RESEARCH ARTICLE

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Current State of Flooding and Water Quality of Nokoue Lake in Benin (Ouest Africa)

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ABSTRACT

A thorough literature review was conducted in order to discover the previous studies that have been done in relation to the problems of flooding and water pollution of Nokoue lake (Benin, West Africa), to identify the limitations of these previous studies, to draw lessons in order to propose how to overcome them. This bibliographic synthesis has shown that previous studies related to the flooding issue have focused on the dynamics of understanding the genesis of flooding. These studies range from the oldest conducted in 1979 to the most recent conducted in 2016. The major results of these studies in relation to floods are hydrodynamic techniques allowing to evaluate in a punctual way the hydrological regime of the Nokoue lake. In other words, they are solutions allowing to reconstitute the floods generated by the river waters. It appeared that these results of flood reconstitution are difficult to generalize because of the complexity of the hydrographic network of Nokoue lake. The hydrodynamics of Nokoue lake is influenced differently by its main water tributaries (the Sô River, the Ouémé River, the Porto Novo Lagoon and the Atlantic Ocean). Therefore, a decision-making issue on planning and flood management must be motivated by a decision support tool. It is moreover recommended in these studies the resumption of the process of hydraulic techniques periodically during the period of high water in order to take advantage of the hydrological behavior of Nokoue lake in terms of overflow which are at the origin of the floods. The need for innovative decision-making solutions on flood planning and management in order to reduce disasters is still a priority for decision-makers. These innovative solutions are undoubtedly the flood forecasting. On the water quality of Nokoue lake, the oldest study conducted dates back to 1987 and the most recent one in 2018. In these studies, water quality is evaluated in two seasons: the low water season (December to mid-May) and the high-water season. It was found that the salinity of the lake increased significantly with an average of 16 ppt during the low water period while during the high-water period, freshwater inflows from the tributaries invaded the lake and prevented water from the Atlantic Ocean from entering. The concentrations of inorganic nutrients in the lake increase from low water to high water. However, the quantification to date of nutrient loads from external sources as well as internal sources to the lake have not been quantified. This implies that further research on the water quality of the lake could be conducted. Prevention actions should consider a predictive monitoring of the water quality index of Nokoue lake.

Keywords: Benin, Flood, Forecast, Lake, Nokoue, Pollution.

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I. Introduction

Coastal lakes and lagoons are mostly shallow water bodies where surges (overflow) and water quality degradation are major environmental problems. Many coastal lakes, especially in developing countries, still lack data on flooding and pollution processes. It is still difficult today to define appropriate planning and implementation strategies in a sustainable manner for the medium and long-term management of tropical coastal lake ecosystems.

In this case, the ecosystem of Nokoue lake in southern Benin in West Africa, the largest body of water on the West African coast Lalèyè *et al.* [1], is threatened by flooding and pollution, the main factors of which are anthropogenic, such as agriculture, changes in land use, surface sealing, oil traffic, streaming from tributary rivers and untreated wastewater discharges [2]. The hardly quantifiable part of the explanatory factors of flooding and pollution are climate change which also influences rainfall, temperature and chemical characteristics [3],[4]. All of these factors negatively impact not only the production and ecosystem services of the lake but also its ability to resist and adapt to climate change. One

of the particularities of the Nokoue lake is the presence of human dwellings built on stilts on the water surface in the northwestern part of the Nokoue lake called Ganvié and Vekki [3]. Nokoue lake is the main breadbasket for more than 400,000 people through various ecosystem services such as traditional fishing, floodplain agriculture and increasing sand mining activities [5].

For the understanding of the recurrence of floods coupled with pollution that affect all aspects of the economy especially health, food production and security, domestic water supply and sanitation, energy, industry and environmental sustainability. Mama *et al.* [3]; Dovonou *et al.* [2] and Zandagba [4] studies are concluded the behavior of the hydrological regime and water quality of Nokoue lake are of primary importance [4]. They define not only the response time of the Nokoue lake watershed and the characteristics of its hydrograph but also the ecological conditions of the lake, control biodiversity and influence the maintenance or decline of ecosystem services. Multiple actions based on decision support tools must be planned for a sustainable and efficient management of Nokoue lake waters. This requires a multidisciplinary approach based on the understanding of elements such as the hydrological regime of Nokoue lake and the water quality (pollution) of Nokoue lake. It is therefore essential that future management strategies include the notion of the hydrological regime and the water quality process as a baseline [3].

This paper aims to inventory all previous studies related to flooding (study of the hydrological regime of Lake Nokoue) and water quality (pollution) of Nokoue lake in order to capitalize on current achievements and highlight future research directions to overcome the impacts of flooding and water pollution of Nokoue lake.

II. Methods

A. Study Area

Located in the South East of Benin in the low delta in the humid tropical zone between 6°20' and 6°40' North latitude and 2°20' and 2°35' East longitude (Fig. 1), it has an average surface area of 150 km² in the low-water period and 450km² in the high-water period [6], [7].

Nokoue lake is 20 kilometers long from east to west and 11 kilometers wide from north to south [3]-[7]. Nokoue lake is shallow, with a bathymetry that varies between 0.4 and 2 m, of which 20% of its surface area is less than 1 meter deep. Nokoue lake conveys flood waters directly to the Atlantic Ocean in the South through the Cotonou channel (4.5 km long, 300 m wide and 5 to 10 m deep) built in 1894 [3]-[6], [8]. The Totché channel links Nokoue lake to the Porto-Novo lagoon to the west. The hydrology of Nokoue lake depends on the functioning of the Ouémé River (46,500 km2 and 523 km long) in the North-East and the Sô River (1,000 km² and 70 km long) in the North-West, but also on the upwelling of marine waters in the lagoon system. The Cotonou channel, linking the lake to the Atlantic Ocean, is the deepest zone where the bathymetry can be up to 8 m [3], [4], [6]-[9]. There are three main types of lithofacies (Texier and al., 1980a) Nokoue lake has a slightly undulating bottom subdivided into three basins : West, Central and East separated by two North South ripples. The nature of the sediments in Nokoue lake is mainly conditioned by the topography of the lagoon floor and the movement of continental and marine water masses whose load and hydrodynamic behavior can vary considerably over the seasons.

Nokoue lake is characterized geologically and geomorphologically by three structures :

The indentation of the lower Ouémé-Sô basin, 90 km long and 20 km wide in its southernmost part (marshy depression deposits and deltaic deposits in the north); The sub-horizontal plateaus of the Continental Terminal and yellow sandbars to the West ; The Ogolian and Holocene barrier beaches to the south (the brown, grey and white sand beaches). The environment of Lake Nokoue is highly urbanised. It is surrounded by 8 municipalities Abomey-Calavi, Adjarra, Aguégué, Cotonou, Dangbo, Porto-Novo, Sèmè-Kpodji and Sô Ava [7]-[11]. The maintenance of the pass since the construction of the port of Cotonou, the uncontrolled dredging and the acadja fishing techniques practiced by the Toffin populations of Ganvié and Zogbo, have largely modified the hydrodynamic, Physico-chemical and ecological conditions of the “lake”.

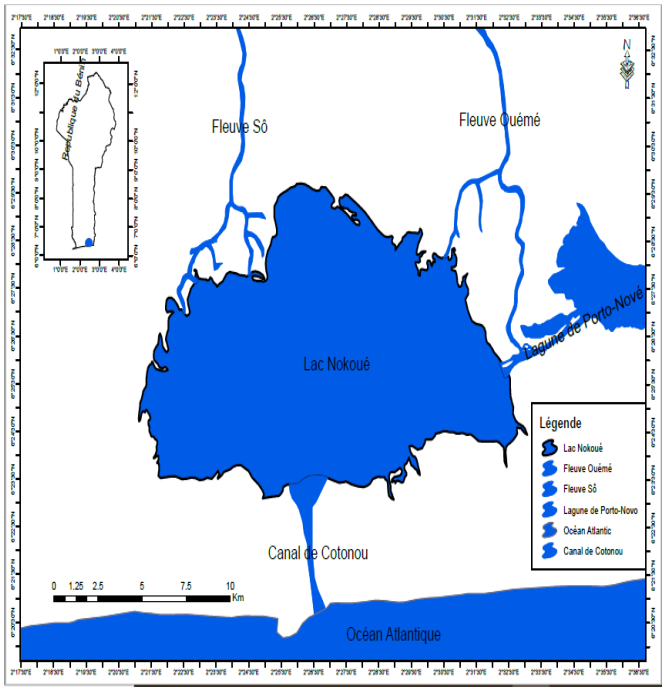

Fig. 1. Location of Nokoue lake.

B. Research Methods

We could not succeed in this review without a coherent, rigorous and reproducible methodological approach. To review and capitalize on the bulk of existing research related to flooding and water pollution in Nokoue lake, a bibliographic search was conducted. To find articles published on Nokoue lake, we consulted scientific databases through search engines such as Scopus, Google Scolar, Sci-Hub. The process included three steps namely:

(i) generation of keywords, (ii) search and (iii) selection of articles related to flooding (study of the hydrological regime of Nokoue lake) and pollution (study of the water quality of Nokoue lake).

Keywords specific to “location”, “flooding or hydrological

regime", "pollution or water quality", and logical connectors "and", "or" were chosen. These are presented in Table I. To narrow down the selection of relevant articles a set of fixed inclusion criteria was adopted: (i) the article must be related to the keyword "Nokoue lake", (ii) it must deal with "hydrological regime" or (hydrological variability) or "water quality" as a main or secondary topic; (iii) at least one of the generated keywords must exist in the article's abstract. Peer-reviewed journal articles on Nokoue lake are almost non-existent. On the other hand, numerous research studies, in this case, doctoral theses, Master's degrees, governmental diagnostic reports, and study offices were found. In total, 41 articles were examined on Nokoue lake. The first article found on the evaluation of the hydrological regime dates from 1979 while the one on water quality dates from 1967. Nearly 68% of the articles are related to the subject of water pollution of Nokoue lake, while only 32% of the articles and reports studied the hydrological regime of Nokoue lake.

TABLE I: KEYWORDS FOR THE LITERATURE SEARCH ON FLOODING AND WATER POLLUTION OF NOKOUE LAKE

	Mots clés
Location	Nokoue lake; Benin; West Africa; Cotonou; Abomey-Calavi
Flooding	Flooding; hydrological regime; simulation; flooding; description of the regime
Pollution	Pollution ; water quality; assessment; description; concentration; polluants

III. RESULTS AND DISCUSSION

A. Hydrological Regime And Flooding

This section presents the authors who have addressed problems related to the hydrological regime and flooding of Nokoue lake. Most of the research has been carried out on: hydro-climatic extremes and their impacts on natural resources in the Nokoue lake basin, characterization of the hydrological regime of Nokoue lake, hydrodynamic modelling of Nokoue lake, evaluation of exchanges between Nokoue lake and its tributaries, description of the environment of Nokoue lake: information on exchanges with the sea, and the impact of global change on lagoon systems in West Africa: the case of Nokoue lake in Benin. These studies range from the oldest to the most recent (1979-2021).

In fact, coastal ecosystems in particular Nokoue lake are characterized by several complex processes that need to be mastered in order to understand the different mechanisms involved in their functioning [12], [13]. This is how Barbe *et al.* [8] and Texier *et al.* [12] are among the first authors to characterise the preliminary hydrological regime of Nokoue lake and to quantify certain variables for the elaboration of hydrological bulletins. This is a difficult task, and the quantitative results still depend heavily on the hypotheses taken to evaluate the value of the hydrometeorological variables. The results of the work of Poulard [14] work confirm that the evaluation of hydrological variables to explain the risk of flooding must also take into account the perspectives of the hydrodynamic evolution of the Nokoue lake basin in order to be part of long-term prevention strategies. According to Hounkpè *et al.* [15] and Zandagba *et al.* [4] the quantification of flood risk the, it is necessary to study its two components: the hazard and the vulnerability. This is a prerequisite for defining a strategy to reduce the impacts. Akim [16], OMIDELTA [6], and Texier *et al.* [12] studied the use of satellite images to better understand the hydrological regime has shown water discharges towards Nokoue lake and lush vegetation around its tributaries. All these factors contribute to the rapid rise in water levels in Nokoue lake. The updating of information on the trends of extreme hydrometeorological events in order to better explain floods has led authors such as Chaigneau *et al.* [9]; Hounkpè *et al.* [15]; Kawoun *et al.* [17] and Leite *et al.* [18] to study rainfall-hydrological variability and impacts on surface water on monthly, seasonal and annual time scales. The increasing trend in rainfall indices has been the major conclusion of this work and consequently the increase in floods. All the same, there are major difficulties linked essentially to the complexity of the hydrographic system, but also the lack of monitoring by an adequate hydrographic network allowing an exhaustive evaluation of the hydrological regime of Nokoue lake. Only a few monitoring stations are installed at the confluences of the lake and its tributaries. The hydrographs resulting from these studies show a hydrological regime of Nokoue lake characterized by: a low flood from May to June, which corresponds to the main rainy season in the south of Benin, a high flood from September to November, corresponding to the main rainy season in the north and to the inflow of water from the Ouémé River, and finally a low water period from December to March [7]-[11]. The absence of studies on the forecasting of the variation in water level of Nokoue lake was made apparent by the lack of authors during the bibliographic synthesis, but also by the many recommendations to orient research on forecasting models.

B. Hydrochemistry And Water Pollution State in Nokoue Lake

Numerous studies have been undertaken on chemical and bacteriological analyses by several authors as Mama [3], Dovonou *et al.* [2], Hounsounou [19], Zandagba *et al.* [4] and Yehounou *et al.* [20] in order to characterize the hydro-chemical functioning and the hydro-biological quality of the waters of the lagoon system. Water samples from Nokoue lake were taken for chemical and bacteriological analyses, which made it possible to characterize its chemical and bacteriological quality and to outline the description of the mineralization processes and the state of the concentration of certain chemical elements [22]. This work clearly shows signs of contamination by chemical elements such as nitrates linked to the spreading of fertilizers, contamination by pesticides, heavy metals and by bacteria with very diverse contents [23], [2]. The mechanisms that are at the origin of mineralization are, among others, the dissolution of carbonate and sulphate minerals and the hydrolysis of silicates. The water quality of Nokoue lake is compromised for two main reasons:

i. a chemical quality compromised by a high content of certain elements, in particular in lake villages such as Ganvié Hounsounou [20] and Zandagba *et al.* [4].
ii. a very poor bacteriological quality [2]. These types of pollution are likely to cause the loss of biodiversity, contamination of groundwater through the surface water table, when they are very close to the catchment works.

However, this risk would be even more manageable when

we have information on its future trend (availability of prediction tools) [4]. Another contamination problem addressed by the authors as Mama *et al.* [3] and Leite *et al.* [19] concerns saline intrusion, which raises chloride and sodium levels in some parts of Nokoue lake. Quantitative and qualitative monitoring has been set up by SONEB, in collaboration with the Laboratory of Applied Hydrology of the University of Abomey-calavi, to monitor this phenomenon, which is to be analysed using hydrodynamic and solute mass transport model [6]. These studies have made it possible to identify the cause and the effect relationships with regard to chemical pollution. Indeed, these studies revealed that the center of Nokoue lake is characterized by moderate or low and high vulnerability in the lake villages and at the periphery and confluences with its tributaries (Ouémé River, Sô River, Atlantic Ocean, Porto-Novo port). This led to the conclusion that the spatial evolution of the concentration rates of chemical elements depends more on the density of the population and is therefore based on the land use map of the study area [1].

Unfortunately, it is still difficult to define strategies for planning and implementing sustainable long-term management solutions due to the lack of knowledge of the future trend [4]. In order to assess the physico-chemical pollution of the waters of Nokoue lake, simulation models were used. The simulation results showed the dispersion of the saline intrusion in Nokoue lake. In fact, Nokoue lake is classified as a RAMSAR site, of the most important water bodies in West Africa due to its size, productivity and exploitation. It is thus subjected to human aggression (linked to the presence of lake villages without sanitation systems, the practice of fish traps “acadjas” and the trafficking of hydrocarbons from Nigeria) and has thus become a receiving basin for solid and liquid waste and other products without any prior treatment (organic matter, nutrients and residues of phytosanitary products (pesticides), but also pollutants from solid household waste). The results of the Amanda [5] study indicate that Ganvié, Vekky, Ouédo-Ague, Dékanmè and Kétonou are the main areas of water pollution. Dovonou *et al.* [2] the study reported the pollution of Nokoue lake by the bad behavior of the local population who throw excreta into the water body. The analysis of the multiple sources of pollution (domestic wastewater conveyed by the rainwater collector, water from tributaries, etc.) reveals that these sources are more concentrated in the south-west (Cotonou commune) and north-west (So Ava district) of Nokoue lake [20]. Through its study entitled Pollution of water for domestic use in disadvantaged urban areas in developing countries, more than 34% of these populations defecate directly into the lake. This is not without consequences for the quality of the water in the lake. A focus on the different parameters for assessing the quality of the water in Nokoue lake is summarized. These different parameters for assessing the quality of the water in Nokoue lake show both temporal and spatial variability.

C. Physics-Chemical Parameters Analyzing

1) Results of temperature research

The surface water temperature of Nokoue lake varies between 23°C and 34°C [3], [4]. It is influenced by the air temperature around the lake and presents a difference significant (P <0.001) [1],[24].

2) Results of the potential hydrogen (ph.) research

According to the results of several authors Mama *et al.* [3], Zandagba *et al.* [4], Lalèyè *et al.* [1] and Texier *et al.* [12], the waters of Nokoue lake are slightly alkaline. Although the extreme potential hydrogen (pH) values (8.5 and 6.5) have not changed significantly from year to year, the spatial distribution of pH values in the lake has changed considerably since 1980. Data presented by Texier *et al.* [12] indicated a spatial variation of 0.4 over the hydrological periods, while Zandagba *et al.* [4] recorded a spatial variation of 2.6 over the hydrological periods.

With regard to the permissible pH limits defined by French research Institute for the exploitation of the sea (IFREMER) and World Health Organization (WHO) for surface waters during the rainy season, the optimal living conditions of aquatic organisms could be compromised at certain locations in the river-lagoon system, such as this increase in spatial variation of pH could be due to the change in local conditions within the lake from 1980 to 2016, such as the presence of water hyacinth that appeared in the lake in the early 1990s and the local increase in waste water discharge from the cities of Abomey-Calavi and Cotonou [10].

3) Results of dissolved oxygen research

It is also a function of the organic load of the environment and is inversely proportional to the water temperature. According to Mama [3] dissolved oxygen in Nokoue lake varies between 9.1 mg/L and 0.5 mg/L throughout the year with higher values during the high-water period. The concentration level of dissolved oxygen in the south-eastern part of Nokoue lake is very low compared to the concentration level of oxygen in other parts of Nokoue lake [4]. This is supported by the hypothesis that the land use around the southeastern part, where agriculture is most important with sugar cane crops in the wetlands, could have influenced these results. Another hypothesis could be a restriction of water circulation that makes this part more susceptible to the development of low dissolved oxygen conditions. These same studies indicate that dissolved oxygen concentrations recorded at the majority of sites are below 6 mg/L, which is the minimum value recommended by IFREMER for fresh water.

4) Results of conductivity and salinity research

Previous studies have shown a low mineralization of the waters of Nokoue lake. This low mineralization decreases further during the rainy season due to the dilution of the water caused by the streaming of rain water [25].

Like all tropical lake ecosystems, Nokoue lake, which is in permanent contact with the Atlantic Ocean, is characterized by desalination during the flood season (due to the contribution of rivers) and high salinity during low water periods [3],[26]. The fresh water streaming from the lake's tributaries during the high-water period keeps the average salinity of the lake very low. According to Zandagba *et al.* [4] and Djihouessi, Aina [10] Nokoue lake is entirely filled with water during the month of October and November the salinity is 0psu, the beginning of salt water intrusion from the Atlantic Ocean through the Cotonou channel is observed at the entrance to Nokoue lake. This variation increases until mid-May. This salinisation of the lake is linked to the tidal currents

combined with the streaming of the lake's tributaries, notably the Sô and Ouémé rivers during this period.

5) Results of nutrients (phosphorus and nitrogen) research

Very interesting studies have been carried out to analyse nutrients. These analyses carried out at various locations reveal low levels of nitrate, ammonium and nitrite in the water [27]. These concentrations are well below the limits defined by IFREMER for fresh water. Total nitrogen levels fluctuate between 1.42 mg/L and 2.47 mg/L. Recent measurements in Nokoue lake indicate that total nitrogen (TN) in the lake varies between 3.9 mg/L and 9.1 mg/L, while total phosphorus (TP) varies between 0.05 mg/L and 2.30 mg/L. Dissolved inorganic nitrogen (N-NO3 + N-NH4) in the lake varies between values below the detection limits to 6.8 mg / L and orthophosphate (P-PO4) varies between values below the detection limit and 0.62 mg / L [3], [4].

During the high-water period, the main source of nitrogen (N) and phosphorus (P) in Lake Nokoue is the Ouémé River, which drains about 90% of the total nitrogen and 60% of the total phosphorus. In low water, the Sô River contributes about 75% of the total nitrogen and 95% of the total phosphorus to the lake [3], [24]. Inorganic Nitrogen (N) and Phosphorus (P) inputs from the two rivers accounted for only 35% of the total nitrogen and total phosphorus loaded into the lake [4], [27]. N and P inputs from the Djonou River are unknown, as are N and P exchanges between the lake and the Atlantic Ocean and Porto Novo lagoon. In addition, nutrient inputs from tributaries, the lake receives nutrient inputs from untreated wastewater from three main sources: the fishing village of Ganvié (more than 2,500 stilt houses), the western city of Calavi (more than 700,000 inhabitants) and the city of Cotonou (more than one million inhabitants) [16].

6) Results of eutrophication research

Some authors have been interested in the problem of eutrophication in Nokoue lake. The aim of these studies is to investigate the seasonal variation of the eutrophication phenomenon. Thus, the results of the Mama, [3] and Zandagba *et al.* [4] showed that Nokoue lake is a eutrophic system with a tendency to hypereutrophic. Indeed, the eutrophication of Nokoue Lake is characterized by the seasonal proliferation of the water hyacinth which covers up to 60% of its surface [19],[20]. The decrease of salinity during the flood period favors the development of aquatic plants each year, while the increase in salinity during the low water period inhibits its growth. Analyses from their studies have shown that the decomposition of this organic waste at the bottom of the reservoir causes the modification of physicochemical parameters which induces the formation of humic acids [21]. This excess biomass leads to an increase in the natural load of the ecosystem in a biodegradable organic matter [32]. The degradation of organic matter present in the water body leads to a decrease in the dissolved oxygen content of the water [23], [24]. As the oxygen stock in the water is very limited, it is rapidly depleted during periods when the respiration of organisms and the decomposition of matter exceeds production by photosynthesis [21]. The environment then becomes anoxic and favorable to the appearance of compounds and gases including thiol and methane, leading to the death of aerobic aquatic organisms (insects, crustaceans, fish) as well as a rapid enrichment of the reservoir with plant detritus resulting from their degradation. Mama *et al.* [3] reported high recycling of phosphorus from the sediment, which could be derived from the decomposition of water hyacinth on the lake bottom. However, the rate and magnitude of this internal preheating cycle and the contribution of water hyacinth to nutrient recycling and thus eutrophication are unknown. The deficit of these studies means that no future information can be obtained.

7) State of pollution by pesticides and heavy metals in the Nokoue lake

Gnohossou [23] and Pazou *et al.* [27] aimed to investigate the impact of pesticide use in the catchment. Chemical analyses in this study revealed the presence of more than 20 categories of pesticides in sediments and fish with concentrations up to 1364 ng/g of residues in fish.

Recent work on the impact of chemical fertilizer uses through surveys conducted with National Society for the Agriculture Promotion (SONAPRA). The results revealed that more than 100,000 ton of chemical fertilizer were applied to the environment between 1994 and 1995. These chemical fertilizers are mainly used in the north of the catchment area for the treatment of cotton crops and pose a serious threat to all aquatic ecosystems in the catchment area, including Nokoue lake [26].

More recently Kaki *et al.* [17] have worked on the contamination of Nokoue lake water by heavy metals. The major heavy metals found in the lake are: zinc (43.40 - 85.26 mg/L), cadmium (09.17 - 21.78 mg/L), mercury (0.62 - 02.16 mg/L), lead (11.49 - 35.84 mg/L), copper (0.16 - 0.29 mg/L) and arsenic (5.84 - 8.35 mg/L). These studies analyzing heavy metal accumulation in sediments revealed that arsenic (7.93 - 395.99 mg/kg) tends to accumulate in sandy mud sediments, while cadmium (0.56 - 22.07 mg/kg) accumulates in mud sediments [16],[5].

In addition, a survey on the spatial distribution of heavy metal pollution shows that housing locations in lake villages (such as

Ganvié and Vekki) were the most contaminated [18]. This could be related to illegal petrol trafficking, as most of the boats and drums used in this activity were parked in Ganvié and Vekki and petrol discharges could occur in the water. Bacteriological analyses carried out in Nokoue lake and the Cotonou channel, Dovonou *et al.* [2] and Adjahouinou et al. [19] studies show a very high level of faecal contamination (E. Coli, coliforms and faecal streptococci). The areas surrounding the villages and lake districts (Ahouansori, Ladji, etc.) show a level of contamination reaching 15 times the recommended limit values for recreational waters intended for bathing. Similarly, analyses of well water in localities close to the banks indicate the presence of faecal streptococci and various pathogenic bacteria (Clostridium, staphylococci, Salmonella, etc.). This exposes the inhabitants of the lake side localities to high risks of diarrheal diseases and dermatitis.

8) Future researches recommending finding in the review

The current major concern in relation to flood and pollution risks of Nokoue lake to support decision-making for better prevention is an issue mainly related to the availability

of quality data for the implementation of forecasting models [27]. This decision making for flood risk and water quality management can consist in influencing the hazard by hydraulic works modifying the overflow and the vulnerability by modifying the level of expected impacts [20]-[24]. To meet this challenge, research must be carried out to develop models for predicting the risk of flooding and water pollution in Nokoue lake. However, the conduct of this future research is absolutely dependent on long series of key data on water quality and flood generation variables [3], [14]. The difficulty of monitoring spatial-temporal data on water quality, daily flow rates of Nokoue lake is tributaries and daily water level coasts of Nokoue lake arises [4], [15]. River and stormwater discharge from Cotonou and Abomey Calavi need to be monitored, including monitoring of water quality parameters (mainly nutrient, pH and organic matter) in the dry and rainy seasons. More importantly, the exchange of nutrients from the lake with the sea, groundwater and the atmosphere are not known [10]. A better understanding of this process could help to improve water quality control and reduce the salinity effect at these locations during low water periods. Our finding objective is to build predictive models for the better management of flood and pollution prevention to the Nokoue lake.

IV. Conclusion

West African water bodies, although often sharing common environmental problems and equally important to local livelihoods and economies, have very little information due to a lack of monitoring equipment. This synthesis adds to the understanding of historical and seasonal changes in the hydrological regime (hydrodynamics) and water quality of Nokoue lake, a coastal lake in West Africa. The lake has experienced a significant increase in salinity since the widening of the Cotonou canal in 1960, which permanently connects it to the Atlantic Ocean. Also, during the dry period, the entire lake is discharged into the Atlantic Ocean. Further studies are still needed to define an appropriate management strategy for Nokoue lake. They should focus on forecasting tools (numerical tools) for flooding and pollution risks monitoring of Nokoue lake. To achieve this, continuous monitoring of the characteristic variables (physico-chemical, biological and bacteriological parameters) of the water quality and the variables (water level, rainfall and flow rates of the tributaries of Nokoue lake) characteristic of the hydrological regime of Nokoue lake is required. This continuous monitoring necessarily requires the acquisition and installation of automatic sensors able of measuring the various variables that characterize the hydrological regime but also the water quality of Nokoue lake.

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Conflicts Of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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