https://doi.org/10.30799/jespr.185.20060101 J. Environ. Sci. Pollut. Res. - Volume 6 Issue 1 (2020) 408–411

Share Your Innovations through JACS Directory

Journal of Environmental Science and Pollution Research

Visit Journal at http://www.jacsdirectory.com/jespr

ISSN: 2455-0272

Spatial and Temporal Variation of Faecal Indicator Bacteria in Three Reservoirs of Ivory Coast (Taabo, Kossou and Fae)

Gogbé Jean-Luc Tiémoko*, Nouho Koffi Ouattara, Cyr-Kevin Yao Kouamé, Allassane Ouattara, Germain Gourène

Environment and Aquatic Biology Lab., Dept. of Environmental Science and Management, Nangui Abrogoua University, 02 BP 801 Abidjan 02, Ivory Coast.

A R T I C L E D E T A I L S

Article history:
Received 26 October 2019
Accepted 12 November 2019
Available online 10 December 2019

Keywords:
Water Quality
Waste Water
Faecal Contamination
Reservoir

A B S T R A C T

The reservoirs of Taabo, Kossou and Fae receive agricultural and domestic wastewaters which may impact their microbial quality, while the reservoir waters are used for fish farming, irrigation and other domestic purposes. This study aimed to evaluate the microbiological quality of these reservoirs by assessing the spatial and temporal distribution of the faecal indicator bacteria (FIB) abundances (*Escherichia coli* (*E. coli*) and Intestinal Enterococci (IE)). Thus, water samples were collected throughout a year at different sites of each reservoir. The FIB abundance (10×10^0 to 1.53×10^4 CFU *E. coli*.100 mL^{-1}; 10×10^0 to 2.67×10^3 CFU IE.100 mL^{-1}) were recorded, with high level values observed during the rainy season. The areas near the shore were more affected by faecal contamination than deepest areas due to the direct domestic wastewaters' releases. According to EU directive, the 90th percentile of the concentration of *E. coli* and IE in Taabo and Kossou reservoirs were lower than the level required for bathing indicating that the bathing could be possible. In contrast, the concentration of *E. coli* and IE in Fae reservoir were higher than the reference values, thus limiting uses of water for domestic purpose and irrigation and fish farming.

1. Introduction

Hydropower reservoirs offer multiple purposes and provide services beyond electricity generation. The Dam waters are used as water supply, drought management, irrigation, fisheries, environmental services, and recreational activities [1]. These hydropower reservoirs also recreate a specific ecosystem with particular food-web structure. The dam water ecosystems are often impacted by the hydraulic condition, the climatic conditions, the operation of the hydropower system and the cumulative effects of industries and activities around or upstream the hydroelectric system [2,3]. The main activities developed around and on reservoirs are: irrigation, fisheries and recreational activities. These reservoirs, connected to the rivers or their tributaries, receive industrial, agricultural and domestic wastewater containing pathogenic microorganisms, organic matter, nitrogen, phosphorus and other heavy metals. These pollutants discharged by sewage waters contribute to disturb the reservoirs ecosystem and also alter waters quality. The physico-chemical and biological pollution from point and non-point sources may cause eutrophication and aquatic animals depletion [4,5].

Dams of Taabo, Kossou and Fae are three hydroelectric reservoirs in Ivory Coast, which are highly impacted by domestic and agricultural wastewaters, causing mortality of fish and diseases for fishers and other users of water bodies [6-8]. Indeed, household waste, aquaculture, cattle farming and agriculture developed around these hydroelectric dams, brought nutrients and other pathogenic microorganisms into these reservoirs [6-8]. The microbiological water quality of these reservoirs is unknown while the waters of these hydroelectric reservoirs are often used for domestic purposes, aquaculture and agricultural activities. Thus, it is appearing very important to perform monitoring studies in order to evaluate the microbiological quality of reservoir waters and then prevent sanitary risk associated to the waters uses.

Assessment of microbiological water quality is based on the quantification of faecal indicator bacteria. Nowadays, *Escherichia coli* (*E. coli*) and Intestinal Enterococci (IE) are the most important faecal indicator bacteria used for assessing faecal pollution in surface waters [9]. They are abundant in the faeces of warm-blooded animals, including humans, and their presence indicates whether faecal contamination is present and whether potential risks from these and other pathogenic bacteria or viral agents may exist [10]. These bacteria have been used in many research studies for assessing microbial quality of water [11-15]. The study aims to i) evaluate the microbiological water quality of these dam waters and ii) determine the spatial distribution and the temporal variation *E. coli* and IE abundances in these reservoirs.

2. Experimental Methods

2.1 Study Area

The study area is composed by three man-lakes located in Ivory Coast: Kossou, Taabo and Fae (Fig. 1). The Kossou reservoir covers an area of 1700 km² in the center part of the country. The Taabo reservoir, located 120 km downstream of the Kossou reservoir, covers an area of 62 km² [6,16]. The Fae hydroelectric dam covers an area of 16.28 km² located in South-western region of Ivory Coast [17]. Watershed of Taabo, Kossou and Fae hydroelectrics reservoirs covers, an area of 58700 km², 32400 km² and 2424 km² respectively. These watersheds are mostly composed by rural area and agriculture [6,7]. Invasive aquatic plants are present and occupy a large part of the surface of the different water bodies.

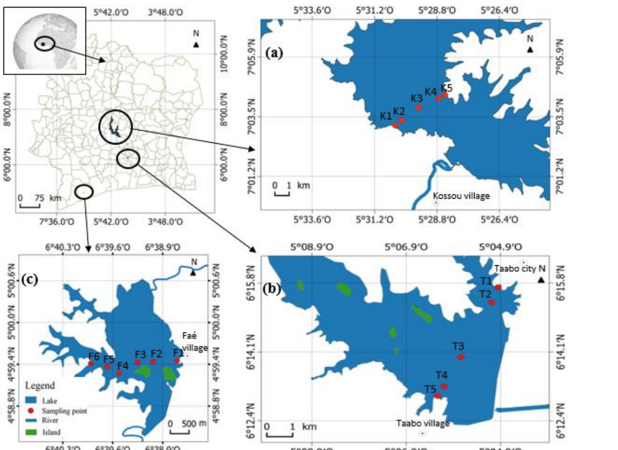

Fig. 1 Reservoirs with sampling points: a) Kossou lake, b) Taabo lake and c) Fae lake

*Corresponding Author:gogbejeanluc_tiemoko@yahoo.fr(G.J-L. Tiémoko)

https://doi.org/10.30799/jespr.185.20060101

2.2 Sample Collection

Sampling was conducted over a period of 1 year, from November 2017 to October 2018 inclusive. A total of 128 samples were collected in the whole lakes. Briefly, sterile bottles of 1 L were filled out with water sampled from the surface of all reservoirs along a transect for comparing the littoral and depth area: 5 sampling points for Taabo and Kossou lakes and 6 sampling points for Fae lake (Fig. 1). The bottles have been labeled and transported to the laboratory on ice in coolers box (4 °C) and processed within a maximum of 8 h after sampling for microbiological analysis. Land use patterns in the areas near sampling points are described in Table 1.

Table 1 Coordinates and characteristics of the sampling sites in each man–made lake

Reservoirs	Location	Description of land use types	Coordinates	
			Latitude (N)	longitude (W)
Taabo	T1	Urban zone near of lake, cattle farming on the shore, agriculture (hevea, cassava crops)	06°15'46.6"	-05°04'57.4"
	T2	Fish farming into the lake, fishing area	06°15'42.5"	-05°04'59.3"
	T3	Fish farming into the lake, fishing area	06°13'58.3"	-05°05'45.2"
	T4	Fishing area	06°13'00.8"	-05°06'13.7"
	T5	Big village close to the lake, fishing area, agriculture	06°12'59.2"	-05°06'14.6"
Kossou	K1	Small village near of the lake, cattle farming, mining activities in the shore	07°03'12.5''	-05°30'25.1''
	K2	Fishing area, mining activities in the shore	07°03'21.2''	-05°30'25.7''
	K3	Fishing area	07°03'53.3''	-05°29'30.1''
	K4	Fishing area	07°04'16.6''	-05°28'37.2''
	K5	of the lake, cattle farming	07°04'24.6''	-05°28'30.2''
Fae	F1	Big village very close to the lake, fishing area	04°59'24.2"	-06°38'01.3''
	F2	Fishing area	04°59'27.2"	-06°38'40.2''
	F3	Fishing area, watercourse pathway, agriculture on the shore (cocoa, hevea)	04°59'26.3"	-06°39'00.8''
	F4	Fishing area, agriculture on shore (cocoa, hevea crops)	04°59'15.9"	-06°39'30.2''
	F5	Fishing area, agriculture on shore (cocoa, hevea crops)	04°59'21.5"	-06°39'40.7''
	F6	Fishing area, agriculture on the shore (cocoa, hevea crops)	04°59'24.5"	-06°39'55"

2.3 Analysis of Physico-Chemical Parameters

Temperature and dissolved oxygen were measured *in situ* by the Oxygen Meter (HANNA HI 9146) and the pH using the pH meter (HANNA HI 991001) with specific probes. The transparency was measured using a Seechi disk. The analytical method used to determine these parameters a well described by Rodier et al. [18]. These parameters are often used to determine the quality of the water and are also key parameters that influence the faecal indicator bacteria growth in environment [19].

2.4 E. coli and IE Enumeration by Plate Count Technique

E. coli and IE were enumerated in water samples by standard plate counts respectively on Tryptone Bile X Glucuronide (TBX) and Slanetz and Bartley (SB) agar supplemented with TTC (0.2%) (Bio-Rad Laboratories, Inc.), according to ISO 16649-2: 2001 (*E. coli*) and NF EN ISO 7899-2 (IE) by filtration method (0.45 µm). Indeed, a water quantity (1 mL, 10 mL, and 100 mL) was filtered on a sterile filter membrane and placed on the agar. TBX plates were incubated at 44 °C for 24 h, whereas Slanetz and Bartley plates were incubated at 36 °C for 24 h.

After the incubation time, filters placed on Slanetz and Bartley plates were translated on Bile Esculine Azide (BEA) and incubated at 44 °C for 2 h before IE enumeration. The protocols used to detect *E. coli* and IE are well described by Rovlev et al. [20] and Kouame et al. [14]. The *E. coli* and IE abundance obtained were compared to European Union directive (EU) guideline for bathing and World Health Organization (WHO) standards for drinking water and irrigation.

2.5 Statistical Analysis

Statistical tools were used to analyse the temporal and spatial variation of physico-chemical parameters values and faecal indicator bacteria abundances. Specifically, Kruskal-Wallis test and U Mann-Whitney test with a significance level of 0.05 were used and applied by RSTUDIO 0.98.490 software. The Spearman test was performed to examine the correlations between physico-chemical variables and faecal indicator bacteria.

3. Results and Discussion

3.1 Environmental Variables and Faecal Indicator Bacteria Abundance

Overall, the values of environmental variables in the studied waters were higher in sampling sites near the shore areas than deepest sites. The temperature values ranged from 27.1 °C to 31.0 °C in the Taabo lake, from 26.7 °C to 29.8 °C in the Kossou lake and from 25.5 °C to 30.0 °C in the Fae lake with median values from 29.3 °C, 28.6 °C and 27.5 °C respectively. These values exceed WHO standards for aquatic living fixed at 25 °C. The pH values ranged between 6.7 and 8.7 in Taabo lake, between 6.8 and 8.3 in Kossou lake and, between 6.9 and 8.7 in Fae lake. The median pH values were 7.39, 7.49 and 7.6 for Taabo, Kossou and Fae respectively. These pH median values are acceptable for good aquatic living and diversity (6.5 and 8.5) [21].

However, according to WHO [22], these pH and temperatures ranges are favourable to the growth of bacteria. This may explain the high correlation recorded between faecal indicator bacteria concentrations and pH values at all sites (Table 2). Pereira et al. [23] also found the highest correlation between faecal bacteria abundance and pH values. In lakes Taabo and Kossou, the dissolved oxygen values ranged from 4.6 mg/L to 7.7 mg/L with respective values median of 5.74 and 5.69, those of Fae lake varied from 2.3 mg/L to 5.6 mg/L with median values of 4.23. These median values are inferior to WHO standard of ≥ 6 mg/L (acceptable values for good aquatic diversity). The low levels of dissolved oxygen could be related to the bacteria increase after breaking down organic matter in aerobic conditions. In contrast to others environmental variables, transparence values were lower in sampling sites near the shore areas than deepest sites. Transparence values highly varied in Taabo lake (22 cm - 120 cm) and in Kossou lake (60 cm - 130 cm). In the Fae lake, these values varied between 27 and 80 cm. The low transparence values were recorded in sampling sites near the shore areas and this could be explained by human activities [24,25] as indicated in the Table 1. The transparence parameter was weakly correlated to the faecal contamination in these lakes (Table 2). Significant differences were reported between the physico-chemical parameters obtained over months in all dam waters (Kruskal-Wallis; $p < 0.05$).

Table 2 Spearman's rank correlations describing the relationship between environmental variables and faecal indicator bacteria concentrations in each reservoir

Reservoirs	Faecal bacteria	Temperature	pH	Dissolved oxygen	Transparence
Taabo	E. coli	-0.16	0.28*	-0.27*	-0.22
	IE	-0.12	0.25*	0.02	-0.39*
Kossou	E. coli	-0.16	-0.24*	-0.15	0.03
	IE	-0.26*	-0.64***	-0.07	-0.04
Fae	E. coli	-0.16	0.28*	-0.27*	-0.44**
	IE	-0.12	0.25*	0.02	-0.21

**Significative correlation à p < 0.05 ; ** Significative correlation à p < 0.01 ;*
**** Significative correlation à p < 0.001*

3.2 Spatial Variation of Faecal Indicator Bacteria in Reservoir

The spatial variation of faecal indicator bacteria abundance in reservoirs is illustrated in Fig. 2. In Taabo lake, the highest median concentrations of faecal indicator bacteria were observed at T1 (2.17×10^2 CFU.100 mL^{-1} for *E. coli* and 4.6×10^1 CFU.100 mL^{-1} for IE) and the lowest concentrations at T4 (10 CFU.100 mL^{-1} for *E. coli*) and T5 (inferior to 10 CFU.100 mL^{-1} for IE) (littoral area) (Fig. 2A). In the Kossou reservoir, the lowest faecal indicator bacteria median concentrations were recorded at station K4 (inferior to 10 CFU.100 mL^{-1} for *E. coli*) and K3 (2.1×10^1 CFU.100 mL^{-1} for IE) situated in depth area, while the highest concentrations (1.11×10^2 CFU.100 mL^{-1} for *E. coli* and 3.4×10^1 CFU.100 mL^{-1} for IE) were recorded at stations K1 and K5 located in littoral area (Fig. 2B). In the Fae lake, the lowest abundances of faecal indicator bacteria were observed at stations F5 (1.3×10^1 CFU.100 mL^{-1} for *E. coli* and inferior to 10 CFU.100 mL^{-1} for IE), while the highest concentrations were recorded at F1 (1.13×10^3 CFU.100 mL^{-1} for *E. coli* and 1.32×10^2 CFU.100 mL^{-1} for IE) (littoral zone) (Fig. 2C). Significative differences were reported between low and high bacteria concentrations in all dam (Kruskal-Wallis: $p < 0.05$). The high concentrations of faecal indicator bacteria observed in the littoral area could be associated to the domestic wastewaters and livestock farming that characterize these sampling stations of Taabo, Kossou and Faé dam waters. The contribution of domestic wastewater and livestock on the faecal pollution of surface waters are reported by Forman [26] and Nguyen et al. [27].

The 90^{th} percentile values of FIB in the reservoir of Taabo, Kossou and Fae were calculated in order to compare the FIB abundances to EU guideline for bathing or other recreational activities.

https://doi.org/10.30799/jespr.185.20060101

Cite this Article as: G.J-L. Tiémoko, N.K. Ouattara, C-K.Y. Kouamé, A. Ouattara, G. Gourène, Spatial and temporal variation of faecal indicator bacteria in three reservoirs of Ivory Coast (Taabo, Kossou and Fae), J. Env. Sci. Pollut. Res. 6(1) (2020) 408–411.

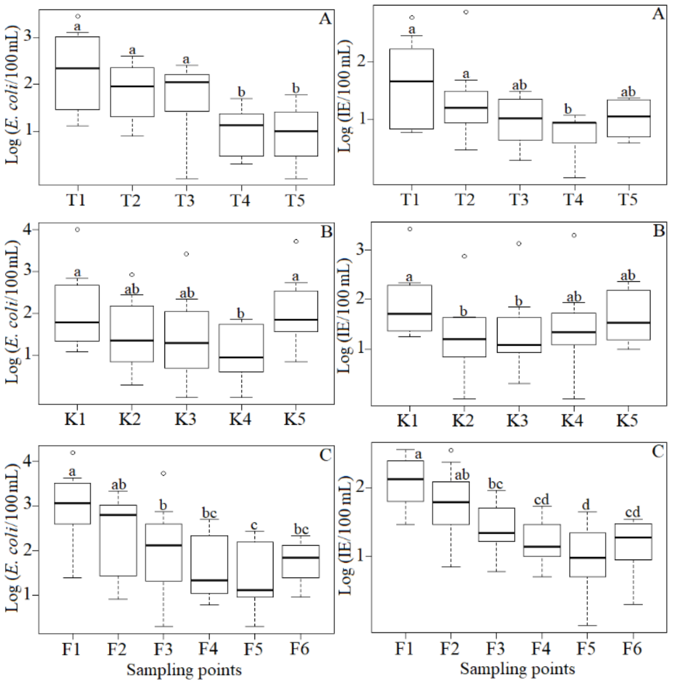

Fig. 2 Spatial variability box plots of faecal indicator bacteria abundance in dams' waters (A: Taabo; B: Kossou; C: Fae). Median (horizontal line in the box), lower and upper quartiles (bottom and top box lines), and the 90th percentiles (bottom and topwhiskers) and the outliers (circles) are shown; Values on the same line having different letters in exponent differ significatively (Kruskal-Wallis; $p < 0.05$)

With regards to EU Directives for bathing (9.0×10^2 CFU.100 mL^{-1} for *E. coli* and 3.3×10^2 CFU.100 mL^{-1} for IE), the 90th percentile of *E. coli* and IE obtained in Taabo and Kossou lakes were below acceptable limits. Therefore, Taabo and Kossou water quality were sufficient for bathing based on the two criteria (*E. coli* and IE) [9]. The 90th percentile of *E. coli* was above the EU guideline for bathing in Fae water unlike that of IE. EU guideline for bathing did not indicate if it necessary to consider that the microbiological quality of the water is acceptable for recreational activities when one of the two criteria is respected.

Accordingly, Fae water exceeded the admissible level required for bathing. The *E. coli* and IE abundances recorded in all dam waters were also compared to WHO standard for irrigation (10^3 CFU.100 mL^{-1} for *E. coli*). Globally, the average concentration of *E. coli* and IE exceed the standard value required for the use of these waters for irrigation. Consequently, the use of the water from these reservoirs for irrigation is not appropriate and presents a health risks particularly during the months of June and September.

3.3 Temporal Variation of Faecal Indicator Bacteria

The faecal indicator bacteria (FIB) abundance temporal variation in Taabo, Kossou and Faé lakes showed two trends (Fig. 3). The first trend was characterized by a low abundance from November to February in the Taabo lake, from November to July in the Kossou lake and in the Fae lake, from November to April. The second trend was characterized by high faecal bacteria abundances from April to October, September to October and from June to October, respectively in Taabo, Kossou and Fae reservoirs.

These trends of bacteria abundance reported to the studied waters could be related to rainy events. In fact, the months showing the low bacteria concentrations were characterized by the low rainy events, while the whole of the months showing the high faecal indicator bacteria concentrations were characterized by the high rainy events. During the rainy season, many organic materials and bacteria could be dumped into water reservoirs due to run-off water way out from the watershed, sewer overflows and defective septic systems located near water bodies [28]. The increase in FIB abundances after rainfall has been widely recognized in the scientific literature [29].

In all studied waters, the lowest faecal indicator bacteria median abundances recorded were inferior to 10 CFU.100 mL^{-1}, while the highest concentrations reported were from 3.8×10^2 CFU.100 mL^{-1} for *E. coli* and 2.4×10^1 CFU.100 mL^{-1} for IE in Taabo dam water (Fig. 3A), 2.53×10^3 CFU.100 mL^{-1} for *E. coli* and 3.5×10^2 CFU.100 mL^{-1} for IE in Kossou dam water (Fig. 3B) and, 4.85×10^2 CFU.100 mL^{-1} for *E. coli* and 5.7×10^1 CFU.100 mL^{-1} for IE in Faé dam water (Fig. 3C). Significative differences were noted between the low and high bacteria concentrations.

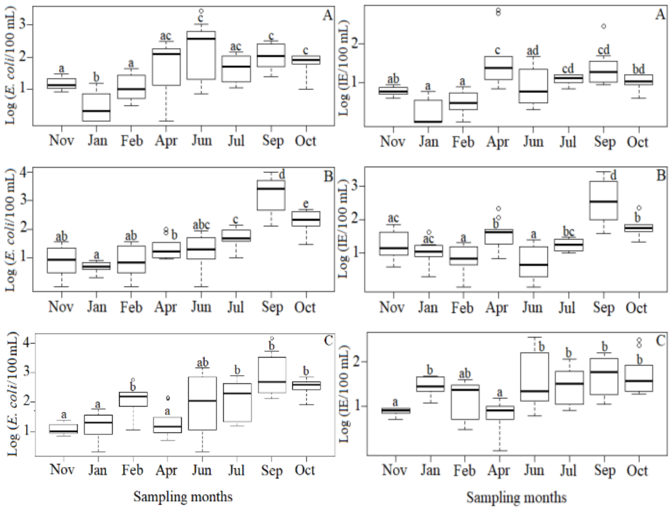

Fig. 3 Temporal variation box plots of faecal indicator bacteria abundance in dams' waters (A: Taabo; B: Kossou; C: Fae). Median (horizontal line in the box), lower and upper quartiles (bottom and top box lines), 90th percentiles (bottom and topwhiskers) and the outliers (circles) are shown. Values on the same line having different letters in exponent differ significatively (Kruskal-Wallis; $p < 0.05$)

Levels of faecal contamination observed in lakes Taabo, Kossou and Fae were close to those found in other surface waters of Côte d'Ivoire. Kouamé et al. [14] showed that concentrations in the Comoe River ranged from 1.09×10^3 and 8.88×10^4 CFU.100 mL^{-1} for *E. coli* then 5.33×10^2 and 4.49×10^3 CFU.100 mL^{-1} for IE. Ouattara et al. [15] also found an abundance of faecal indicators ranging from 1.72×10^1 CFU.100 mL^{-1} and 1.48×10^2 CFU .100 mL^{-1} for *E. coli* and between 2.26×10^3 CFU.100 mL^{-1} and 7.72×10^3 CFU.100 mL^{-1} for IE in the waters of the Aghien lagoon. The variation observed between the abundance of faecal bacteria in the studies reported above may be related to the size and type of hydrosystem, anthropogenic pressures, and climatic seasons. In Ghana water dams', Kpieta and Laari [30] found that faecal pollution was between 10^1 to 65×10^1 CFU.100 mL^{-1} for faecal coliform knowing that bacteria *E. coli* was included in faecal coliform group.

3.4 Relationship Between E. coli and IE Abundances

Globally, *E. coli* abundances were higher than those of IE in the water samples of these three lakes. This may indicate that these reservoirs received continuously faecal pollution from domestic sewage [11]. According to literature, the *E. coli* abundance obtained in surface waters is most often higher than that of IE. The Spearman test showed that *E. coli* and IE abundances (in log units) were positively correlated (Taabo: $0.27 < r^2 < 0.66$; Kossou: $0.50 < r^2 < 0.79$; Fae: $0.48 < r^2 < 0.77$), moreover these correlations were significant (Taabo: $r^2 = 0.53$, $p < 0.001$; Kossou: $r^2 = 0.77$, $p < 0.001$; Fae: $r^2 = 0.62$, $p < 0.001$) (Fig. 4). Charrière *et al.* [31] and Simmons *et al.* [32] showed that, due to their same origin, *E. coli* and IE abundances were strongly linked. This could explain why these two FIBs were significantly correlated on the three sites. Significant correlations between these two FIBs were already reported in research studies [11,20].

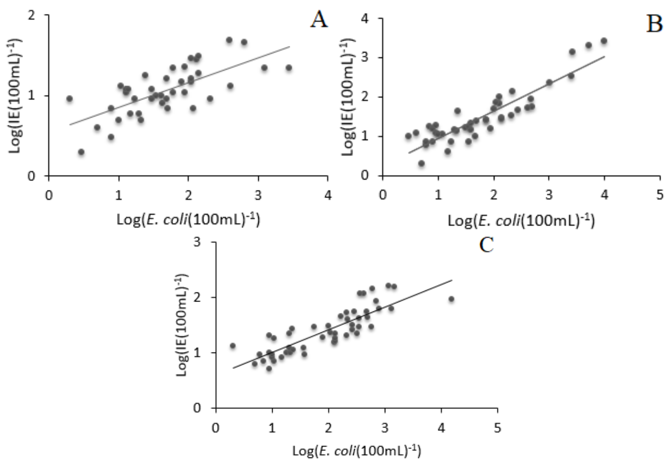

Fig. 4 Log–log linear regression between IE and *E. coli* abundances in reservoir dam of Taabo (A), Kossou (B) and Fae (C) ; A : log (IE/100 mL) = 0.30 log (*E. coli*/100 mL) + 0.54 ($r^2 = 0.53$; n = 40; p < 0.001), B : log (IE/100 mL) = 0.69 log (*E. coli*/100 mL) + 0.23 ($r^2 = 0.77$; n = 40; p < 0.001), C : log (IE/100 mL) = 0.41 log (*E. coli*/100 mL) + 0.58 ($r^2 = 0.62$; n = 48; p < 0.001)

https://doi.org/10.30799/jespr.185.20060101

4. Conclusion

Natural conditions, as well as human activities, in catchment areas of surface reservoirs of Taabo, Kossou and Fae significantly affect the quality and safety of stored water. This study showed that for every reservoir, the shore indicated evidence of pollution more than those far from the shore. The levels of faecal indicator bacteria found are most of the times higher than those of the standard values required for water quality related to public health risk. It is important to sensitize decision makers and different stakeholders on a sustainable management of lakes.

Acknowledgement

This work represents one aspect of a research project initiated by DAP (Direction de l'Aquaculture et des Pêches) and PAGDRH (Programme d'Appui à la Gestion Durable des Ressources Halieutiques) in Ivory Coast. We would like to thank DAP, PAGDRH and Nangui Abrogoua University authorities.

References

[1] E. Branche, The multipurpose water uses of hydropower reservoir: the share concept, C.R. Phys. 18 (2017) 469-478.
[2] F. Bunea, G.D. Ciocan, G. Oprina, G. Băran, C.A. Băbuţanu, Hydropower impact on water quality, Environ. Engineer. Manag. J. 9(11) (2010) 1459-1464.
[3] J.R. Mor, A. Ruhí, E. Tornés, H. Valcárcel, I. Muñoz, S. Sabater, Dam regulation and riverine food-web structure in a Mediterranean river, Sci. Total Environ. 625 (2018) 301-310.
[4] S. Schmutz, J. Sendzimir, Riverine ecosystem management, Springer, Cham, 2018.
[5] S. Karmakar, O.M. Musthafa, Lakes and reservoirs: Pollution, In:Encyclopedia of Environmental Management, CRC Press, USA, 2013, 1576-1587.
[6] N. Groga, A. Ouattara, K.S. Da Costa, A. Dauta, O. Beauchard, et al., Water quality and water-use conflicts in lake Taabo (Ivory Coast), Open J. Ecol. 2 (2011) 38-47.
[7] K. Koffi, State of hydropower in Ivory Coast, ECOWAS Regional Small Hydropower Attendant, Monrovia, Liberia, 2012.
[8] A.A. Kouao, J.P. Jourda, K.J. Kouamé, T.J-J. Koua, A.E. Eba, G. Lazar, Demarcation of protection perimeters for surface waters of Taabo (Ivory Coast) watershed using GIS and multicriteria analysis, Environ. Engineer. Manag. J. 11(12) (2012) 2123-2131.
[9] European Union Directive (UE), Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality, Official J. Eur. Communities 64 (2006) 37-51.
[10] M. Bennami, H. Amarouch, A. Boukanjer, H. Nadre, M. Lalaoui, et al., Influence of environmental factors on fecal bacteria loads in the Mediterranean coast of Morocco, Eur. J. Sci. Res. 1(71) (2012) 24-35.
[11] K.N. Ouattara, J. Passerat, P. Servais, Faecal contamination of the water and sediment in the rivers of the Scheldt drainage network, Environ. Monitor. Assess. 183 (2011) 243-257.
[12] J. Passerat, N.K. Ouattara, J.M. Mouchel, V. Rocher, P. Servais, Impact of an intense combined sewer overflow event on the microbiological water quality of the Seine River, Water Res. 45 (2011) 893-903.
[13] T.B. Atherholt, N.A. Procopio, S.M. Goodrow, Seasonality of coliform bacteria detection rates in New Jersey domestic wells, Ground Water 55(3) (2016) 346-361.
[14] Y.C-K. Kouamé, N.K. Ouattara, O.Y.M. Achiépo, A. Ouattara, Impact and seasonal variability of faecal indicators bacteria contamination in downstream part of Comoe river and its two tributaries (Ivory Coast), Int. J. Curr. Microbiol. App. Sci. *7*(10) (2018) 827-840.
[15] N.K. Ouattara, Y.C-K. Kouamé, B. Kamagaté, L.G. Droh, A. Ouattara, G. Gourène, Impact of faecal bacteria contamination on drinking water supply in Aghien Lagoon, Abidjan, Ivory Coast, Afr. J. Microbiol. Res. 12(42) (2018) 965-972.
[16] N. Koné, Study of fishing, population parameters and reproductive biology of clupeidae *Pellonula leonensis* boulenger, 1916 in the lakes of Kossou and Taabo dams (Bandama river, Ivory Coast), PhD Thesis, Felix Houphouet Boigny University, Ivory Coast, 2012.
[17] K.S. Da costa, Y.M. Diétoa, Typology of fishing on the Faé lake and implication for a rational management of the halieutic resources, Bull. Fr. Piscic Fishing. 384 (2007) 1-4.
[18] J. Rodier, B. Legube, N. Merlet, R. Brunet, Microbiological analysis of waters, In:The analysis of water, 9th Edn., Enforcement of obstruction, Paris, France, 2009, pp.717-869.
[19] U.M. Qureshimatva, R.R. Maurya, S.B. Gamit, R.D. Patel, H.A. Solanki, Determination of physico-chemical parameters and water quality index (Wqi) of Chandlodia Lake, Ahmedabad, Gujarat, India, J. Environ. Anal. Toxicol. 5 (2015) 288:1-6.
[20] P. Roslev, S. Bastholm, N. Iversen, Relationship between fecal indicators in sediment and recreational waters in Danish Estuary, Water Air Soil Pollut. 194(1-4) (2008) 13-21.
[21] G.R. Pearce, C.M. Ramzan, S. Ghulam, A simple methodology for water quality monitoring, Department for international development, HR Wallingford, HK, 1999.
[22] World Health Organisation (WHO), Guidelines for drinking-water quality. Third edition incorporating the first and second addenda, Vol. 1 recommandation, OMS, Geneva, 2008.
[23] V.M.G. Pereira, R.B. Gomes, Marcelo Sá, Correlation between *Escherichia coli* and limnological variables in water samples of the Lagoa da Maraponga, Fortaleza, Ceará State, Brazil, Acta Scientiarum Biol. Sci. 33(2) (2011) 145-151.
[24] Z.S. Shawky, S.A. Rabeh, Evaluation of microbial quality of the river Nile waters at Damietta Branch, Egypt, Egyptian J. Aquat. Res. 33 (2007) 301-311.
[25] HELCOM, Guidelines for monitoring of water transparency (Secchi depth). http://www.helcom.fi/helcom-at- work/projects/eutro-oper/ (Accessed on: 20.10.2019)
[26] R.T.T. Forman, Urban ecology: Sciences of cities, Cambridge university press, UK, 2014.
[27] H.T.M. Nguyen, Q.T. Phuong Le, J. Garnier, J.L. Janeau, E.R. Newall, Seasonal variability of faecal indicator bacteria numbers and die-off rates in the Red River basin, North Viet Nam, Sci. Rep. 6 (2016) 21644:1-12.
[28] K.V. Kiran, W. Jianjun, C. Long, Y. Tianma, J.M. Alan, S. Raju, Assessment of water quality and identification of pollution risk locations in Tiaoxi river (Taihu watershed), China. Water 10 (2018) 183:1-19.
[29] D. Ackerman, S.B. Weisberg, Relationship between rainfall and beach bacterial concentrations on Santa Monica Bay beaches, J. Water Health 1 (2003) 85-89.
[30] B.A. Kpieta, B.P. Laari, Small-scale dams' water quality and the possible health risk to users of the water in the uppers west region of Ghana, Eur. Sci. J. 10(14) (2014) 18-57.
[31] G. Charrière, D.A.A. Mossel, P. Beaudeau, H. Leclerc, Assessment of the marker value of various components of the coli-aerogenes group of Enterobacteriaceae and of a selection of *Enterococcus* spp. for the official monitoring of drinking water supplies, J. App. Bacteriol. 76 (1994) 336-344.
[32] G. Simmons, V. Hope, G. Lewis, J. Whitmore, W. Gao, Contamination of potable roof-collected rainwater in Auckland, New Zealand, Water Res. 35 (2001) 1518-1524.

https://doi.org/10.30799/jespr.185.20060101

Cite this Article as: G.J-L. Tiémoko, N.K. Ouattara, C-K.Y. Kouamé, A. Ouattara, G. Gourène, Spatial and temporal variation of faecal indicator bacteria in three reservoirs of Ivory Coast (Taabo, Kossou and Fae), J. Env. Sci. Pollut. Res. 6(1) (2020) 408–411.