

Pesticide and Nutrient Loads of Lake Bosomtwe in the Ashanti Region of Ghana

Collins Kuffour¹, David Kofi Essumang², Hugh Komla Akotoye³,
Richard Amankwah Kuffour¹, Janice Dwomoh Abraham⁴

¹Department of Environmental Health and Sanitation Education, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Mampong, Ashanti Region, Ghana

²School of Physical Sciences, University of Cape Coast, Cape Coast, Central Region, Ghana

³Department of Environmental Science, University of Cape Coast, Cape Coast, Central Region, Ghana

⁴Department of Biological Sciences Education, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Mampong, Ashanti Region, Ghana

Email: ckuffour@uew.edu.gh

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Abstract

Pollution of Lake Bosomtwe is a major concern in Ghana due to its derived socio-economic benefits such as employment, ecotourism and major protein source to the people in the basin. Besides these benefits, the lake water is used for domestic purposes and has since served as the drinking water source to the people. However, the use of agrochemicals within the basin has intensified within the last decade. The problems associated with fertilizer and pesticide use in the Bosomtwe basin seem to carry with it a higher price, which, if not identified and checked, will overshadow the desired benefits of the lake. This study assesses pesticide and nutrient loads of Lake Bosomtwe in the Ashanti Region of Ghana. Fifty-four (54) lake water samples were collected from September 2016 to February 2017. Pesticide samples were extracted using the solid phase extraction method and GCMS to identify the pesticides present in the water samples and determine their loads. The data obtained were analyzed using Statistical Product Service Solutions (SPSS version 20) for descriptive statistics. The concentration of dichlorvos was a bit lower when compared with the WHO/USEPA guidelines of 5 ppb for surface water. Diazinon had a mean concentration of 0.28 ± 0.03 ppb which was higher than the WHO 0.05 ppb and USEPA 0.04 ppb for surface water bodies. The detection of diazinon confirms the findings from the field survey, which revealed that diazinon, is an active ingredient of a pesticide with a trade name “Akate suro”, which was extensively used by cocoa farmers along the banks of the lake. The mean concentration recorded for nitrate and phosphate were 0.15 ± 0.05 mg/L and 0.40 ± 0.12 mg/L respectively. The pesticides application inventory and implications of pesticide and nutrient loads on the lake are discussed in the paper.

Keywords

Organochlorine, Organophosphorus, Pesticide, Fertilizer, Bosomtwe

1. Introduction

Lakes are vulnerable, and their overall condition is deteriorating globally [1]. Pollution of Lake Bosomtwe is a major concern in Ghana due to its derived socio-economic benefits. “Reference [2] enumerated employment, ecotourism and major protein source as some of such benefits.” Besides these benefits, the lake water is used for domestic purposes and has since served as the drinking water source to the people in the basin. However, the use of agrochemicals within the Lake Bosomtwe basin has been intensified within the last decade [3]. The agrochemicals have brought increased productivity and other benefits in terms of food security [4]. On the other hand, exposure to residues of the agrochemicals may affect the environment and human health through different emission routes [5]. The problems associated with fertilizer and pesticide use in the Lake Bosomtwe basin seem to carry with it a higher price, which, if not identified and checked, will overshadow the desired benefits [6] [7]. Pesticide and fertilizer residues carried into the lake water may potentially impair the quality of the lake water [8]. Mostly, the quality of the lake water in terms of its physico-chemical properties is often assessed to the exclusion of pesticides. This study was to assess pesticide and nutrient loads of the Lake Bosomtwe in the Ashanti Region of Ghana.

2. Materials and Methods

2.1. Study Area

The study was conducted in three communities that engaged in extensive farming along the banks of Lake Bosomtwe as shown in **Figure 1**. The Lake is located in the Bosomtwe-Atwima-Kwawoma District of the Ashanti Region of Ghana. The District lies within latitude 6°43' North and longitude 1°46' West.

The Lake Bosomtwe area is located within the equatorial zone with a rainfall regime typical of the moist semi-deciduous forest zone of Ghana [9]. The lake almost covers all the flat-leveled low lands between the high lands of the Bosomtwe basin and the remaining little flat-leveled low lands of the basin are used by local inhabitants to carry out subsistence agriculture. Most of the farmers are also involved in other cash crop farming such as cocoa, oil palm and citrus plantations which are done on a relatively small scale [9].

2.2. Research Design

Field and laboratory techniques were used in this study. Purposive sampling technique was used to sample water from the selected communities for laboratory analysis. Fifty-four (54) lake water samples were collected from September,

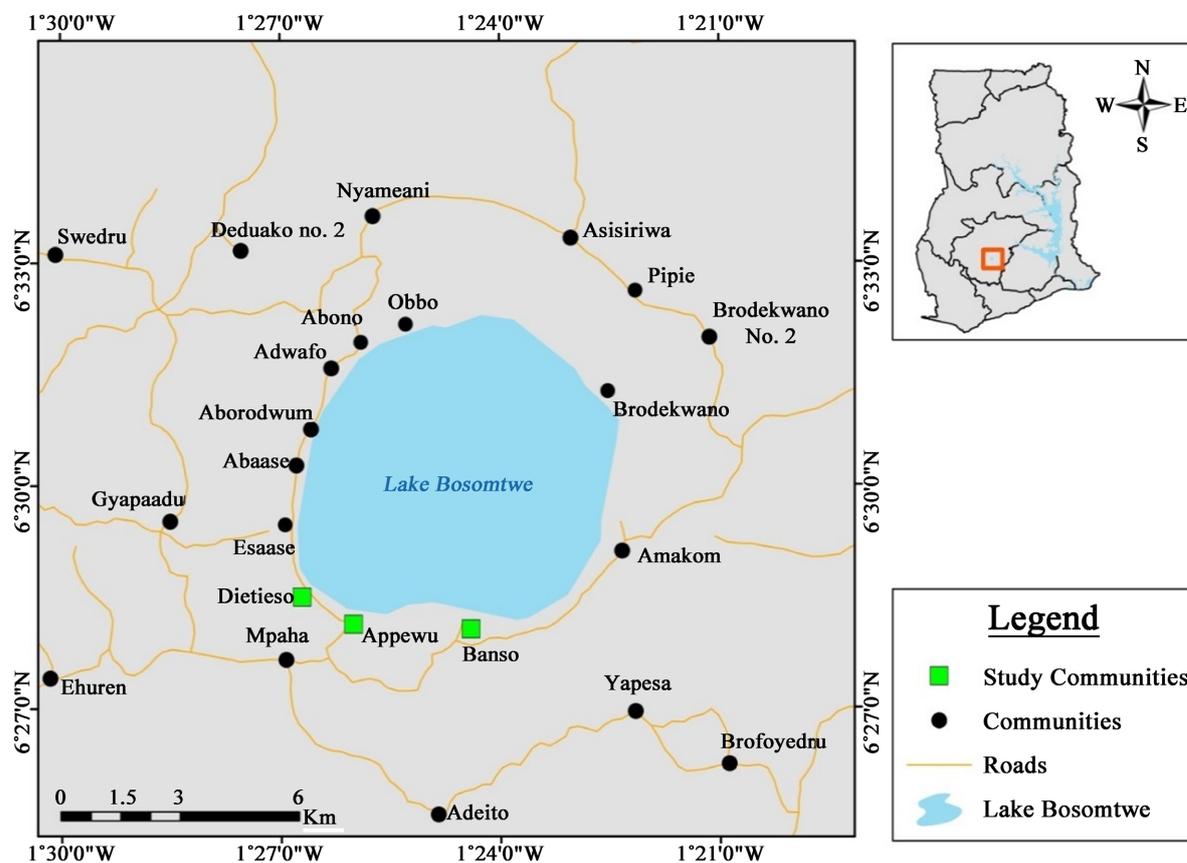


Figure 1. A map of the lake area showing sampling sites.

2016 to February 2017 to the laboratory for analysis of pesticides and nutrient loads. Samples were analyzed using the procedures prescribed by American Public Health Association [10] with minor modifications. A structured questionnaire was used to assess the level of use of pesticides and fertilizers by inhabitants within the Bosomtwe basin. Using discriminative snowball which is also non-probability sampling technique, sixty (60) respondents, twenty (20) from each community were selected for interview to take inventory of pesticides and fertilizers application in the basin.

2.3. Solid Phase Extraction and Elution of Pesticides

The water samples were filtered by passing each sample through a filter paper. A volume of 500 mL of each sample was extracted at room temperature using solid phase extraction method. A weak anion exchange solid extraction octadecyl C_{18} cartridges were preconditioned with 5 mL of 0.1% NH_4OH in methanol followed by double distilled water. Water samples were passed through C_{18} column cartridges through polypropylene tubing under vacuum at a high flow rate (10 mL per minute). A volume of 2 mL of methanol was used to elute the uncategorized organic compounds into a sample valve. Each extract was then dried using Na_2SO_4 . Extracted samples were fortified with 20 μL of the 200 $\mu g/L$ of mixed internal standards. The spiked extracts were subjected to nitrogen evaporation

until the final volume required for analysis was obtained. The samples were analyzed using Gas Chromatograph Mass Spectrometer

Quantification and Limit of Detection of Pesticide

The residue levels of the pesticides were quantitatively determined by the external standard method using peak area. Measurement was carried out within the linear range of the detector following the procedures described by [11] [12]. The peak areas whose retention times coincided with the standards were extrapolated on their corresponding calibration curves to obtain the concentration. The limit of detection of the pesticides determined was based on the extract of the fortified samples that were serially diluted by a factor of two to give different concentrations. One out of each concentration that gave a response three times the standard deviation of the least fortified sample was noted

2.4. Quality Assurance

Linearity was evaluated in the 15 - 150 µg/L concentration range. Four standard concentrations (15, 30, 75 and 150 µg/L) were prepared and used to construct a calibration curve to check the linearity of the instrument response and also for quantification. The regression coefficients (R^2) of the calibration curve were calculated by plotting area ratio against concentration. For most of the targeted compounds, regression coefficient was 0.99 indicating good linearity. Four blank samples were analyzed and the average concentrations of each analyte in the blanks were used to correct the concentration of the corresponding analyte in the test samples. Recovery test was conducted by spiking a mixture of native standards (150 µg/L) into deionized water and then extracted following the same procedures used for the real samples. The reproducibility of the method was then determined. The obtained recoveries and RSD values were largely satisfactory, indicating a fairly good precision for most of the analytes. The limit of detection (LOD) (*i.e.*, concentration that yielded signal to noise ratio of ≥ 3) and limit of quantification (LOQ) (*i.e.*, concentration that yielded signal to noise ratio of ≥ 10) for the various analytes were determined for each sample and the median LOD and LOQ values were reported as the threshold values for each analyte.

Nutrient Loads of the Lake Water

Phosphate and Nitrate were the main nutrients whose loads were determined following the standard procedures prescribed by reference [10].

2.5. Data Analysis

The data obtained were analyzed using Statistical Product Service Solutions (SPSS version 20) for descriptive statistics and the results were presented as shown below.

3. Results and Discussion

3.1. Organophosphate Pesticides

Table 1 shows the mean concentrations of pesticide loads of Lake Bosomtwe.

Table 1. Mean pesticide loads of the lake water in (ppb).

Pesticides	Conc. (ppb)	Skewness	Kurtosis	Minimum	Maximum
<i>Organophosphorus</i>					
Dichlorvos	0.11 ± 0.09	0.31	0.72	0.03	0.18
Diazinon	0.28 ± 0.03	-0.14	-1.06	0.12	0.44
Chlorpyrifos	0.16 ± 0.05	0.58	0.67	0.08	0.28
methyl-chlorpyrifos	0.19 ± 0.05	-0.59	-0.73	0.09	0.26
Triphenyl phosphate (TPhP)	0.16 ± 0.06	0.24	0.61	0.06	0.31
Coumaphos	0.10 ± 0.05	0.44	-0.16	0.01	0.21
<i>Organochlorines</i>					
Lindane	0.22 ± 0.04	4.05	16.85	0.04	1.81
Dichlorobenzophenone	0.05 ± 0.02	1.43	3.72	0.02	0.13
Heptachlorepoxyde	0.11 ± 0.03	0.24	-0.58	0.05	0.19
γ chlordane	0.27 ± 0.10	0.93	0.08	0.08	0.65
α chlordane	0.12 ± 0.05	0.53	0.46	0.03	0.24
Dieldrin	0.04 ± 0.02	1.07	1.23	0.01	0.09
Dichlorodiphenyldichloroethylene (DDE)	0.12 ± 0.07	0.92	1.63	0.01	0.31
Endoslfan Sulphate	0.15 ± 0.06	0.11	-0.80	0.05	0.27
<i>Synthetic pyrethroids</i>					
Permethrin	0.48 ± 0.30	1.32	1.45	0.10	1.32
<i>Phenol group</i>					
σ phenylphenol	0.05 ± 0.05	0.84	-0.349	0.00	0.1714

Source: field data, 2017.

Dichlorvos recorded a mean concentration of 0.11 ± 0.09 ppb with minimum and maximum concentrations of 0.03 ppb and 0.18 ppb respectively. The concentration of dichlorvos was a bit lower when compared with the WHO/USEPA guidelines of 5 ppb for surface water. “Reference [13] attributed movement of contaminants into the lake Bosomtwe to farming activities occurring in the basin.” According to [14], the toxicity of dichlorvos for freshwater and estuarine fish is moderate to high, and it does not bioaccumulate in fish. However, dichlorvos has the potential to induce altered immune response in fish [15].

Diazinon had a mean concentration of 0.28 ± 0.03 ppb during the study. “Reference [16] recorded lower concentration (0.03 ppb) of this same pesticide for surface waters in Dormaa West in Brong Ahafo Region of Ghana.” The mean concentration of diazinon was higher than the WHO 0.05 ppb and USEPA 0.04 ppb for surface water bodies. The detection of diazinon confirms the findings from the field survey, which revealed that diazinon, is an active ingredient of a pesticide with a trade name “Akate suro”, which is extensively used by cocoa farmers along the banks of the lake. Diazinon has been found to capably cause

acute and chronic intoxication [17].

Chlorpyrifos and Methyl-Chlorpyrifos respectively had mean concentrations 0.16 ± 0.05 ppb and 0.19 ± 0.05 ppb. The mean concentrations of both chlorpyrifos and methyl-chlorpyrifos were higher when compared with the 0.08 ppb limit prescribed by the USEPA. Chlorpyrifos like other organophosphate insecticides acts on the nervous system of the parasites and other organisms such as fish, birds and mammals that come in contact with these pesticides. It inhibits acetylcholinesterase an enzyme that hydrolyses acetylcholine.

TPhP and Coumaphos respectively had mean concentrations of 0.16 ± 0.06 ppb and 0.10 ± 0.05 ppb. Coumaphos, TPhP and other organophosphate pesticides have been extensively reported by [6] in Fosu lagoon, Chemu lagoon, Korle lagoon all in Ghana. Coumaphos has been linked to cause so many disturbances in aquatic systems particularly lakes [18]. An increasing number of studies linked exposure to TPhP with reproductive and developmental toxicity, neurotoxicity, metabolic disruption, endocrine effects, and genotoxicity. TPhP has also been found to induce significant estrogenic activity. Organophosphates have been identified to be a contributing factor of eutrophication in water bodies particularly lakes [19].

3.2. Organochlorine Pesticides (OC's)

Eight (8) problematic class of organochlorine pesticide residues were detected in the samples as shown in **Table 1**. They include Lindane Dichlorobenzophenone, Heptachlorepoxyde, Gamma chlordane, Alpha chlordane, Dieldrin, DDE and Endoslfan sulphate. It was observed from the analysis of the questionnaire that most of the organochlorine pesticides detected in the lake water were not actively used in the basin anymore but their concentration still persists. This could be in line with the assertion of [6] that OC's are resistant to microbial and photolytic degradation, and are therefore persistent in the environment (soils and water) where they are applied. Similar concentrations of OC's have been reported by [6] for Fosu, Korle and Chemu lagoons in Ghana.

Exposure to concentrations of organochlorine pesticides over a long period may eventually lead to a substantial body burden of toxic chemicals. Acute ingestion of aquatic products contaminated with organochlorine pesticides may cause a loss of sensation around the mouth; hypersensitivity to light, sound, and touch; dizziness, tremors, nausea, vomiting, nervousness, and confusion [20]. Population-based studies have revealed possible relations between the exposure to organochlorine pesticides and serious health effects including cardiovascular diseases, negative effects on the male reproductive system and on the nervous system, dementia, and also a possible increased risk for non-Hodgkin's lymphoma [21].

3.3. Synthetic Pyrethroids

Permethrin was the only pesticide identified under this group and a phenol type

pesticide, σ -phenylphenol as shown in **Table 1**. The mean concentration recorded for Permetrin and σ -phenylphenol were 0.48 ± 0.30 ppb and 0.05 ± 0.05 ppb respectively. “Reference [16] reported similar concentration for surface water bodies in Dormaa West.” The mean concentration of Permetrin observed at the various sampled sites with detectable residues was found to be higher than the World Health Organization (WHO) Maximum Residue Limit of 0.05 ppb for Permetrin. It is reported that, exposure to synthetic pyrethroids can cause hyper-excitation, aggressiveness, incoordination, whole-body tremors, and seizures [16].

3.4. Nitrate

The nitrate levels recorded during the study ranged from 0.01 mg/L to 0.25 mg/L with a mean value of 0.15 ± 0.05 mg/L as shown in **Table 2**. The mean nitrate value recorded for the study was a bit lower when compared with the overall mean nitrate concentration of 1.3 mg/L recorded by [13] for Lake Bosomtwe. However, the concentration observed for this study (0.16 mg/L) by far fell in line with the nitrate levels obtained by [22] in Lake Volta (0.2 - 1.70 mg/L) and elsewhere in Nigeria (0.10 - 2.60 mg/L) by [23]. The level of nitrate in the lake was far below the W.H.O limit of 10 mg/L. Nitrate levels exceeding 5 mg/L in most cases are indicative of anthropogenic pollution which could be harmful to aquatic organisms and humans. The level of nitrate in the Bosomtwe could be attributed to the use of nitrogenous fertilizers along the bank of the lake by most farmers. “Reference [13] attributed nitrate levels in surface water to increase in surface runoff, bare areas and leaching of nitrogenous fertilizers from nearby farmlands.” A study by [24] concluded that, nitrogen fertilizer application contributed to an increase in nitrate levels in surface water through surface run-off. Fertilizers on farmlands could be sub-lethal to native fish species and other aquatic organisms [25].

3.5. Phosphate

The phosphate level ranged between 0.098 mg/L to 0.68 mg/L with a mean concentration of 0.40 ± 0.12 mg/L as shown in **Table 2**. The mean concentration of phosphate had marginally increased when compared with the mean values of 0.40 mg/L recorded by [13] in the same lake. The mean phosphate concentration for this study was slightly higher when compared with the values (0.031 mg/L) recorded by [26] in the same lake. In view of this, lake can be said to be polluted considering the fact that the minimum phosphate level for most uncontaminated lakes ranges from 0.01 - 0.03 mg/L [27]. The level of phosphate in the lake water

Table 2. Nutrient Load of the Lake Water.

	Sept	Oct	Nov	Dec	Jan	Feb	G. mean	min	Max
NO³⁻ (mg/L)	0.13 ± 0.06	0.10 ± 0.03	0.21 ± 0.03	0.17 ± 0.04	0.13 ± 0.06	0.171 ± 0.03	0.15 ± 0.05	0.011	0.250
PO⁴⁻ (mg/L)	0.40 ± 0.13	0.33 ± 0.17	0.47 ± 0.08	0.38 ± 0.06	0.46 ± 0.13	0.35 ± 0.05	0.40 ± 0.12	0.098	0.680

Source: field data, 2017.

may be attributed to high activities such as rapid evaporation and mineralization of decomposed material in the water [23] [28]. More so, the gradual increase in phosphate concentration in the lake water may be also attributed to the use of phosphate fertilizers, detergents and waste from domesticated animals around the lake. This is an indication of anthropogenic pollution [29]. “Reference [30] reported that high values of phosphate support algae growth and may affect the fish in the lake water.”

3.6. Pesticide and Fertilizer Application Inventory

3.6.1. Background Information about Farmers

The study revealed that majority of the respondents about 34% had no formal education and 43%, had basic education as shown in **Figure 2**. “Reference [13] enunciated that, the low level of education of the people in the Bosomtwe basin could also be an indicator of poor or misapplication of agrochemicals on farms.” Misapplication of agrochemicals enhances movement of chemicals into water bodies causing a whole lot biological and chemical disturbances [31].

Furthermore, most of the farmers within the Bosomtwe basin were low income earners. 90% of the respondents earned between 100-300 Ghana Cedis within a month as shown in **Figure 3**. In view of this, there may be over dependence on the few resources available while the inhabitants quest to get means of subsistence. Often the problems of income earned and the environment are intertwined

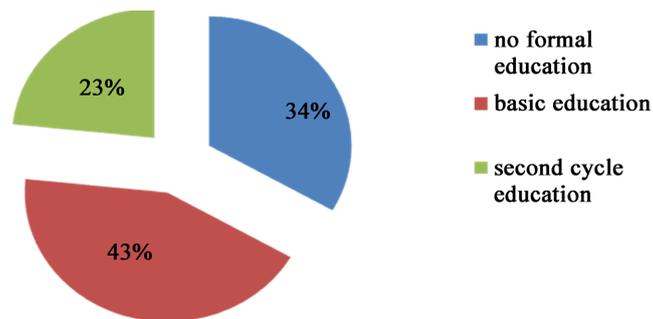


Figure 2. Split pie chart showing educational levels of farmers.

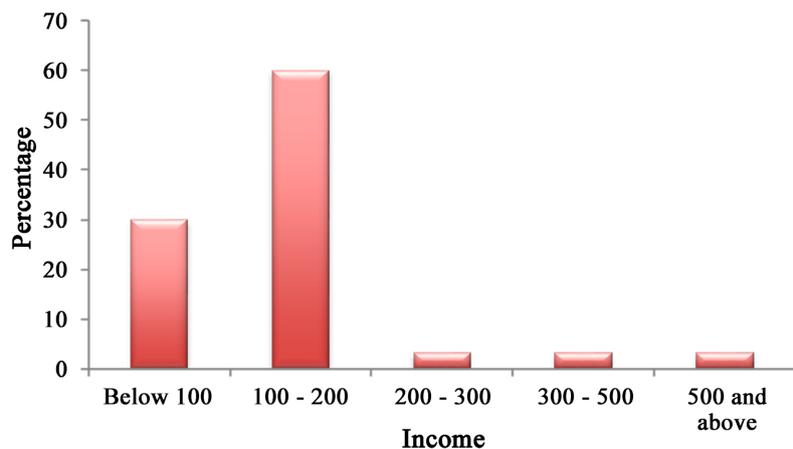


Figure 3. Bar chart showing income levels of farmers.

and poverty varies proportionally to environmental degradation [32]. The World Bank maintains a notion that the poor do not willfully degrade the environment but poor communities often lack the resources to avoid degrading their environment [32]. The inhabitants within such communities therefore adopt poor low technological and ecologically threatening land use practices which significantly affects the lake water quality [33] [34].

3.6.2. Farmers' Knowledge of Pesticide

“Reference [35] posited that the manners in which pesticide products are used are likely to be driven by the extent of knowledge an individual has on the product.” Pesticide labels though are contained in features that are known or easily comprehended and not too abstract to users [36], it was however revealed that 60% of the farmers were unable to read the manufacturer’s instruction while 40% were able to read manufacturer’s instructions. Meanwhile 53% of the total respondents that could read manufacturers instruction did not respect manufacturer’s instruction. This may give satisfactory reasons for farmers’ poor knowledge of the risks associated with the use of pesticides, including the essential role of the correct application and the necessary precautions [37]. Another study has reported that even farmers who can read the manufacturers’ instructions are sometimes unable to translate this awareness into their practices [17] and this is not different from farmers within the Bosomtwe basin.

3.6.3. Farmers' Perception of Pesticide and Fertilizer Use

To find the extent of farmers’ perception of pesticides and fertilizers use, it was divulged that 83% of the farmers within the Bosomtwe basin used pesticide and fertilizer in securing good crops while 13% did not use pesticides or fertilizer at all. The perception of the use of pesticides in the Bosomtwe basin was not different from the perception of most farmers in developing countries [15]. Farmers within the Bosomtwe basin see agrochemicals (pesticide and fertilizer) as a common element of agricultural technology and are commonly utilized throughout production seasons for controlling diseases, pests and weeds [38]. Farmers enumerated reasons for using agrochemicals which were in line with the claims of [39] which include economic benefits such as yield and quality of crops, decrease of other inputs like labor and fuel, etc.

4. Conclusion and Recommendation

The findings from the survey and laboratory results showed appreciable levels of pesticides and nutrients in the lake water. Most of the organochlorine pesticides detected in the lake water were not actively used in the basin anymore but their concentration still persists. The mean concentration of diazinon (0.28 ± 0.03 ppb) was higher than the WHO 0.05 ppb and USEPA 0.04 ppb for surface water bodies. The detection of diazinon confirms the findings from the field survey, which revealed that diazinon, is an active ingredient of a pesticide with a trade name “Akate suro”, which is extensively used by cocoa farmers along the banks

of the lake. The level of nitrate in the lake was far below the W.H.O limit of 10 mg/L. The mean concentration of phosphate in the lake water had marginally increased when compared with the mean values of 0.40 mg/L recorded by [13] in the same lake. The low level of education of the people in the Bosomtwe basin could also be an indicator of poor or misapplication of agrochemicals on farms which lead to nutrients and pesticides residue in the lake water. Farmers enumerated reasons for using agrochemicals which include economic benefits such as yield and quality of crops, decrease of other inputs like labor and fuel. It is highly recommended that farmers within the basin practice zero-tillage agriculture in order to reduce the movement of soil sediments and the constituent thereof (pesticides and nutrients) into the lake water. The Ministry of Food and Agriculture (MOFA) through their extension services gives periodic training and workshops to farmers within the Bosomtwe Basin on good use and correct application of agrochemicals.

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Conflicts of Interest

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

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