Pesticides Bioconcentration Potential of Aquatic Plants in the Volta Lake

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Abstract

The Volta Lake is known for the proliferation of numerous aquatic plants in its shallow waters. A major cause for the presence of the luxuriant vegetation is the intensive agricultural activities along the banks. These activities are heavily dependent on agrochemicals including fertilizers, which eventually get into the aquatic ecosystem via water ways. In this study, two aquatic plants; *Ceratophyllum demersum* and *Nymphaea lotus* were investigated in a pilot study to determine their bioconcentration of pesticides. Levels of organochlorine (OCs) and synthetic pyrethroids (SPs) were analysed using gas chromatograghy equipped with electron capture detector while gas chromatography equipped with pulse flame photometric detector was used for the organophosphorus pesticides (OPs) determination in the plant tissues. The ambient concentrations of these pesticides in the aqueous medium were also determined and the ratios of pesticide concentration in the plant and water samples estimate bioconcentration potential of the plants. Out of 38 detected pesticides, 22 (representing 58%) were bioconcentrated by the aquatic weeds. The Bioconcentration Factor (BCF) range for *Ceratophyllum demersum* was 1.06 – 4,470 and that for *Nymphaea lotus* was 1.27 – 800. By the standard of the European Union regulation for registration of chemicals, levels of diazinon and chlorpyrifos in *Ceratophyllum demersum* fulfilled the 'bioaccumulation' criterion (i.e BCF > 2000) while fenitrothion, with BFC of 5500 in the same plant fulfilled 'very bioaccumulation' criterion (BCF ≥ 5000). This study shows that aquatic weeds in their natural ecosystem have the remediation potential, though to varying degrees and hence play a role in the improvement of water quality.

Introduction

The Environment around fresh water bodies are naturally areas of much activity. One such activity is the cultivation of food crops, due to the availability of water for irrigation. This industry along water bodies is often depended upon agro-chemicals input for economic yields. Remnants of such chemicals in the soil often find their way by means of run-offs into the aquatic medium causing chemical contamination. Contamination of water bodies can directly or indirectly affect human health and ecosystem integrity by inducing a significant threat to aquatic environments and drinking water resources (Dabrowski and Schulz, 2003).

Aquatic plants are known to have great potential as on-site biosinks and biofilters of aquatic pollutants (Gao *et al.*, 2000). Many of them have been identified to be good sequesters of selected heavy metals and nutrients (Bragato *et al*., 2006). For instance, *Lemna minor, Elodea canadensis* and *Cabomba aquatica* have been established to have good accumulative capacities and therefore efficient as agents of phytoremediation of heavy metal and nutrient-contaminated water (Wahaab et al., 1995; Kähkönen and Manninen, 1998; Olette *et al*,. 2008).

Recent data show that aquatic plants also have the ability for remediating pesticide-contaminated media (Gao et al., 2000; De Carvalho, et al., 2007; Dosnon-Olette et al., 2009; Moore et al., 2009) through bioconcentration. The extent of chemical bioconcentration is usually expressed in the form of a bioconcentration factor (BCF) (Katagi, 2010) which is the ratio of the chemical concentrations in the organism and in water. (Nowell et al., 1999). The ability of aquatic macrophytes to bioconcentrate pesticides is an extremely important ecosystem service since this can be a cost-effective and eco-friendly means of removing contaminants from water and sediments (Greger,1999; Prasad et al., 2006).

The banks of the Afram arm of the Volta Lake in Ghana is heavily used for irrigated agriculture for the production of various kinds of food crops all year-round, especially fruits and vegetables. Successful cultivation is dependent on the input of agrochemical for desired yields. The residues of these chemicals in the soil eventually find their way by means of diffuse run-offs into the water body (Koranteng et al., 2016). de Graft-Johnson, (1999) established that the shallow banks of the lake is rich in emergent, floating and submerged aquatic vegetation, including: *Typha sp., Cyperus articulates, Vossia sp., Nymphaea lotus, Ceratophylum sp., Vallisneria sp., Potamogeton sp., Pistia sp., Salvinia sp,* and *Eichornia sp.* Even though their excessive growth has become very problematic due to the numerous challenges they impose on the use of the lake, they also perform useful functions such as: addition of dissolved oxygen, stripping nutrients from water, maintaining aquatic flora diversity, stabilization of lake banks and habitat for organisms. By stripping nutrients and increasing the dissolved oxygen content, aquatic plants improve the quality of water for possible potable usage. In this study, two aquatic weeds (*Ceratophyllum demersum* and *Nymphaea lotus*) along the Afram arm of the Volta Lake where irrigated agriculture is practiced were investigated for their bioconcentration potential as indicators of their ability to biofilter organochlorine, organophosphorus and synthetic pyrethroid pesticides from the aquatic system.

Study area and Target plants

The study was carried out along the lower banks of Afram arm of the Volta Lake. This area was chosen because it part experiences intensive cultivation of fruits and vegetables such as watermelon, cucumber, onion, tomato, okra, pepper and garden eggs, both on smallholder (of average of 0.75 hectares) and commercial (more than 2.0 hectares) bases. The cultivation of these crops is highly dependent on pesticides and fertilizer inputs. The lower banks of the Afram arm were surveyed for the presence of submerged aquatic plants. Submerged plants were targeted so as to ensure that the source of pesticides exposure to the plants was entirely from the water body. In this respect, only two plants (*Ceratophyllum demersum* and *Nymphaea lotus*) were encountered at three different locations (sampling sites) at the time of study, namely Odortom (N 06° 34′ 290″, W 000°14′ 096″), Kwahu Amanfrom (N 06° 37′ 399″, W 000 20′ 198″) and Kotoso (N 06° 43′ 524″, W000 37′ 752″). The coordinates of the sampling sites were marked using a Global Positioning System (GPS) Garmin 60 CSX. Whereas *Ceratophyllum demersum* (*C.demersum*) is a completely submerged and floating aquatic plant, *Nymphaea lotus* (*N. lotus*) on the other hand is a rooted plant that is either completely submerged or has some parts floating or above the water surface, depending on the stage of its maturity.

Materials and methods

Sampling

Ceratophyllum demersum and submerged parts of *Nymphaea lotus* were manually harvested separately at twenty different points of the sampling site on the water body into jute sacks. Sampling of water preceded that of the plants at each point that a plant was harvested. The water samples were taken with a 3 L Goflon water sampler into 1 L amber glass bottles that were previously washed with detergent, rinsed copiously with distilled

water, dried and finally rinsed with acetone. Prior to sample collection, each bottle was rinsed with the sample water three times. Ten samples each of about 5 kg of each of *C. demersum* and *N. lotus* and twenty water samples were taken per site. Thus in all, sixty plants as well as sixty water samples were taken. All the samples were stored on ice and transported. The water samples were brought to the pesticide laboratory of the Ghana Standard Authority and stored in a refrigerator at 4°C. The aquatic plants were identified in the Ghana Herbarium sited in the Department of Plant and Environmental Biology, University of Ghana, Legon. Thereafter, they were thoroughly cleaned under gentle running tap water to remove adhering algae, insect larva and other exogenous materials. They were then put in zip-locked plastic bags stored in a deep freezer at the pesticide laboratory at the Ghana Standard Authority.

Chemicals and Reagents

Reagents used in the study comprised: Methylene chloride, Ethyl acetate and Acetone were of purest grade (pesticide grade) and so were anhydrous sodium sulphate and sodium chloride. All these were acquired from BDH laboratory Supplies, England. Silica gel was purchased from Phenomenex (Torrence, CA, USA). The individual pesticides reference standards used for the quantification and identification of the pesticides were of high purity (Purity > 99%) and obtained from Dr. Ehrenstofer GmBH (Augsburg, Germany) for the following pesticides that were analysed: **Organochlorines;** *α-Lindane, β- Lindane, γ- Lindane, δ-lindane, aldrin, heptachlor, γ-chlordane, α-endosulfan, p,p'DDE, dieldrin, endrin, β-endosulfan, p,p'-DDT, p,p'-DDD, Endosulfan-sulfate* and *Methoxychlor;* **organophosphorus:** *Methamidophos, Ethoprophos, Phorate, Diazinon, Fonofos, Dimethoate, Pirimiphos-methyl, Chlorpyrifos, Malathion, Fenitrothion, Parathion, Chlorfenvinphos, Profenofos* **and synthetic pyrethroids:** *Allethrin, Bifenthrin, Fenpropathrin, Lamda-cyhalothrin, Permethrin, Cyfluthrin, Cypermethrin, Fenvalerate, Deltamethrin*.

Extraction of samples of aquatic plants and clean-up

Samples were wet extracted following the method of Takatori et al., (2006) with necessary modifications as outlined by Koranteng et al., (2018). Briefly, frozen homogenized samples were thawed and allowed to attain ambient temperature. Ten (10) gramme portions of samples were placed in 50 ml polypropylene tubes and 10 ml acetonitrile added. The content of the tube was homogenized by vortex mixer (Thermolyne-maxi mix-plus) at high speed for one minute. Four (4) grammes of anhydrous magnesium sulphate and 1g of sodium chloride were then added and vigorously shaken for another minute. The mixture was centrifuged for 5 minutes and 4 ml supernatant organic layer transferred into a conditioned Supelclean Envi-Carb/LC-NH_2 SPE cartridge (500mg/500mg, 6ml size) and eluted with two portions of 5 ml acetonitrile into a pear-shaped 50ml flask, using a 12 port visiprep vacuum manifold. The eluate was evaporated to dryness using Buchi rotary vacuum evaporator (Buchi Rotovapor R.210). The concentrate was re-dissolved in 2 ml ethyl acetate and transferred into a 2ml standard opening vial for Gas chromatograph analyses.

Extraction of water samples and clean-up

Water samples were removed from fridge

and allowed to equilibrate with the ambient temperature. The samples were extracted according to Mathur et al., (2003). Briefly, water samples were well shaken and filtered through whatman filter paper no.1. After filtration, 1 litre water sample was taken into a 2 litre capacity separatory funnel and 30 mL of saturated sodium chloride solution was added. The water sample was partitioned with 100 mL of methylene chloride by shaking the separatory funnel vigorously for 2-3 minutes and releasing the pressure intermittently. The layers were allowed to stand for 10 minutes to separate. The organic layer was drained into 250 mL conical flask while the aqueous phase was re-extracted twice with 100 mL methylene chloride. The extracted organic phase was combined and dried by passing through anhydrous sodium sulphate in a glass funnel and subsequently concentrated to about 1 mL using rotary vacuum evaporator.

One litre of deionized water was taken as a procedural blank and similarly extracted. The concentrated extracts were then cleaned-up as described below.

Clean-up of the 1 mL concentrate was carried out with a column chromatograph consisting of a layer of 2 g activated silica gel (previously conditioned by heating at 130°C for 2h) sandwiched between two layers, each of 1 g sodium sulphate in a 10 mL polypropylene cartridge. The column was conditioned with 10 mL of methylene chloride and not allowed to dry. The 1 mL concentrate from the extraction was then loaded onto the conditioned cartridges by rinsing the flask with two portions of 5 ml methylene chloride and allowing the column to elute into a pear-shaped flask. The elution was repeated with another 10 ml portion of methylene chloride. The combined eluate was collected and evaporated to just dryness using rotary vacuum evaporator. The final extract was re-dissolved in 1 mL of ethyl acetate (HPLC grade) and transferred into a 1.5 mL standard opening vial for quantitation with GC-ECD and GC-PFPD.

Instrumental analysis

Organochlorines and synthetic pyrethroid pesticides in the final pesticide extracts were analyzed by Gas Chromatograph- Varian CP-3800 (Varian Association Inc. USA) equipped with combiPal autosampler and 63Ni electron capture detector (ECD). The GC conditions used for the analysis were capillary column coated with VF-5 (30 m + 10 m guard column x 0.25 mm i.d, 0.25 µ m film thickness). The injector and detector temperatures were set at 270^{o}C and 300^{o}C respectively. The oven temperature was programmed as follows: 70^{o}C held for 2 min, ramp at 25^{o}Cmin-1 to 180^{o}C, held for 1 min, and finally ramp at 5^{o}C min-1 to 300^{o}C. Nitrogen was used as carrier gas at a flow rate of 1.0 mLmin-1 and detector make-up gas of 29 mL/min. The injection volume of the GC was 1.0 µ L. The total run time for a sample was 31.4 min.

Organophosphorus pesticides on the other hand were analyzed by Gas Chromatograph-Varian CP-3800 (Varian Association Inc. USA) also equipped with combiPal autosampler and pulse flame photometric detector (PFPD). The GC conditions used for the analysis were capillary column coated with VF-1701 (30 m x 0.25 mm i.d, 0.25 µ m film thickness). The injector and detector temperature were set at 270^{o}C and 280^{o}C respectively. The oven temperature was programmed as follows: 70^{o}C held for 2 min, ramp at 25^{o}Cmin^{-1} to 200^{o}C, held for 1 min, and finally ramp at 20^{o}Cmin^{-1} to 250^{o}C maintained for 3.3 min. Nitrogen was used

as carrier gas at a flow rate of 2.0 $mLmin^{-1}$ and detector make-up gases (17.0, 14.0 and 10.0 $mLmin^{-1}$) for hydrogen, air-1 and air-2, respectively. The injection volume of the GC organophosphorus pesticide determination was 2.0 µ L. The total run time for a sample was 14 min. Each sample underwent triplicate analyses.

Analytical quality control

Recoveries were calculated for three replicate de-ionised water samples spiked with 5 ml of 0.05 µg/L standard mixture solutions of organochlorines, organophosphorus and synthetic pyrethroid pesticides. The percentage recovery ranged between 96 -104. Sample analysis data were therefore not corrected for recoveries. Reagent and procedural blanks were also extracted in the same manner as samples and found to be devoid of any interfering agents and for each batch of 10 samples, a procedural blank, and a pair of spiked blank were processed. Limit of quantification (LOQ) of the method was assessed based on lowest analyte concentration that could consistently and reliably yield 70% or more recovery from spiked samples and also gave signal:noise ratio of 3 (Scholtz, et al., 1999). This lowest concentration was run 10 times and the standard deviation (SD) of the signals calculated. Three times the SD gave the limit of detection (LOD) while 10 times the SD gave the limit of quantification. The LOQ for the pesticides was 0.01 µg/L. Recalibration curves were run with each sample batch to ensure that correlation coefficient was not below 0.99. All glass wares were washed with hot water and detergents and copiously rinsed with distilled water. After drying, the glass wares were further rinsed with acetone.

Data Analysis

Frequencies of occurrence of pesticides in the three matrices (*C. demersum, N. lotus*, and water samples) were calculated. Concentrations of pesticides did not differ significantly at sampling sites ($p \geq 0.05$) hence in determining the BCFs, mean concentrations of pesticides over the entire study area were used. By this, a generalised indication of the bioconcentration potentials of the target aquatic plants were estimated. Means were calculated based on number of samples in which residues were quantified. Bioconcentration factors (BCFs) of pesticides in aquatic plants were determined by the following expression:

$$BCF = \frac{\mathrm{Cb}}{Cw}$$

Where ***Cb*** and ***Cw*** respectively represent concentration of pesticides in biota (aquatic plants) and water.

Results

Tables 1 and 2 present pesticides residues in *Ceratophyllum demersum* and *Nymphaea lotus* respectively and the extent to which the pesticides are bioconcentrated by these aquatic plants. The presence of 3 organochlorines, 4 synthetic pyrethroids and 7 organophosphorus pesticide residues (OPs) were recorded in *C. demersum* (Table 1). Of the detected organochlorine pesticides (OCs), endrin recorded the highest mean concentration of 5.90 µg/kg whilst β-lindane recorded the lowest concentrations of 0.50 µg/kg. The incidence rate of all of them were high, ranging from 80% to 100% (Table 1). The levels of synthetic pyrethroids (SPs) were generally low, with mean concentration range of 0.62 – 2.17 µg/kg. Cypermethrin registered the highest mean residue of 2.17 µg/kg among the pyrethroids. The organophosphorus residues

recorded the highest levels in *C. demersum* with a mean concentration range of 2.86 – 129.0 µg/kg. Methamidophos registered the highest mean concentration (129.0 µg/kg) while malathion recorded the lowest (2.86 µg/kg). From the values in Table 1, organophosphorus pesticides had the highest load (241.66 µg/kg) followed by the OCs (6.93 µg/kg) and SPs (5.21 µg/kg) in *Ceratophyllum demersum.* While the concentration of the organophosphorus pesticide residues in *Ceratophyllum demersum* were comparatively high, their levels in water were relatively low, leading to high BCF values. The general order of BCF values follows: OPs > SPs > OCs.

Nymphaea lotus on the other hand registered the presence of more pesticide residues (Table 2). The presence of 4 organochlorines pesticides, 6 synthetic pyrethroids and 8 organophosphorus pesticide residues were detected. The highest mean residue was recorded for γ-lindane (35.90 µg/kg), followed by methamidophos (8.66 µg/kg) (Table 2). Unlike *Ceratophyllum demersum, Nymphaea lotus* bioconcentrated OCs most, followed by OPs and then SPs (Tables 1 and 2), however, the BCF values still follow the order as observed in *Ceratophyllum demersum*, viz OPs > SPs > OCs. This is so because the high levels of OCs in *Nymphaea lotus* is matched by corresponding relatively high levels in water whereas levels of OPs in water were relatively very low.

Examination of the results reveals that all the detected pesticides in the aquatic plants were bioconcentrated, with the exception of endrin in

TABLE 1
Pesticides in *Ceratophyllum demersum* and bioconcentration factor

	Mean Conc. in *C. demersum* (µg/kg)	Conc. range (µg/kg)	Freq. (%)	Ambient mean conc.in water (µg/L)	Bioconcentration Factor (BCF)
Organochlorines					
β-HCH	0.50 ± 0.23	0.50-0.61	100	3.800	0.13
p,p'-DDE	0.53 ± 0.00	0.50-0.61	80	0.050	1.06
Endrin	5.90 ± 0.50	5.30-6.40	80	2.400	2.45
Load	**6.93**				
Pyrethroids					
Lamda-cyhalothrin	1.42 ± 0.59	1.10-2.10	60	0.068	20.90
Cyfluthrin	1.00 ± 0.14	0.80-10.00	40	0.011	91.00
Cypermethrin	2.17 ± 0.50	1.81-2.74	60	0.720	3.00
Fenvalerate	0.62 ± 0.47	0.50-1.30	80	0.010	62.00
Load	**5.21**				
Organophosphates					
Methamidophos	129.00 ± 21.80	113.60-154.30	60	0.390	330.80
Diazinon	44.70 ± 1.2	3.10-5.30	60	0.010	4470.00
Chlorpyrifos	46.10 ± 6.4	38.70-50.00	60	0.020	2305.00
Malathion	2.86	2.86	20	0.010	286.00
Fenitrothion	11.00 ± 3.50	8.50-13.40	40	0.014	5500.00
Parathion	4.70 ± 0.32	4.50-5.10	60	nd	-
Profenofos	3.30 ± 1.10	2.50-4.10	40	0.010	330.00
Load	**241.66**				

Load = Total of the means of all residues in each pesticide group

Nymphaea lotus and β-HCH (in *Ceratophyllum demersum*) (Tables 1 and 2). Endrin in *Nymphaea lotus* was not bioconcentrated as its concentrations in the aqueous medium was more than its corresponding concentrations in the plant tissues. It is also observed that *Ceratophyllum demersum* generally has higher bioconcentration of OPs than *Nymphaea lotus*. For instance whereas the bioconcentration factors for methamidophos, diazinon and chlorpyrifos in *C. demersum* respectively were 330.8, 4470.0 and 2305, the corresponding figures for the same pesticides in *N. lotus* were 22.2, 800.0 and 305.0 (Tables 1 and 2).

Discussion

Reconnaissance survey of the study area revealed that organophosphorus and synthetic pyrethroids were the predominant insecticides employed in controlling insect infestation of food crops on farmlands along the lake. This may account for their higher incidence and in some cases, higher frequencies of detection and concentrations, relative to the organochlorines. The use of organochlorines for crop production in general has been banned in Ghana however, illicit peddling of some of them still goes on (result from field observation) and this could partly account for the presence of few of them in the environment.

TABLE 2
Pesticides in *Nymphaea lotus* and bioconcentration factor

	Mean Conc. in *N. lotus* (µg/kg)	Conc. range (µg/kg)	Freq. (%)	Ambient mean conc. in water (µg/L)	Bioconcentration Factor (BCF)
Organochlorines					
β-HCH	3.90 ± 2.80	1.30-8.00	80	3.800	1.27
γ-HCH	35.90 ± 4.90	29.60-39.90	100	0.100	359.00
p,p'-DDE	0.66 ± 0.63	0.50-1.10	40	0.050	13.20
Endrin	0.70 ± 0.27	0.50-0.90	40	2.400	0.30
Load	**41.16**				
Pyrethroids					
Bifenthrin	2.33 ± 0.71	1.31-2.93	80	0.049	47.00
Lamda-cyhalothrin	2.20 ± 0.99	1.00-3.00	80	0.068	32.40
Permethrin	0.80 ± 0.31	0.50-1.00	40	0.032	25.00
Cyfluthrin	6.20 ± 0.89	5.60-7.50	80	0.011	563.60
Cypermethrin	1.90 ± 0.45	1.57-2.20	40	0.720	2.60
Deltamethrin	0.52 ± 0.00	0.50-0.54	40	0.330	1.58
Load	**13.62**				
Organophosphates					
Methamidophos	8.66 ± 4.95	2.24-14.30	80	0.390	22.20
Ethoprophos	5.10 ± 0.57	4.70-5.50	40	0.030	170.00
Phorate	2.80 ± 0.46	2.40-3.10	40	0.006	466.70
Diazinon	4.00	4.00	20	0.010	800.00
Pirimiphos-methyl	2.14	2.14	20	0.010	214.00
Chlorpyrifos	6.10 ± 0.36	5.80-6.50	60	0.020	305.00
Parathion	4.70 ± 0.46	4.36-5.00	40	nd	-
Chlorfenvinphos	2.93	2.90	20	0.080	36.60
Load	**32.8**				

Load = Total of the means of all residues in each pesticide group

The number of pesticides detected in *N. lotus* was more (18) than that in *C. demersum* (14) however, concentration of the pesticides were relatively higher in *C. demersum*, resulting in corresponding higher BCFs. For instance, the range of BCF of pesticides in *N. lotus* is 0.30 – 800 while that for *C. demersum* is 0.13 – 5500. Uptake of pesticides from water by aquatic plants among others, depend on the framework and anatomy of the plants (Olette et al., 2008). The higher surface area of *C. demersum* may contribute to its better uptake of chemicals and consequently its higher bioaccumulative potential of pesticides. In laboratory experiments, Olette et al., (2008, 2009) also demonstrated the ability of aquatic plants to bioconcentrate pesticides. In their studies (Olette *et al*., 2008), concentrations of three pesticides (copper sulphate, flazasulfuran and dimethomorph) in three aquatic plants Lemna minor (30µg g-l), *Elodea canadensis* (27µg g-l) and *Cabomba aquatica* (11µg g-l) exceeded the aqueous concentration which was in the range of 0 – 1 mg L-1. Similarly, the levels of dimethomorph and pyrimethanil in these aquatic plants recorded up to 48 µg g-l when the exposure concentration in the aqueous medium was 600 µg L-l (Olette *et al*., 2009).

The European Union Regulation for Registration of Chemicals (2011) designates a chemical to fulfill 'bioaccumulation criterion' when its bioconcentration factor in an aquatic biota is equal to or higher than 2000 and 'very bioaccumulative' when the bioconcentration factor is equal to or greater than 5000. Three pesticides levels in *C. demersum* are worthy of note in this regard, namely diazinon, fenithrothion and chlorpyrifos. Whereas diazinon fulfilled the very bioaccumulation criterion, the other two fulfilled bioaccumulation criterion. Even though none of the chemicals fulfills any of the criterion in *N. lotus*, a good number of them had BCF exceeding 200. Indeed with the exception of endrin (in *N. lotus*) and β-HCH (in *C. demersum*), all of them (more than 90% in both plants), though to varying degrees, have been bioconcentrated by the plants. The implication of this is that *C. demersum* and *N.lotus* serve as biofilters of pesticides from the aquatic medium thus improving the quality of water that has been chemically contaminated as a result of farming activities. In a further study, Dosnon-Olette et al., (2010) established that aquatic plants are capable of phytoremediation for the removal of organic pollutants from aquatic medium. The bioremediative function and ecosystem service of the plants in this study is of prime importance since the riparian communities directly depend on the lake water for potable use. There is the need for further studies to identify more aquatic plants that are efficient biofilters.

It is a known fact that there has been excessive growth of hydrophytes in the littoral regions of the Volta Lake and many have become nuisance in the lake waters, prompting several efforts at clearing them. The 'Sudd' formers in particular (e.g. *Leersia, Cyclosorus* and *Scirpus spp.*) have been impediment to boat movements for tourism and lake transport as well as restriction to the use of fishing gears (de Graft-Johnson, 1999) and every efforts must be made to eradicate them or to control their growth. However, others may be less problematic and may be providing essential or useful ecosystem services. Perhaps, selective harvesting of the aquatic plants in favour of existence of the beneficial ones could be contemplated.

Conclusions

The potential of two aquatic plants (*Ceratophylum demersum* and *Nymphaea lotus*) as biosinks and biofilters of pesticides in the waters of the Afram arm of the Volta Lake was explored based on their bioconcentration determination from field data. These two aquatic plants were chosen because the source of pesticides they sequestered could be guaranteed to be entirely from the aqueous medium. More than 90% of the pesticides detected in them were bioconcentrated. Whereas diazinon, cyfluthrrin, phorate, γ-HCH and chlorpyrifos respectively had bioconcentration factors of 800.0, 563.6, 466.7, 359.0 and 305.0 in *Nymphaea lotus*, fenitrothion, with BCF of 5500 fulfilled 'very bioaccumulative' criterion while diazinon (BCF of 4470) and chlorpyrifos (BCF of 2305) fulfilled 'bioaccumulative' criterion in *Ceratophylum demersum*. By this, the two aquatic plants, especially *Ceratophylum demersum* have been identified under natural conditions to be good sequesters of pesticides and agents of improving quality of lake water and therefore reducing the health hazard that may be associated with its potable use by the riparian communities. The phytoremediative ability of aquatic plants must therefore be appreciated and considered as an option in decontamination processes in aquatic media.

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