this work was to determine the water quality of some wells in the town of Tiko by measuring the physicochemical parameters. It is also intended to identify potential biodiversity indicators in groundwater and to reinforce public awareness of the necessity to conserve the quality and quantity of groundwater and its biodiversity by emphasising on its economic, social, and scientific value together with its detriment on the health of the population when it’s quality is bad or not good for consumption.

2. Materials and Methods

2.1 Study area

Fako division experiences the subequatorial climate with two distinct seasons: more than four months of dry season from November to mid-March and seven months of rainy season that runs from mid-March to October with a mean annual rainfall of about 3.100 mm ±1.100 (Che *et al.*, 2012) [10]. Annual rainfall is thus high, with yearly precipitations varying from 1.500 to 6.000 mm whereby peak rainfall is recorded from June to August and at times in September. The mean annual temperature is approximately 26 °C and shows only limited variations of approximately 4°C throughout the year (Che *et al.*, 2012) [10].

2.2 Sampling points

The sampling for physicochemical and fauna analyses was carried out from January to December 2017. A total of ten sampling points was chosen for this study and sampling was done twice per season in the town of Tiko, which is situated in Fako division of the South West Region of Cameroon with coordinate points being latitude 4°04'00" N and longitude 9°21'18" E (Figure 1).

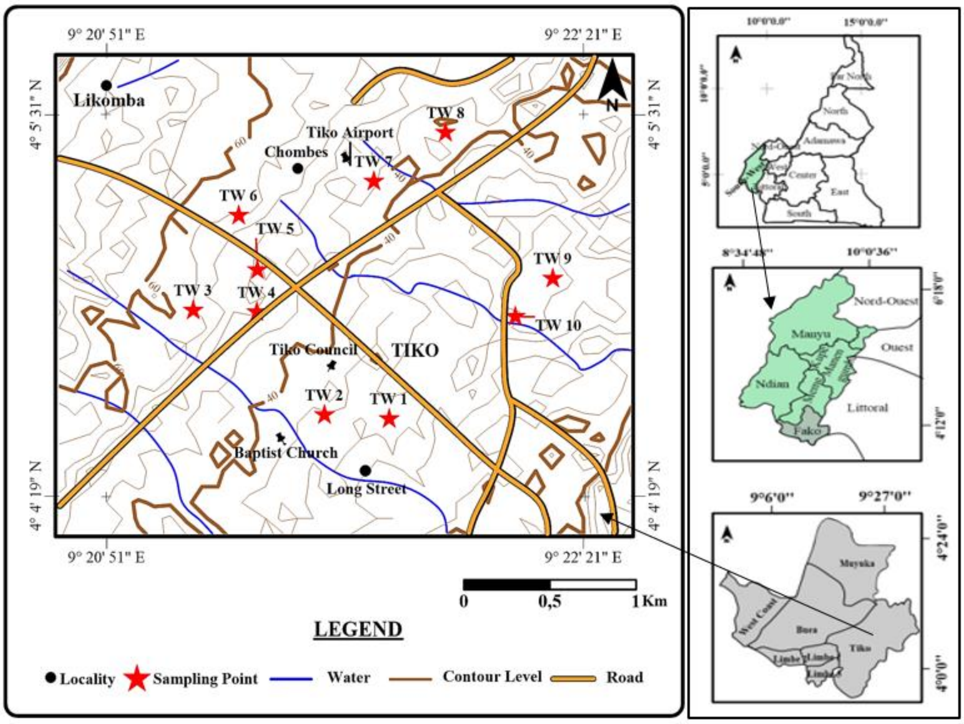

Fig 1: Map of Tiko showing sampling points during the study period

2.3 Sampling of water

Water for the physicochemical analysis was collected in 250 mL and 1000 mL polyethylene bottles and transported to the laboratory in a cooler at approximately 4° C. The physicochemical properties were measured following standard techniques described by APHA (1998) [11] and Rodier (2009) [12] using appropriate devices.

2.4 Sampling of fauna

The fauna were collected from the bottom of the wells using a Phreatobiological net sampler (Cvetkov, 1968) [13] with the net having a mesh size of 180-200 µm (Dumas & Fontanini, 2001) [14]. In the laboratory, the fauna were rinsed, sorted and identified and counted using a binocular magnifying loupe of the Wild M5 brand and an optical microscope IVymen R system using appropriate identification keys (Tachet *et al*., 2010, Moisan, 2010) [15, 16].

2.5. Statistical analysis

The software SPSS 20.0 was and Microsoft Excel 2016 program were used to analyse the results. Boxplots were used to represent the distribution of the physicochemical variables while a pie chat was used to represent the different taxa collected during the sampling period.

3. Results and Discussion

3.1 Physicochemical parameters

The lowest mean seasonal value of temperature was obtained in the rainy season (25 °C) and the highest value was obtained in the dry season (28.4 °C) with a mean seasonal value of 27 ± 0.83 °C. (Figure 2A). The mean seasonal value of total dissolved solids (TDS) was higher in the dry season than in the rainy season and the highest value was obtained in the dry season (210.5 mg/L) while the lowest value was obtained in the dry season (49 mg/L) with a mean seasonal value of 129.52 ± 52.75 mg/L(Figure 2B). The U test of Mann Whitney did not show any significant difference from one season to another for temperature and TDS. The highest value of suspended solids (SS) was obtained in the dry season (18.5 mg/L) while the lowest mean seasonal value of 2.5 mg/L was obtained in the dry season, with a mean seasonal value of 8.27 ± 4.90 mg/L. The U test of Mann Whitney showed a significant difference for SS value from one season to another (p=0.002) (Figure 2C). The value of colour varied from 10.50 mg/L in the dry season to 52.00 mg/L in the rainy season with a mean seasonal value of 32.17±13.35 mg/L (Figure 2D).

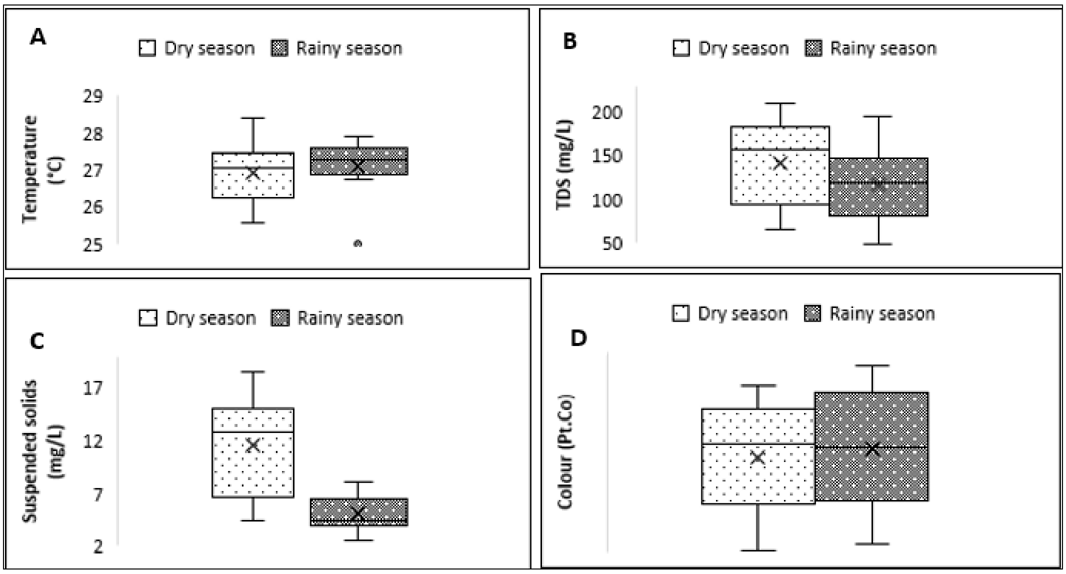

Fig 2: Boxplots showing the seasonal distribution of temperature (A), TDS (B), SS (C) and Colour (D) in the wells studied in Tiko

Turbidity values oscillated between 3.00 FTU in the rainy season and 29.00 FTU in the dry season and the U test on Mann Whitney showed a significant difference between the rainy and the dry season ($p < 0.05$) (Figure 3A).The mean seasonal value of salinity was distributed between 0.04 PSU in the dry season and 0.19 PSU, obtained in both the rainy season and the dry season, with a mean value of 0.11 ± 0.04 PSU (Figure 3B).The value of electric conductivity varied from 98.50 µS/cm in the rainy season to 416 µS/cm in the dry season, with a mean seasonal value of 256.95 ± 104.52 µS/cm and no significant difference was observed for this parameter (Figure 3C). The mean seasonal value of pH varied significantly during the study period, with lowest value being 5.63, obtained in the rainy season while the highest value was 7.24, obtained in the dry season. A significant difference was observed between the dry and rainy season as shown by the U test of Mann Whitney (p<0.05) (Figure 3D).

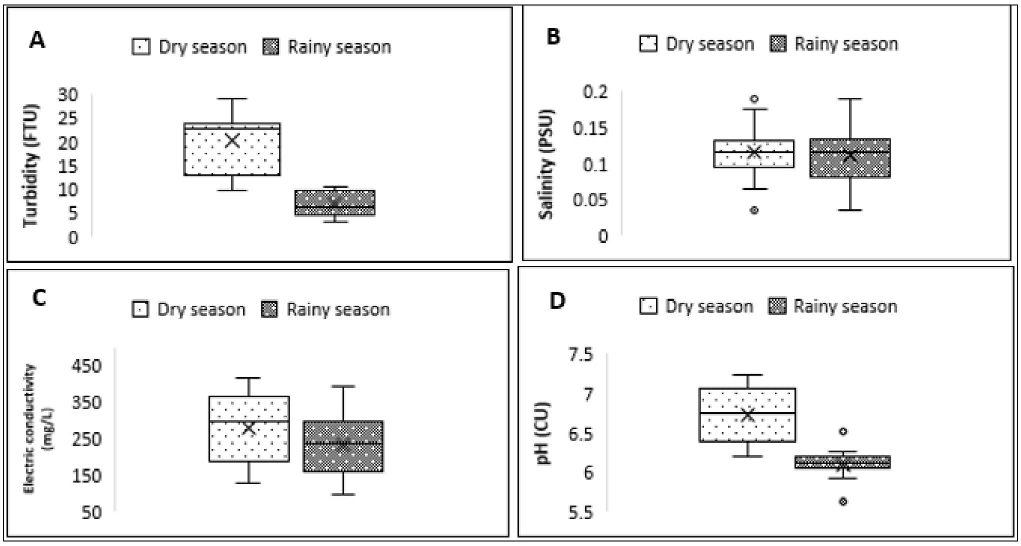

Fig 3: Boxplots showing the spatial and temporal distribution of turbidity (A), salinity (B), electric conductivity (C) and pH (D) in the wells studied in Tiko.

Orthophosphates values fluctuated between 0.17 mg/L in the rainy season with a mean of 0.51 ± 0.15 mg/L and 2.40 in the dry season whereby the U test of Mann Whitney showed a significant difference from one season to another (p = 0.007) (Figure 4A). The values of oxidability oscillated between 1.19 mg/L in the rainy season and 6.02 mg/L in the dry season and the U test of Mann Whitney showed a significant difference between the rainy and dry season (p = 0.09) (Figure 4B). The mean seasonal value of nitrate ions varied from 0.20 mg/L as lowest value to 2.75 mg/L as highest value, both obtained in the dry season with a mean value of 1.19 ± 0.61 mg/L and the U test of Mann Whitney did not show any significant difference between the seasons (Figure 4C). As for nitrite ions the values were higher in the rainy season than in the dry season and varied from 0 mg/L, obtained in the dry season to 0.06 mg/L, obtained in the rainy season, with a mean value of 0.02 ± 0.01. The U test of Mann Whitney did not show any significant difference from one season to another for nitrite ion (Figure 4D).

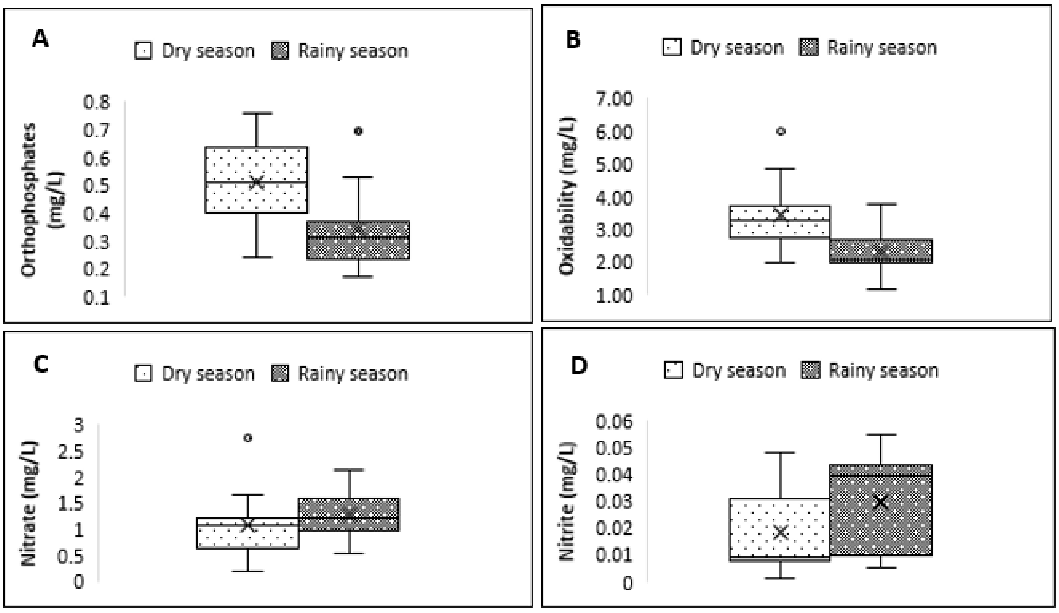

Fig 4: Boxplots showing the seasonal distribution of orthophosphate (A), oxidability (B), nitrate (C) and nitrite (D) in the wells studied in Tiko

Dissolved oxygen values were distributed from 47.70 % to 75.75 %, with all values obtained in the dry season with a mean value of 59.57± 6.48 % (Figure 5A). The mean seasonal value of dissolved carbon dioxide was varied from 0.35 mg/L in the rainy season to 6.03 mg/L in the dry season and the U test of Mann Whitney showed a significant difference between the rainy and dry season with a p value of 0.001 (Figure 5B).

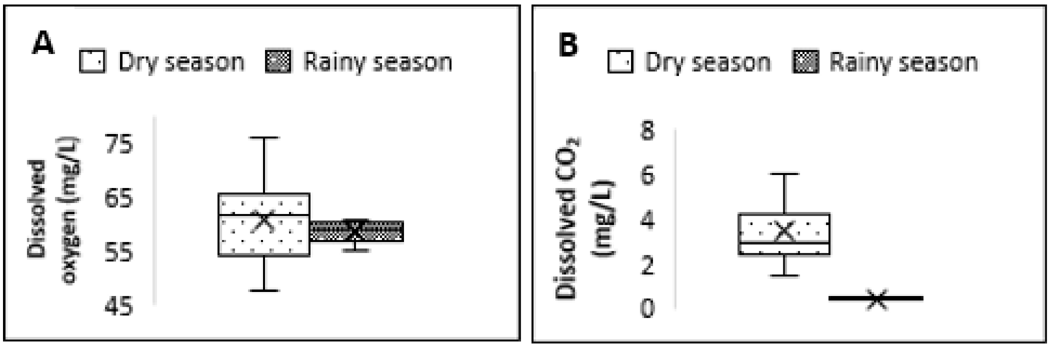

Fig 5: Boxplots showing the seasonal distribution of dissolved oxygen (A) and dissolved carbon dioxide (B) in the wells studied in Tiko

3.2 Groundwater fauna of Tiko

The organisms collected during the sampling period was a total of 6290 organisms belonging to 02 phyla (Annelida and Arthropoda), 09 classes, thirteen orders, 29 families and 26 genus/sub family. This fauna was diversified and dominated by Ostracods which alone had a total abundance of 46.51%, followed by Copepods with an abundance of 43.3 %. The taxonomic richness of the wells varied between eight individuals in TK 10 and 19 individuals in TK7. The fauna collected in the studied stations is characterized by the prevalence of epigean taxa (from external origin), at the detriment of a very small number of hypogean taxa (stygobiont groups). The fauna collected shows that, the wells in Tiko are largely dominated by the class Crustacean with principal representatives being families of Cytherididae, Cyprididae and Cyclopoidae (Figure 6).

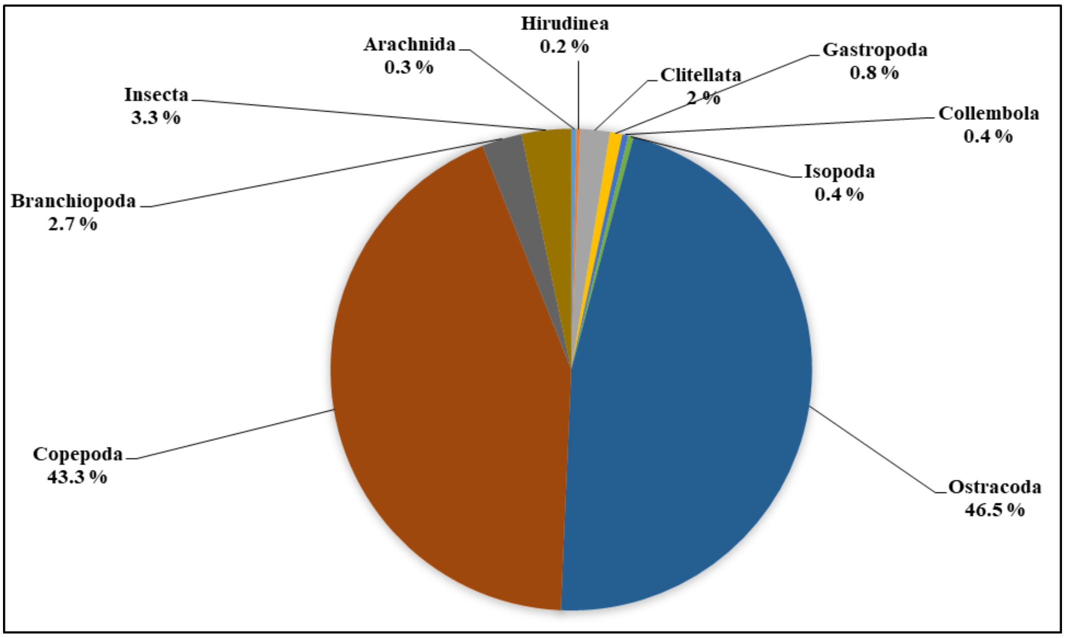

Fig 6: Distribution of the different classes of the 6290 invertebrates collected in groundwater during the sampling period in the wells in Tiko.

Cyclopoidae were present in all the 10 sampling points and were abundant in sampling points that showed high organic matter and that are fairly mineralized as far as the physicochemical analyses are concerned. Cyprididae (Ostracods) stygophiles or stygobites taxa, very small of size, widespread and less studied, were present in all the wells except for TW10 (Table I). Insects of the family Chironomidae were abundantly collected. Out of the 6292 organisms collected, 43 organisms were stygobites represented by three families; Stenasellidae, Darwinulidae and Asellidae and a total of 20 Stenasellidae was collected in six out of the ten wells that were sampled (TW3, TW5, TW7, TW8, TW9 and TW10). The second stygobite family was Asellidae (Proasellus), collected in TW7 with a total of just one individual. The third group was Darwinulidae whereby a total number of 22 individuals were collected in TW1, TW6 and TW8. The diversity index (H) of Shannon and Weaver showed that the fauna in Tiko was more diversified in the rainy season (1.19 ± 0.48) than in the dry season (1.06 ± 0.4) and the equitability index (J) also showed that the rainy season was more equitable (0.57 ± 0.25) than the dry season (0.51 ± 0.13).

Table 1: Groundwater fauna collected during the study period in the ten wells in Tiko

Class	Order	Family	Genus/sub family	Tk1	Tk2	Tk3	Tk4	Tk5	Tk 6	Tk7	Tk8	Tk9	Tk10	Total
Arachnida	Acarina	Tetragnathidae	Tetragnatha	0	0	0	0	0	0	5	0	1	0	6
		Ceratozetidae		0	0	0	0	0	0	0	0	1	2	3
Hirudinea	Euhirudinea	Bdellidae	Bdellina	0	0	8	2	0	0	0	0	1	0	11
		Piscicolidae	Rhynchobdellida	0	0	0	2	4	0	0	2	1	0	9
Clitellata	Oligochaeta	Lumbriculicidae	Lumbriculus	1	7	0	0	29	0	0	2	0	0	39
		Naididae	Dero	28	2	4	42	9	3	5	5	0	0	98
		Physidae	Physa	24	1	0	0	19	0	8	0	0	0	52
Collembola	Entomorbryomorpha	Isotomidae	Folsoma	7	0	2	0	3	2	4	2	0	0	20
		Entomobryiidae	Orchesella	1	2	0	0	1	0	1	0	0	0	5
Isopoda	Isopoda	Asellidae*	Proasellus*	0	0	0	0	0	0	1	0	0	0	1
		Stenasellidae*	Metastenasellus*	0	0	4	0	3	0	2	3	7	1	20
Ostracoda	Podocopida	Cytherididae		698	45	0	0	85	5	100	47	6	5	991
		Cyprididae	Psychrodromus	697	510	4	5	376	65	171	67	19	0	1914
		Darwinulidae*		12	0	0	0	0	2	0	8	0	0	22
Copepoda		Cyclopidae		580	417	197	50	342	683	158	94	65	139	2725
Branchiopoda	Cladocera	Moinidae	Moina	0	0	0	0	0	0	161	7	1	0	169
Insecta	Diptera	Culicidae	Culex	0	0	0	0	0	0	6	1	0	0	7
		Chironomidae	Chironomus	9	18	0	3	0	2	22	3	0	0	57
			Chironomini	0	0	1	0	0	0	8	0	0	0	9
		Ceratopogonidae	Dasyheilea	0	0	0	3	1	0	0	0	1	1	6
			Bezzia	0	0	0	0	0	0	6	0	0	0	6
		Psychodidae	Pericoma	0	0	0	2	0	3	0	0	0	1	6
		Ephydidae	Scatella	0	0	2	0	0	1	1	0	0	0	4
	Dysticidae	Dysticidae	Laccophilus	0	1	0	0	0	0	0	0	0	5	6
		Hydrophylidae	Hydrophilus	1	0	0	0	1	0	0	0	0	0	2
		Elmidae	Macrelmis	0	2	0	1	0	0	6	0	0	7	16
	Ephemeroptera	Caenidae	Caenis	0	11	0	3	0	0	0	7	0	0	21
	Hemiptera	Mesovelidae	Mesovelia	0	0	0	0	0	0	2	0	0	0	2
		Aeshnidae	Aeshna	0	0	3	0	0	0	0	10	0	0	13

	Hymenoptera	Formicidae		0	3	5	2	12	1	13	10	0	0	46
	Orthoptera	Blattidae	Panesthia	2	0	1	0	0	0	0	1	0	0	4
Total number of individuals				2060	1019	231	115	885	767	680	269	103	161	6290
Total number of taxa				12	12	10	11	15	10	19	16	10	8	
Stygobitic richness				1	0	1	0	2	1	2	2	1	1	

* represents the stygobite families and genus

4. Discussion

4. 1. Physicochemical analysis

The high values of temperature obtained in the rainy season could be due to the reduction of the water level and the depth of the wells, which allowed sunlight to directly penetrate into these wells and the characteristics of each sampling point such as, vegetation canopy, topography of the site in relation to the external milieu (Huang F. *et al.*, 2019) [17].As for TDS, the values were relatively high due to infiltration of sea water into the underground milieu as a result of the nature of the soil in Limbe. Values are within the limit set by WHO (2017) [18] for water meant for consumption and the high values in the dry season was due to the decrease in water level and from the weathering of volcanic rocks and erosion of the soil around by rain water. The high values of electrical conductivity in the dry season is due to the decrease in water level brought about by constant fetching of the water by the users. According to Rodier (2009) [12], the acceptable level in drinking water is between 0 µS/cm and 600 µS/cm. Zébazé Togouet *et al.* (2009) [19], Tuékam Kayo (2013) [8] obtained same kind of results in the Centre and Littoral regions respectively. This gives a picture of very little solute dissolution generally in the groundwater, rapid ion-exchange between the soil and water.

Turbidity values were higher than the 5 FTU recommended by WHO (2017) [18] and it could be due to the poor nature of the protection of the wells which allows rain water to penetrate into wells. Good protection of wells prevents the penetration of running rainwater which most of the time, is loaded with plant and animal debris and these particles could be a sign of pollution, which can bring microorganisms that live principally in biofilm state in groundwater (Nana Nkengmeni *et al.*, 2015, Zébazé Togouet *et al.*, 2011) [9, 7]. The values of Suspended Solids were very high in the dry season compared to the rainy season due to particles as a result of decrease in water column. Generally, almost all the sampling points had an acidic pH during the rainy season and acidic to slightly basic pH in the dry season. These waters were slightly acidic, and this acidity is justified by the Prévosto *et al.*, (2004) [20] who observed that, the pH of volcanic substratum vary between 5.7-6.4. This is true as Fako division is made up of volcanic soil due to the presence of Mt Fako which is an active volcano. This kind of result had first been observed by Tuékam Kayo (2013) [8] in the town of Douala and Yaounde, which is a characteristic of the Cameroon substrata. Salinity values were generally low and fall within WHO (2017) [18] standards for drinking water. Orthophosphate values are above the standard recommended by WHO (2017) [18] (0.40 mg/L) for drinking water, which could be related to the proximity of the sampling points to the CDC rubber and palm plantations and the presence of traditional latrines in the neighbourhoods. Zebaze Togouet *et al.*, (2011) [7] observed that the high percentages of orthophosphates would come from agricultural fertilizers and fecal pollution which would arrive in underground milieu by infiltration. The average value of nitrate ions in all the sampling points was within the level permitted by WHO (2017) [16] for drinking water. According to Bengouni *et al.*, (2004) [21] the concentration of nitrate ions in natural environment seldom exceeds 0.45 mg/L. The high values could be due to the infiltration of water containing nitrate fertilizers used by the CDC and even by the population themselves in their farmlands. Chapman *et al*, (1996) [22] affirmed that values higher than 0.45 mg/L in subsoil waters indicate worn water discharges and especially an excessive use of fertilizers for agriculture. Nitrite is an intermediate in the oxidation of ammonia to nitrate, such oxidation can proceed in soil, and because sewage is a rich source of ammonia, water which show any appreciable amounts of nitrite is regarded as being of highly questionable quality (Istifanus *et al.*, 2013) [23]. Levels in unpolluted waters are normally low, below 0.03 mg/L. Values greater than this indicate sewage pollution which could explain the case in the rainy season due the proximity of the wells to latrines of the owners. The percentage of saturation of dissolved oxygen recorded during the study period reveals that this water is fairly oxygenated, with an average value of (62.03 ± 7.27 %). In groundwater, the dissolved oxygen contents are relatively weak compared to those of surface water, because of the absence of the photosynthetic plants, the weak water-atmosphere contact and the absence of water turbulence (Humphreys 2002) [24]. Ammonium ions translate richness of water in organic matter, which according to Nisbet and Verneaux (1970) [25] would indicate a certain degree of pollution and it comes from agricultural processes and the decomposition of living matter by the micro-organisms since naturally, groundwater does not contain nitrogen compounds.

The groundwater studied did not contain amounts that could be of danger to human health and the ammonium levels were within the range permitted for drinking water, which is 10 mg/L WHO (2017) [18]. Due of a strong carbon limitation, the underground ecosystems are placed in extreme position along a gradient of productivity (Chelius *et al.*, 2009) [26]. Therefore, the carbon present in the groundwater of Tiko would be primarily ascribable to the degradation of organic particles by bacteria and to expiration by underground invertebrates. Moreover, the organic carbon contributions in dissolved form constitute the basal resource of the underground trophic networks. The studied wells in Tiko are rich in parameters of organic pollution and therefore, the groundwater water quality in Tiko is polluted due to anthropogenic impacts such as infiltration of sewage effluent discharges, run-off from informal settlements and agricultural activities such as livestock farming.

4.2 Groundwater fauna in Tiko

These are two very important communities of organisms (epigean and hypogean) in groundwater and each of them play a well-defined role: hypogean organisms inform about the state of ground water while epigean organisms give an idea on the input from exogenic origin, on the hydrological characteristics, the level of protection and on the morphometric and hydrological characteristics of the wells (Nana Nkemegni *et al.*, 2015) [9]. Zebaze Togouet *et al.*, (2011) [7] suggest that the taxonomic richness of a well depends on the intrinsic characteristics of each station, its relations with the surface medium and also on the nature and characteristics of the various land which form the aquifers in which this ground water flows from. The prevalence of microcrustaceans would be in relation with the moderate or even weak quantity of organic matter recorded in the wells. In this connection, Broyer and Rodin (2003) [27] proposed that under natural conditions, Crustaceans are most widespread in groundwater; they account for approximately 60% of underground aquatic fauna. In Tiko, Crustaceans dominated (Ostracods (46.5 %) and Copepods (43.3 %). Chironomids Diptera larvae born from the laying of eggs by adult insects. Their existence depends on the local microclimate, protection of water points and on the physico-chemical characteristics of water (Tuékam Kayo, 2013) [8]. Chironomids were abundant in TK7, TK2 and TK1, which are wells that were partially protected by the owners. The presence of stygobites in some wells is in accordance with the suggestion of Zebaze Togouet *et al*. (2011) [7] about a positive relation between a high aquatic biodiversity and the presence of stygobite species though in relatively small numbers. This small number of stygobites compared to epigean taxa can probably be linked to the nature of the water bodies since there is a certain degree of pollution. Groundwater ecosystems are generally poorer in nutrients and oxygen than surface water ecosystems (Galassi *et al.*, 2017) [28]. In order to reduce energetic costs, groundwater ectotherms have evolved metabolic rates that are lower than those of their close epigean relatives (Issartel *et al.*, 2005) [29]. The family Stenasellidae was observed in Cameroon by Zebaze Togouet (2006) [6] for the first time and later described by Zebaze Togouet *et al.*, (2009, 2011, 2013) [19, 7, 28]. The Stenasellidae family sampled in Tiko presented the same characteristics described by Zebaze Togouet *et al.*, (2009) [19] by being of different sizes and with more abdominal and cephalic appendages which are different from those found in other countries. They have an entirely pink body in fresh samples and whitish body in specimens preserved in alcohol, regular in form and similar to individuals of the other species of their kind, with lateral margins of a parallel body. The high levels of most of the parameters in the dry season could be the result of the less diversity obtained in the dry season.

4.3. Relationship between biodiversity and physicochemical parameters

Stygofauna were recorded living in physico-chemically diverse groundwater systems like the case of LW1, including in systems with groundwater ranging in depth from 0.61 in LW1 and 15 metres in TW5. Glanville *et al.*, 2016 [31] have shown that, stygofauna can be found at depth of 0.1 to 63.2 metres below ground level with electrical conductivity ranging from 11.5 to 54.800 µS/cm, groundwater temperatures ranging from 17.0 to 30.7 degrees Celsius and groundwater pH ranging 3.0 to 11 CU. Information on the wide variance in the physico-chemical properties of known groundwater habitats is valuable in developing understanding of the characteristics of groundwater systems that support groundwater communities. Stygofauna taxon richness shows a general negative trend with increasing depth to groundwater, Total dissolved solids and electrical conductivity in the wells. Taxon richness was highest in neutral to slightly alkaline pH groundwater systems and in water temperatures between approximately 12.6 and 27 degrees Celsius. Humphreys, 2008 [32] considered that groundwater systems in volcanic and sedimentary rocks may tend towards acidic environments that would be less suited to supporting stygofauna due to constraints imposed by the reducing environment. This is consistent with Tiko experience where taxon richness decreases sharply with increasing groundwater acidity. The richness in the well depends at the same time on the underground species (Stygobites) and the surface species (Stygoxene and Stygophiles) (Dole-Olivier *et al.*, 2009b) [33].

5. Conclusion

The present study showed that, the aquatic fauna of Tiko is relatively rich with a total of 29 families collected during the study period. The distribution and abundance of groundwater fauna families and genera are influenced by physicochemical conditions, and the characteristics of the wells and also the season. Most of the physicochemical parameters measured were high in the dry season than in the rainy season which brought about changes in fauna structure of the wells. This change in functional groups and habits of aquatic ecosystems could fundamentally alter the normal functioning of these ecosystems. This could directly affect the diversity and distribution of groundwater fauna especially stygobites that depend upon the water quality for their survival. Stygobites were collected in sampling points with high electric conductivity and low results of parameters that are indicators of organic pollution. The results show that, there is an important pollution of groundwater which limits the presence of stygobitic species as seen in the abundance of pollution resistant species such as copepods, ostracods and oligochaetes.

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