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Assessment of Organochlorine Pesticide Residues in Inlay Lake

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Assessment of Organochlorine Pesticide Residues in Inlay Lake

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Abstract

The tested results of the Organochlorine pesticides (OCPs) residues of the water samples were compared with the World Health Organization maximum residue limit for pesticides in water (WHO MRLs) and the United States Environmental Protection Agency (U.S. EPA) maximum permissible level. According to the results, trans-chlordane, endrin, dieldrin, endrin aldehyde, dichloro-diphenyldichloroethane (4,4'-DDD) dichloro- diphenyl trichloroethane (4,4'-DDT) and endosulfan sulphate, endosulfan I ad endosulfan II, were detected in some sampling points of the lake. The concentration of pesticide residues at the C7 (Lake entrance stream) is significantly lower than that in other areas inside the lake. Moreover, it has been found that the levels of pesticide residues in floating gardens were higher than in other areas. The excessive use of fertilizers and pesticides in floating gardens, which are the main agricultural activity in Inlay Lake, is considered to be the main reason for the high levels of pesticide residues in the lake water. According to the results, the content of pesticide residues in some sampling points in the lake were higher than the WHO MRL standard values and U.S.EPA maximum permissible levels. Many OCPs and their metabolites are highly toxic and have been implicated in a wide range of adverse health effects such as cancer, neurological damage, reproductive system deformities, birth defect, and damage to the immune system, hence their presence is of serious concern. It can therefore be concluded that water pollution due to high concentration of OCPs poses a threat to local people and aquatic lives in the study area. The results of this study can provide baseline information on organochlorine pollution, especially in the Inlay Lake area, which may benefit stakeholders in establishing regulations related to organochlorine pollution in the future. The immediate attention should also be paid on the management of floating gardens if the open lake area and water quality are to be preserved. Government and relevant organization should address pesticide importers and users with effective laws on the import and use of banned pesticide because some farmers in Inlay Lake thought that this banned pesticide was more efficient than other. Moreover, training and education program of proper pesticide usage would be the important role in decreasing the concentration of pesticide residues in the Lake area.

Keywords: organochlorine pesticides, OCPs, pesticide residues, Inlay Lake

အင်းလေးကန်အတွင်း အော်ဂန်နိုကလိုရင်းပိုးသတ်ဆေးခတ်ကြွင်းများ ပါဝင်မှုအား ဆန်းစစ်လေ့လာခြင်း

ဒေါက်တာသီတာချို၊ ဒေါက်တာသီတာဆွေ
လက်ထောက်သုတေသနအရာရှိ၊ သစ်တောသုတေသနဌာန

စာတမ်းအကျဉ်း

ရေနမူနာများ၏ စမ်းသပ်ထားသော အော်ဂဲနစ်ညစ်ညမ်းမှု ခတ်ခွဲရလဒ်များကို ကမ္ဘာ့ကျန်းမာ ရေးအဖွဲ့၏ ရေတွင် ပိုးသတ်ဆေးအတွက်ခတ်ကြွင်း အများဆုံးပါဝင်မှု ကန့်သတ်ချက် (World Health Organization maximum residue limit for pesticides in water -WHO MRLs) နှင့် United States Environmental Protection Agency(U.S. EPA)၏ သုံးရေတွင်အမြင့်ဆုံးလက်ခံနိုင်သောပါဝင်မှုပမာဏ သတ်မှတ်ချက်များနှင့် နှိုင်းယှဉ်၍ သုံးသပ်တင်ပြထားပါသည်။ ခတ်ခွဲ တွေ့ရှိချက်အရ ကန်၏ ရေနမူ နာကောက်နေရာ အချို့တွင် trans-chlordane၊ endrin၊ dieldrin၊ endrinaldehyde, dichlorodiphenyl -dichloro-ethane (4,4'-DDD)၊ dichlorodiphenyl trichloroethane (4,4'-DDT)၊ endosulfan sulphate၊ endosulfan I နှင့် endosulfan II ပိုးသတ်ဆေးခတ်ကြွင်းများ ပါဝင်နေကြောင်း ဆန်းစစ်တွေ့ရှိရပါ သည်။ အင်းအဝင်ချောင်း (C7) ၏ ပိုးသတ်ဆေးခတ်ကြွင်းများ ပါဝင်မှု သည် ကန်အတွင်းရှိ အခြား နေရာများထက် သိသိသာသာနည်းနေပြီး ရေခြံနေရာများမှ ရေနမူ နာများတွင် ပိုးသတ်ဆေး ခတ်ကြွင်းများ ပါဝင်မှုပမာဏ အများဆုံးဖြစ်ကြောင်း တွေ့ရှိရပါ သည်။ အင်းလေးကန်အတွင်း အဓိက စိုက်ပျိုးရေး လုပ်ငန်းဖြစ်သည့် ရေခြံများတွင် ခတ်မြေ ဩဇာနှင့်ပိုးသတ်ဆေးများ အလွန်အကျွံသုံးစွဲခြင်းသည် ကန်ရေအတွင်း ပိုးသတ်ဆေး ခတ်ကြွင်း များ မြင့်မားလာရခြင်း၏ အဓိက အကြောင်း အရင်း ဖြစ်သည်ဟု ယူဆပါသည်။ ခတ်ခွဲ တွေ့ရှိချက်အရ ပိုးသတ်ဆေးခတ်ကြွင်းများ၏ ပါဝင်မှု သည် WHO MRLs နှင့် U.S.EPA တို့၏ စံနှုန်း သတ်မှတ်ချက်များထက် ကျော်လွန်နေပါသည်။ အော်ဂန်နိုကလိုရင်း ပိုးသတ်ဆေး ခတ်ကြွင်းများနှင့် ၎င်းတို့၏ ဆင့်ပွားခတ်ပေါင်းများသည် အလွန် အဆိပ်ပြင်း ပြီး ကင်ဆာ၊ အာရုံကြော ပျက်စီးခြင်း၊ မျိုးပွားခြင်းစနစ် ပုံမမှန်မှုနှင့် ခုခံအားစနစ် ပျက်စီး ခြင်း စသည့် များပြားသော ကျန်းမာရေးဆိုင်ရာ ဆိုးကျိုးသက်ရောက်မှုများရှိပါသည်။ ထို့ကြောင့် OCPs များမြင့်မားစွာ ပါဝင်မှုကြောင့် ရေထုညစ်ညမ်းမှုသည် ဒေသခံပြည်သူများနှင့် ရေနေ သတ္တဝါများ၏ အသက်အန္တရာယ်ကို ခြိမ်းခြောက်လျက်ရှိသည်ဟု ကောက်ချက်ချနိုင်ပါသည်။

ဤလေ့လာမှု၏ ရလဒ် များသည် အနာဂတ်တွင် အော်ဂန်နိုကလိုရင်းညစ်ညမ်းမှုနှင့် ပတ်သက်သည့် စဉ်းမျဉ်းများ ချမှတ်ရာ တွင် သက်ဆိုင်သူများကို အကျိုးပြုနိုင်စေမည့် အထူးသဖြင့် အင်းလေး ကန်ဧရိယာအတွင်း ဖော်ပြပါ ပိုးသတ်ဆေးများ ညစ်ညမ်းမှုဆိုင်ရာ အခြေခံအချက်အလက်များကို ပေးစွမ်းနိုင်ပါသည်။ ရေပြင်ကျယ် ဧရိယာနှင့် ရေအရည်အသွေး ထိန်းသိမ်းထားနိုင်ရန် ရေခြံများ စီမံအုပ်ချုပ်ရေးကိုလည်း ချက်ချင်း အာရုံ စိုက်သင့်ပါသည်။ အင်းလေးကန်ရှိ တောင်သူအချို့က တားမြစ်ထားသော ပိုးသတ်ဆေးသည် အခြား ပိုးသတ်ဆေးများထက် ပိုမိုထိရောက်သည်ဟု ယူဆသောကြောင့် အစိုးရနှင့် သက်ဆိုင်ရာအဖွဲ့အစည်း များက ပိုးသတ်ဆေးတင်သွင်းသူများနှင့် သုံးစွဲသူများအား တားမြစ်ထားသော ပိုးသတ်ဆေးများ တင်သွင်း သုံးစွဲခြင်းဆိုင်ရာ ထိရောက်သော ဥပဒေများ ချမှတ်ဆောင်ရွက်သင့်ပါသည်။ ထို့အပြင် အင်းလေးကန် ဧရိယာအတွင်း ပိုးသတ်ဆေးဓာတ်ကြွင်းများ လျော့နည်းသွားစေရန် လေ့ကျင့် သင်ကြားပေးခြင်းနှင့် ပညာပေးအစီအစဉ်သည် အရေးကြီးသော အခန်းကဏ္ဍမှ ပါဝင်မည် ဖြစ်ပါသည်။

Assessment of Organochlorine Pesticide Residues in Inlay Lake

1. Introduction

For increasing world population and food production, the utilization of high-yielding crop varieties, fertilizer application, irrigation and pesticide application becomes a predominant factor to recent global changes in food production. According to FAO (2011), most of the imported pesticides in developing countries have been banned for agricultural use in most developed countries. However, these chemicals are still widely used in developing countries countries owing to its cheaper cost, lack of better alternatives, insufficient knowledge, technology and finance. Therefore, there is a high probability that pesticide usage and pesticide induced side effects will grow more rapidly in developing countries as a whole than in the developed ones. Reviewing the pesticide utilization in Southeast Asia countries, Malaysia is the highest pesticide user followed by Thailand and Myanmar. Moreover, it is expected that the consumption rate of pesticides in these countries will be increased (FAO, 2013).

Inlay Lake is the second largest lake in Myanmar and is situated in Nyaung Shwe Township, Southern Shan State, Myanmar. The lake provides livelihood to the local people in term of cultivating a variety of crops in its floating islands, fisheries, gold and silver smithies, cotton weaving, black smithy, trade and transportation, and source of electricity (Lwin and Sharma, 2012). It is one of the largest vegetable production areas in the country. People in Inlay Lake grow various cash crops such as tomato, cauliflowers, flowers, pod, cabbage, and eggplant on floating gardens. Among them, tomato is the major cash crop especially in the flooded villages. As the tomato seed used in Inlay Lake is hybrid variety, the tomato growers have to use a lot of chemical fertilizers, pesticides and insecticides. Floating gardens, mostly for tomato cultivation, are a unique and profitable method of agriculture used by people living on and around the lake. During the cultivation and processing stage, farmers use pesticides to reduce the potential for economic loss and to maintain quality of the products (Santarelli *et al.*, 2018). The local farmers are using different kinds of agricultural chemicals such as pesticides, herbicides, insecticides, fungicides and fertilizers etc., (Lwin and Sharma, 2012). Hence, agriculture activities represent the main anthropogenic sources of organic pollutants in lake. Moreover, the contaminants are coming from various sources such as agrochemicals, sewage, small-scale textile industries, gold, silver and black smiths, and hotel and resorts wastes, solid and liquid wastes from villages (Zin Mar Lwin, 2013). The aquatic ecosystem in the lake is therefore being more and more polluted.

A few research works have been conducted on the surface water quality of Inlay Lake. However, toxic organic contaminants, especially organochlorine pesticides (OCPs), in the water of lake has not been recorded. Therefore, the present work was planned to assess the pollution status of organochlorines in water of Inlay Lake. The results of this study can provide baseline information on organochlorine pollution, especially in the Inlay Lake area, which may benefit stakeholders in establishing regulations related to organochlorine pollution in the future.

2. Literature review

Organochlorine pesticides (OCPs) are a group of organic, chlorinated, and hydrophobic compounds that have been used widely in the agriculture and health sectors (Li and Macdonald, 2005). Organochlorine pesticides, such as dichlorodiphenyltrichloroethane (DDT), aldrin, dieldrin, endrin, chlordane, hexachlorobenzene, mirex, toxaphene, and heptachlor, are groups of organic molecules with added chlorineand considered persistent compounds that remain active for years (Ensley, 2018).

OCPs are characterized by low polarity, low aqueous solubility and high lipid solubility (lipophilicity) and as a result they have a potential for bioaccumulation in the food chain posing a great threat to human health and the environment globally (Afful *et al.*, 2010). Owing to their pervasive, persistent, toxic, and bioaccumulative nature, they are classified as persistent organic pollutants (POPs) (Oliveira *et al.*, 2016). Due to the high persistence and bioaccumulation potential, the Stockholm Convention has classified most of the Organochlorie (OC) compounds as environmental hazards and banned the use of many of them. Residues and metabolites of many OC pesticides are very stable, with long half lives in the environment (El-Mekkawi *et al.*, 2009).

Hence, to understand the pollution status of OCPs in the water body, it is important to assess the residue levels of OCPs in the water. Many OCPs and their metabolites are highly toxic and have been implicated in a wide range of adverse health effects such as cancer, neurological damage, reproductive system deformities, birth defect, and damage to the immune system (Ahlborg *et al.* 1995; Sosan *et al.* 2008; Leena *et al.* 2012). OCPs are volatile and can move off-site via air-drift and surface runoff to contaminate remote areas (including water bodies) (Miglioranzaa *et al.* 1999; Kuranchie-Mensah *et al.* 2012). As a result of their lipophilicity and persistence, organo-chlorine pesticides bio-accumulate along the food chain posing health threats to human beings (Mbakaya *et al.*1994; Manirakiza *et al.* 2002; Botwe *et al.* 2012; Kuranchie-Mensah *et al.* 2012). The adverse consequences associated with the use of organochlorine pesticides are the reasons why many of them were banned or have their use restricted (Botwe *et al.* 2012; Asiedu 2013). However, there are evidence of their continuous usage in some developing countries due to their efficacy and low cost and possibly due to weak import control and lack of logistics to monitor pesticides (Darko and Acquaah 2007; Asiedu 2013).

Organochlorine pesticides (OCPs) can bioaccumulate through the food chain. In humans, OCPs and their metabolites have been associated with health complications, such as cancer, cardiovascular diseases, diabetes, and neurological and reproductive disorders. (Alharbi *et al.*, 2018, Kafilzadeh, 2015, Lee *et al.*, 2011, Ruzzin, 2012). Short term exposure to high dosage of pesticide can cause irritation of the skin, eyes, nose and throat, difficulty in breathing, impaired functioning of the lungs, delayed response to a visual stimulus, impaired memory, stomach discomfort and possible changes in the liver and kidneys. Both short- and long-term exposure can also affect the nervous system (Hashmi,2011). They can also be transported long distances like most organo-pesticides, as evidenced by the accumulation in arctic wildlife (Dietz *et al.*, 2004).

Alpha-hexachlorocyclo hexane, Gamma-hexachlorocyclohexane (γ-BHC -Lindane), Beta-hexachloro cyclohexane, Heptachlor, Endosulfan, aldrin, Chlordane, Dieldrin, endrin, DDT, *etc*. are the chemicals which have been banned in Myanmar due to their adverse effects in the environment (ECD, 2019). Moreover, certain greenhouse gas emissions arise from substances emitted from pesticides are also a major tool for the fight against climate change. Agriculture, including land use change and forestry accounts for nearly one-third of global greenhouse emissions (WRI, 2008). According to CSO (2012), pesticide utilization in agriculture of Myanmar gradually increased from 2003 to 2010 especially in granule type (6000,000 lb.).

3. Objectives

Objectives of the study are:

- ❖ To assess the water quality status of Inlay Lake based on persistence organic pollutant contents,
- ❖ To investigate the concentrations levels of organochlorine pesticides (OCPs) residues and
- ❖ To provide baseline information on organochlorine pollution, especially in the Lake area.

4. Materials and Methods

4.1 Water Sampling

The water samples were collected from 10 locations, such as center of lake, the east and west of the lake, Nant latt stream, north of the Nant Pan village, near Khit SanYin weaving factory, near Ywar Ma Village. A map showing the location of sampling points and the sampling points information are presented in the figure and table below.

Table 1. Explanation of water sampling points in Inlay Lake

Sr. No	Sampling Points	Explanations	Water Depth (cm)	Above Sea level (m)	Latitudeı Longitude	Category
1.	A1	Near Inn Oo village	139.7	883	N 20° 36.5635, E 96° 53.9300	floating garden
2.	B1	Floating Garden	238.76	887	N 20° 31.9979, E 96° 55.3734	
3.	A3	Open Lake area	116.84	886	N 20° 36.3853, E 96° 54.9238	open lake area
4.	B3	Open Lake area	190.5	885	N 20° 34.2248, E 96° 55.0758	
5.	C1	Near Shwe Inn Ther Hotel	279.4	885	N 20° 28.8205, E 96° 53.7361	restaura nt
6.	C8	Inside the Nant Pan Village/ East of the Golden Kite Restaurant	170.18	885	N 20° 27.4997, E 96° 54.5077	
7.	C7	Thantaung stream	96.52	882	N 20° 38.0575, E 96° 55.2635	Lake entrance
8.	C3	North of Nant Pan village	139.7	883	N 20° 28.6314, E 96° 54.5979	village
9.	C10	Near Ywar Ma Village	96.52	885	N 20° 29.6314, E 96° 53.1690	
10.	C9	Near Khit SanYin weaving factory	96.52	885	N 20° 26.8052, E 96° 53.8961	weavin g factory

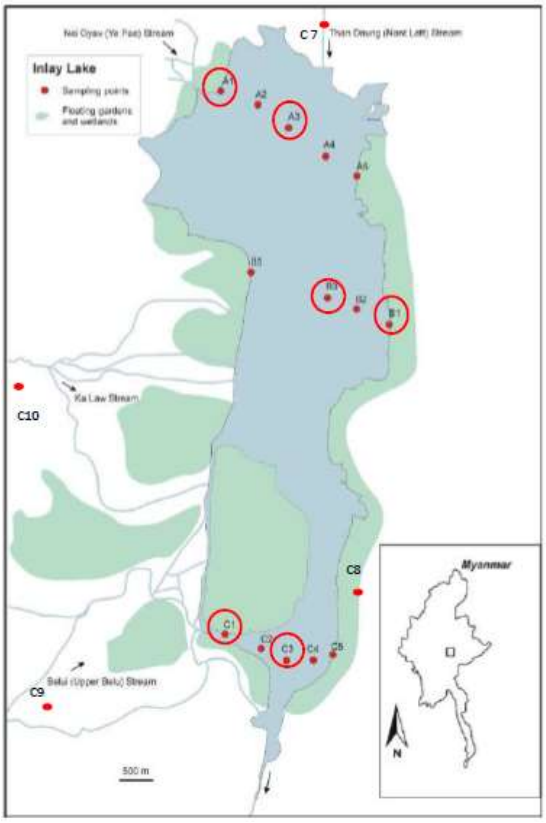

Figure 1. Map showing the location of water samling points in Inlay Lake

4.2. Sample Preparations

4.2.1 Extraction of Pesticides from Water

Filtered water samples (1 L) were passed through the cartridge (filled with 500 mg of Octadecyl bonded silica) at a constant flow rate (3 ml/min) using vacuum manifold. The packing material was conditioned prior to loading the sample by passing distilled waer (5 ml) and methanol (5 ml) respectively. Suction was continued for 35 min to dry out the packing material after sample were passed through the cartridge. Adsorbed analytes were eluted with ethyl acetate (5 ml) and n-xexane (5 ml). The eluate was passed through anhydrous sodium sulfate and then it was concentrated by drying with nitrogen gas. The concented dried eluate was mix with n-xexane (1 ml) and transferred it to GC vial for analysis.

4.2.2 Standards and Reagents

The organochlorine pesticide mixture (standards) with > 99% purity and organic solvents, methanol, n-xexane, and acetone (HPLC grade) were purchased from Smartx Analytics Engineerig Co., Ltd. All the chemical reagents used were high-purity analytical grade reagents. All aqueous solutions were prepared in ultra-pure water. High purity, (99.99% purity) Nitrogen gas, Air Zero gas and Hydrogen gas were used in the present study.

4.2.3 Solutions Preparation

Stock solution (8 ppm) containing 20 organochlorine pesticides was prepared from 2000 ppm (1 ml) standard solution (Supelco, Bellefonte, PA, USA) in acetone and stored at 4 ◦C. For calibration, fresh standard working solutions of various concentrations i.e., 0.12, 0.24, 0.48, 0.96, and 1.92 ppm were prepared from (8 ppm) stock in ultra-pure water containing all

20 organochlorine pesticides. For calibration, calibration plots were used for quantitative analysis of organochlorine pesticides in water samples.

4.2.4 GC/ ECD Conditions

All chromatographic analysis of chlorinated pesticides were carried out on an Agilent gas chromatograph (6890 N series, Agilent Technologies, Palo Alto, CA, USA) equipped with ECD (electron capture detector). A GC capillary column of Elite-CLP (30 m × 0.25 mm ID., 0.25um df thickness, was used for method development and sample analysis. For GC/ECD, nitrogen was used as carrier gas at a rate of 1.2 mL/ min. A 1µL aliquot of the sample extract was injected in splitless mode by an autosampler. The operating GC conditions for the analysis of organochlorine pesticides in water samples were as shown in Table 2.

Table 2. Instrument setting for analysis of 20 organochlorine pesticides with GC-ECD

Aspect	Setting	Aspect	Setting
Injection temperature	250°C	Flow rate	1.2 ml min^{-1} (99.99% purified nitrogen gas)
Detector	temperature	250°C	Make up flow 25 mL
Injection volume	1µL	Oven program	Initial 90°C to 170°C (ramped with 3.5°C min^{-1}), then up to 280°C (ramped with 5°C min^{-1}). Total runtime is 31 min.

4.3 Water Sample Analysis

Organochlorine Pesticides - OCPs (Persistent Organic Pollutants - POPs) content of water samples were analyzed at the Water Quality Laboratory of Forest Research Institute (FRI), Yezin. Twenty types of organochlorine pesticide residues in surface water samples from Inlay Lake were identified using solid phase micro-extraction (SPME), in combination with gas chromatograph (GC) with electron capture detection (ECD).

4.4 Data Analysis

The tested results were analysed in excel. The OCPs organic pollutants levels of the collected water samples were compared with the World Health Organization maximum residue limit for pesticides in water (WHO MRLs) and the United States Environmental Protection Agency (U.S. EPA) maximum permissible level.

5. Results and Discussion

The concentration of OCPs residues in all water samples collected from the sampling point C7 - lake entrance stream, B3 and A3 – open lake area, C1 and C8- restaurant, C3and C10 – village, C9- weaving factory, B1and A1 – floating garden are discussed below.

5.1 Alpha-hexachlorocyclohexane (α-BHC)

The World Health Organization maximum residue limit for pesticides in water (WHO MRLs) and the United States Environmental Protection Agency (U.S. EPA) maximum permissible level do not specify a standard concentration for α –BHC. Alpha-hexachlorocyclohexane (α-BHC) was not detected in all water samples collected from 10 locations of Inlay Lake. It can have negative consequences for liver, fetotoxic and reproductive effects, tumors in animals.

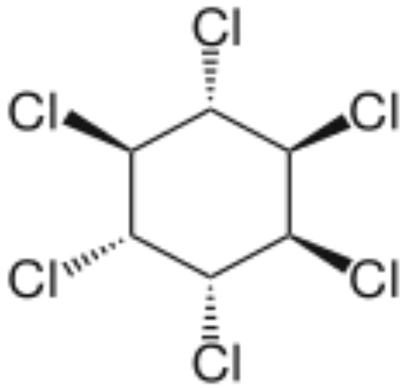

Figure 2. Structure of Alpha-hexachlorocyclohexane (α –BHC) (Willett *et al.*, 1998)

5.2 Gamma-hexachlorocyclohexane (γ-BHC - Lindane)

γ- BHC - Lindane Orgaochlorine Pesticide residue was not detected in all water samples of Inlay Lake.The proposed World Health Organization maximum residue limit (WHO MRLs) for γ-BHC – lindane in water is 2ug/l. The U.S. EPA's maximum permissible level for γ-BHC is 0.2ug/l. Exposure to large amount of lindane have been reported to have negative effects on the nervous system with symptoms from headaches and dizziness to convulsions and more rarely, death (Leena *et al.* 2012).

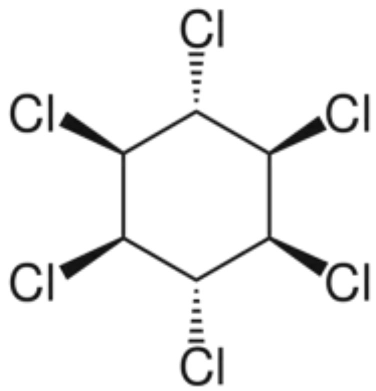

Figure 3. Structure of γ- BHC – Lindane (Ughy *et al.*, 2015

5.3 Beta-hexachlorocyclohexane (β-BHC)

WHO and U.S. EPA have not proposed a maximum acceptable concentration level for β-BHC. It was found that beta-hexachlorocyclohexane (β-BHC) residue was not detected in all water samples of Inlay Lake. β-BHC has advert health effects such as carcinogenicity. It is persistent in environment, bioaccumulation and carcinogenic potential.

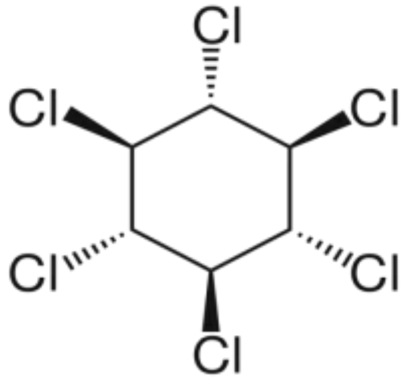

Figure 4. Structure of beta hexachlorocyclohexane (β-BHC) (Cruz-González *et al.*, 2017)

5.4 Delta-hexachlorocyclohexane (δ–BHC)

There is no standard for δ–BHC in the WHO MRL setting and U.S. EPA's statement of maximum acceptable concentration. There was no detection of δ–BHC pesticide residues in all water samples collected from 10 sampling points of Inlay Lake.

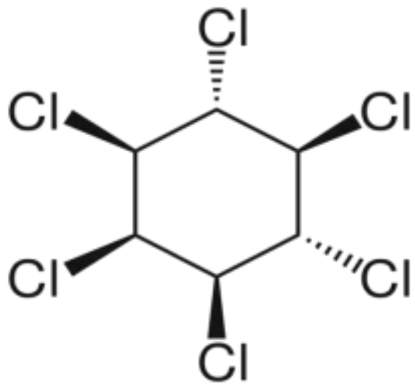

Figure 5. Structure of Delta-hexachlorocyclo hexane (δ–BHC) (Košková *et al.*, 2022)

5.5 Heptachlor

Heptachlor has long residual effect and bioaccumulate in the environment for long periods without losing their toxicity. For heptachlor, the US EPA's maximum acceptable concentration is 0.4 ug/l and the WHO MRLs for heptachlor is 0.03 ug/l. According to the analysis results, heptachlor pesticide residue was not detected in the water samples collected from Inlay Lake areas.

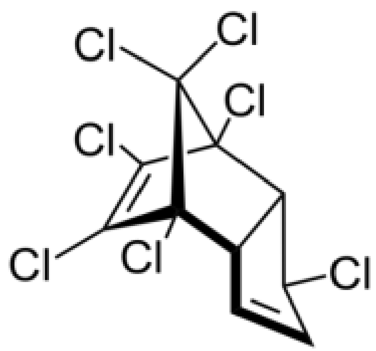

Figure 6. Structure of Heptachlor (Xiao *et al.* 2011)

5.6 Aldrin

Dieldrin is an epoxide of aldrin. Long-term expoure to aldrin can cause carcinogenicity, hazard to wildlife, bioaccumulation and chronic effects. All water samples collected from all sampling sites of Inlay Lake was found to be lack of Aldrin residue. There is no U.S. EPA standard limit for aldrin pesticide. However, the proposed WHO MRLs for aldrin in water is 0.03ug/l.

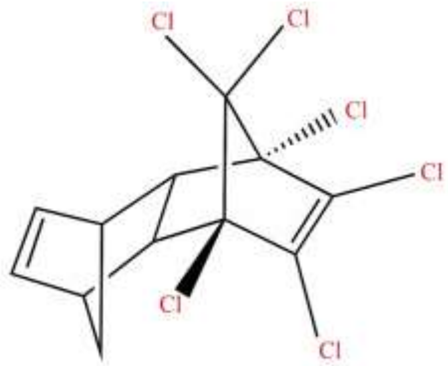

Figure 7. Structure of Aldrin (Kumar *et al.*, 2025)

5.7 Heptachlor epoxide

WHO MRLs for heptachlor epoxide in water is 0.03 ug/l and U.S.EPA's the maximum acceptable concentration for heptachlor epoxide is 0.2 ug/l respectively. In accordance with the results, all water samples collected from 10 locations of Inlay Lake were free of heptachlor epoxide pesticide residue. Heptachlor epoxide is created when a substance called heptachlor is released to the environment and mixes with oxygen. Like heptachlor, it has negative effects on human and the environment.

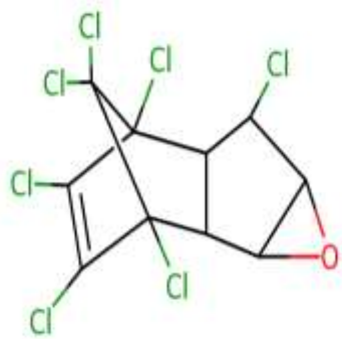

Figure 8. Structure of Heptachlor epoxide (Xiao *et al.* 2011)

5.8 Trans-Chlordane

For trans-chlordane, World Health Organization maximum residue limit for pesticides in water is 0.2 ug/l and the United States Environmental Protection Agency has set a maximum acceptable limit of 2 ug/l. According to the results, trans-chlordane pesticide residue was not detected in the water samples collected from C7 (lake entrance), A1 (floating garde), B3 (open lake area), and C10 (within Ywar Ma Village). The other sampling points, B1 (floating garde), B3 (open lake area), C3 (village), C1 and C8 (restaunts) and C9 (weaving factory area) were found to detect the trans-chlordane pesticide residue. It was in a condition that exceeds the WHO and US.EPA standard values. It was also found that the trans-chlordane content of floating garde (B1) was higher than that of samples collected from other areas. The high occurrence of trans-chlordane in the water samples suggests the continual usage of the illegal pesticide by floating garde in the Inlay Lake area. It may also be attributed to previous contamination as well as environmental persistence from past usage of the chlordane. Trans-chlordane is a different geometric isomer of the pesticide chlordane, meaning it has the same chemical formula but different spatial arrangement of its atom, with "trans" indicating they are on opposite sides; Trans-chlordane is considered major component of technical chlordane mixtures. It can cause nausea, vomiting, diarrhea, headache and abdominal paint. Like heptachlor, it has long residual effect, carcinogenicity and hazard to living organism.

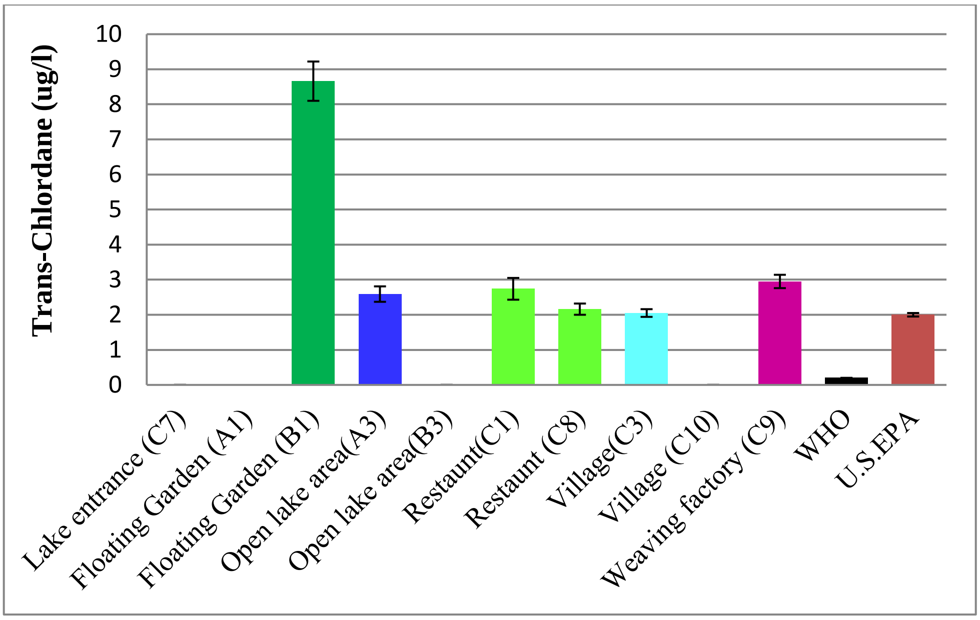

Figure 9. Trans-Chlordane content in Inlay Lake

5.9 Cis-Chlordane

The maximum acceptable cis-chlordane concentration level set by U.S.EPA is 2 ug/l. The WHO MRL standard value for cis-chlordane is 0.2 ug/l. Cis-chlordane pesticide residue.was not detected in water samples. Cis-chlordane is a isomer of chlordane, with "cis" indicating that certain functional groups are on the same side of a molecule. It is a major component of technical chlordane mixtures. Like chlordane. It has long residual effect, carcinogenicity and hazard to living organism.

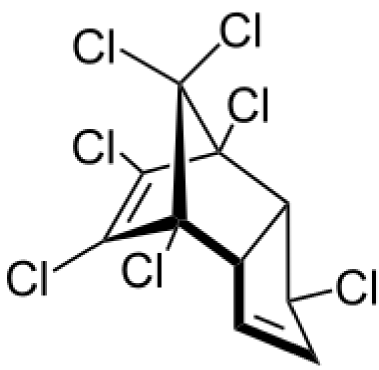

Figure 10. Structure of Cis-Chlordane (Waisner *et al.*, 2011)

5.10 Endosulfan I

Endosulfan I, an isomer of the parent chemical endosulfan, was detected in the water samples of floating garde (B1), and weaving factory (9), which was higher than the WHO MRLs of 0.01 µg/l for drinking water. Endosulfan I pesticide residue was not detected in the remaining areas. It was also found that the concentration level of endosulfan I in the floating garden area (B1) was higher than that of the weaving factory area (C9). The occurrence of endosulfan I in the water samples most likely reflects the current or previous use of the pesticide. The use of endosulfan I and endosulfan II were banned in Myanmar (in 2006), farmers may still have access that pesticide. Endosulfan I is the isomers of the pesticide endosulfan, pose significant health hazards primarily affecting the nervous system, causing symptoms like tremors, convulsions, hyperactivity, and even death upon acute exposure through inhalation, ingestion, or skin contact; long-term exposure can lead to potential damage to the liver, kidneys, and reproductive system, with concerns regarding developmental neurotoxicity and potential links to cancer in some studies. It has long residual action, bioaccumulation in fatty tissues, volatile and persists in the environment for long periods. It can therefore be concluded that water pollution due to endosulfan poses a threat to consumers in the Inlay Lake area.

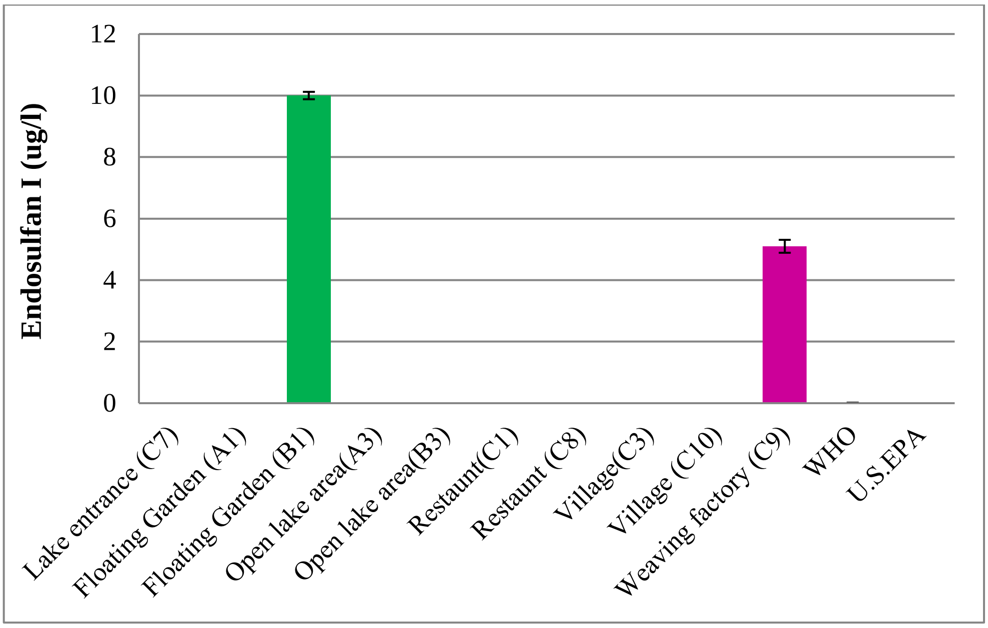

Figure 11. Endosulfan I content in Inlay Lake

5.11 4,4'-Dichlorodiphenyldichloroethylene(4,4'-DDE)

4,4'-Dichlorodiphenyldichloroethylene(4,4'-DDE) is the breakdown product of DDT. Like DDT, long-term DDE exposure may be associated with adverse health outcomes such as breast cancer, diabetes, birth defects, infertility, decreased semen quality, spontaneous abortion, and impaired neurodevelopment in children. WHO and U.S.EPA did not specify the standard amoun for 4,4'-DDE. All water samples collected from the Inlay Lake area were found to be free of 4,4'-DDE pesticide residues. DDE is more stable than DDT and decomposes more slowly by micro-organisms, heat and ultraviolet rays (EsmailiSari, 2002).

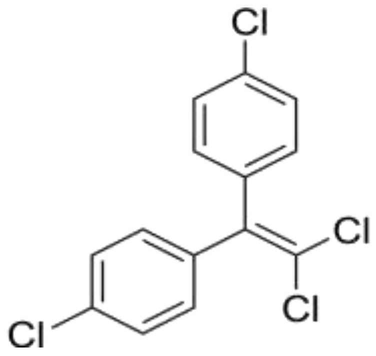

Figure 12. Structure of 4,4'-DDE (Aislabie, *et al.*, 2000)

5.12 Dieldrin

WHO MRL for dieldrin in water is 0.03 ug/l. U.S.EPA has not set a maximum acceptable limit for dieldrin. Dieldrin was detected in the water sample collected from floating garden (A1), which was higher than the WHO MRL of 0.03 µg/l for drinking water. It was not detected in the water samples collected from the remaining sampling locations of the Inlay Lake. The presence of dieldrin in the water samples suggests the degradation of aldrin to dieldrin in the environment as aldrin was not detected in all water samples of Inlay Lake. However, current or direct application and bioaccumulation of dieldrin as an insecticide cannot be entirely ignored. Long-term exposure to dieldrin has been reported to have adverse effects such as carcinogenicity, bioaccumulation, and hazard to wildlife, other chronic effect and long residual effect.

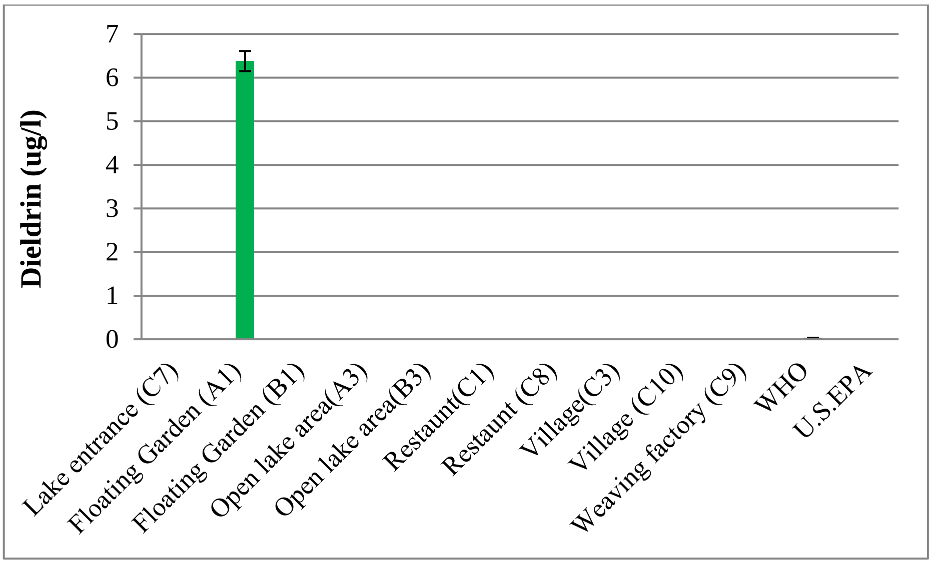

Figure 13. Dieldrin content of in Inlay Lake

5.13 Endrin

The U.S.EPA maximum acceptable concentration level for endrin is 2 ug/l and WHO MRL for endrin is 0.03 ug/l. Accordig to the laboratory findings, all water sampling sites contained the endrin pesticide residues, which were exceedingly higher than the U.S. EPA maximum acceptable concentration level. In addition, the concentration of endrin in the garden and weaving factory areas was found to be higher than other areas. Due to highly persistent and toxicity, the use of endrin was banned in Myanmar. However, there are evidence of their continuous usage in some developing countries, due to their efficacy and low cost and possibly due to weak import control and lack of logistics to monitor pesticides (Darko and Acquaah 2007; Asiedu

2013). In addition, the presence of enldrin could be attributed to the current or previous use of endrin as insecticide. Endrin has been implicated in a wide range of adverse effects such as oncogenecity, teratogenecity, reduction in endangered and non-target species and long residual effects.

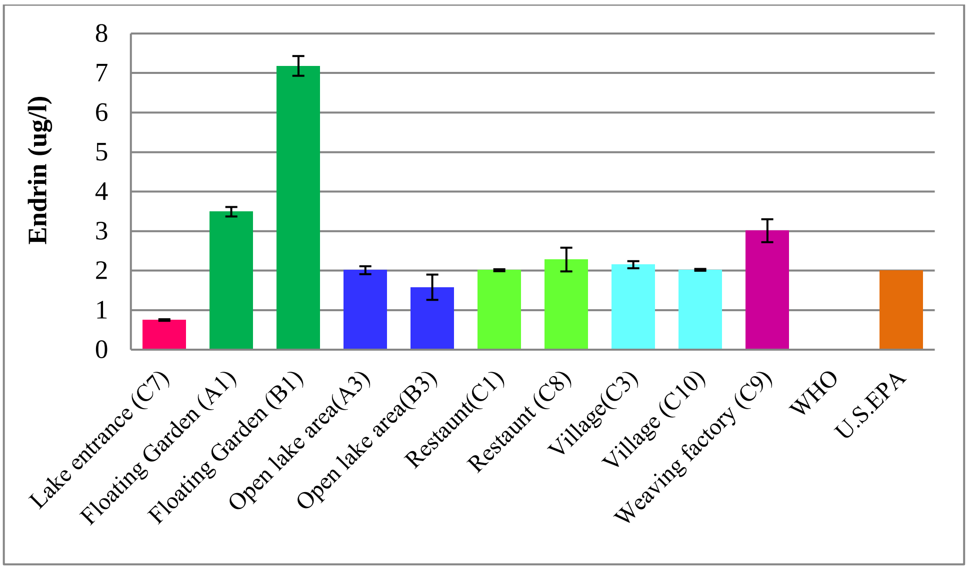

Figure 14. Endrin content in Inlay Lake

5.14 4,4'-Dichlorodiphenyldichloroethane (4,4'-DDD)

Dichlorodiphenyldichloroethane (DDD) is degradation product of DDT. The water quality standard limit for 4,4'-DDD pesticide residues set by WHO MRL is 2 ug/l, which is not listed as a maximum acceptable concentration level by the U.S.EPA. According to the results, the water sampling sites floating garden (A1) and weaving factory (C9) were detected 4,4'-DDD which were higher than WHO MRL of 0.01 μg/l for drinking water. The rest of the water sampling sites, did not detect the mentioned organochlorine pesticide residue. It was also found that the 4,4'-DDD residue content in floating garden areas was higher than the rest. The presence of DDD in the water sample may also be as a result of previous contamination, as they degrade slowly and very persistent and bioaccumulate in the environment. Long-term exposure to DDD can cause adverse health effects as DDT.

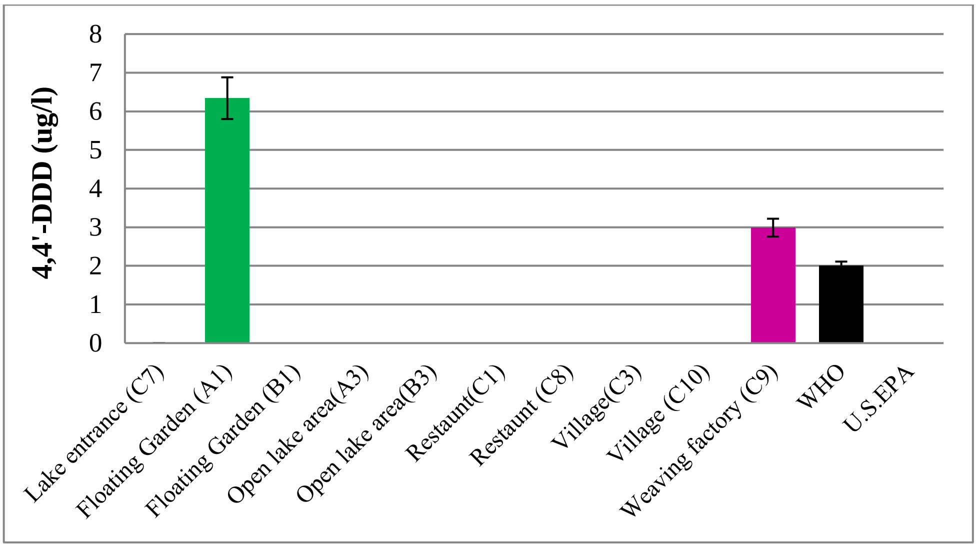

Figure 15 4,4'-DDD content in Inlay Lake

5.15 Endosulfan II

Like Endosulfan I, Endosulfan II is an isomer of the parent chemical endosulfan. The U.S.EPA water quality standards do not specify the levels of Endosulfan II pesticide residue. World Health Organization maximum residue limit for Endosulfan II pesticides in water is 0.01 µg/l. It was detected in the water samples of floating garde (B1), and weaving factory (9), which was higher than WHO MRL of 0.01 µg/l for drinking water. The rest of the water sampling sites did not detect the mentioned organochlorine pesticide residue. The presence of Endosulfan II in the water could be attributed to the current or previous use of that chemical as insecticide. Endosulfan II can cause many of the same hazard health effects as Endosulfan I. It has long residual action, bioaccumulation in fatty tissues, volatile and persists in the environment for long periods without losing their toxicity.

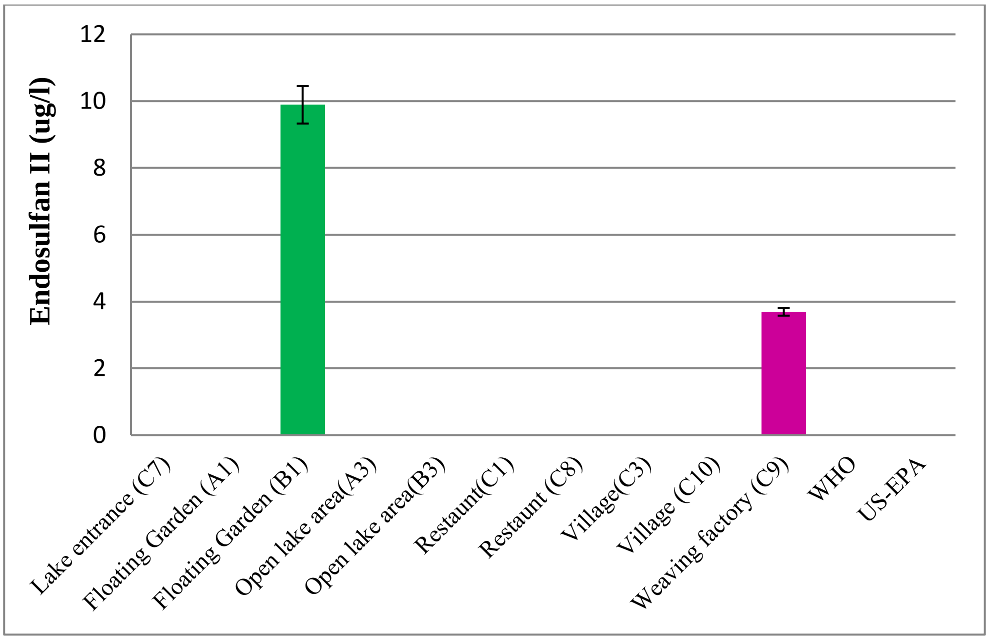

Figure 16. Endosulfan II content in Inlay Lake

5.16 Endrin aldehyde

Endrin aldehyde is a breakdown product of the endrin. U.S.EPA's maximum acceptable concentration level and WHO MRL water quality standards do not mention the amount of Endrin aldehyde pesticide residue. According to the results, the floating gardens (A1 and B1), village (C3) and weaving factory (C9) areas contain endrin ketone residue, while the remaining areas were not detected the mentaioned residuce. It was also found that the endrin ketone residue content of the floating garden (B1) was significantly higher than the other areas. Since endrin aldehyde is a breakdown product of the endrin, it may have similar adverse effects on organisms and the environment as endrin.

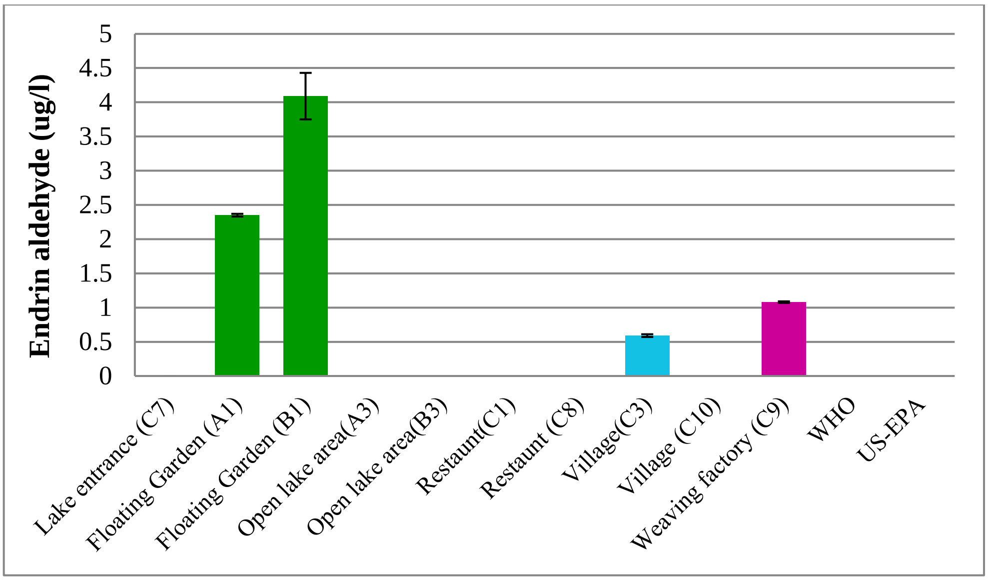

Figure 17. Endrin aldehyde content in Inlay Lake

5.17 4,4'-Dichlorodiphenyltrichloroethane (4,4'-DDT)

4,4'-DDT, an isomer of DDT, was detected in the water samples collected from the floating garden (A1) and weaving factory (C9), while the remaining water sample collection sites did not detect the mentioned pesticide residue. The WHO MRL for 4,4'-DDT in water is 2ug/l. There is no U.S.EPA standard limit for 4,4'-DDT pesticide residues. 4,4'-DDT contents of these sampling points were higher than the specified standard values. The presence of 4,4'-DDT in the water samples may be current usage of pesticides which might contain DDT by farmers in the study area. Moreover, it might also be as a result of previous contamination, as they degrade slowly and persist in the environment for a long time. DDT (dichlorodiphenyl trichloroethane) is a man-made chemical that does not occur naturally in the environment. DDT is banned worldwide owing to its negative health effects. Long-term exposure to DDT is linked to birth defects, infertility, breast cancer, diabetes, decreased semen quality, spontaneous abortion, and impaired neurodevelopment in children. Exposure to DDT and its metabolites is related to neurobehavioral disorders (Frazier, 2007), elevated risk of male genital abnormalities (Acerini and Hughes, 2006), and breast cancer (Sultan *et al.*, 2023) in human beings.

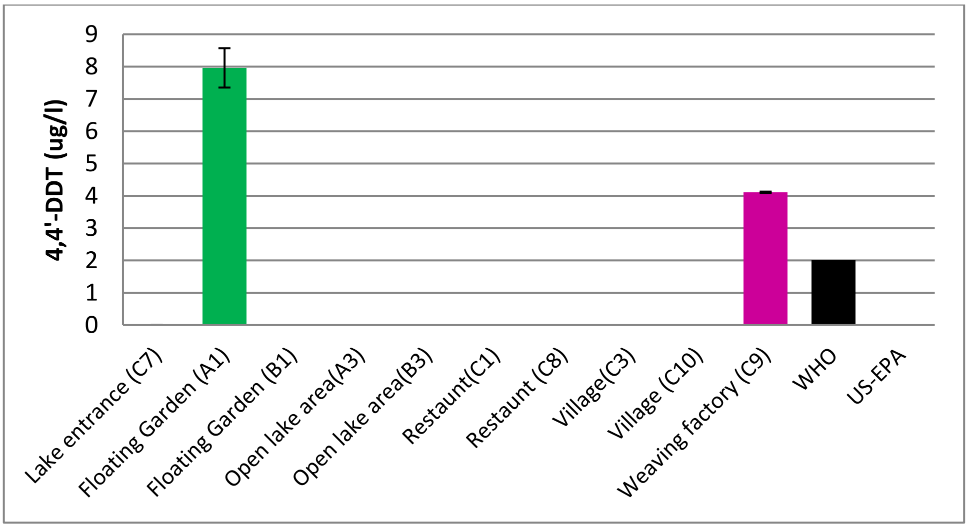

Figure 18. 4,4'-DDT content in Inlay Lake

5.18 Endosulfan sulphate

Endosulfan sulfate, a metabolite of endosulfan, was detected in water samples from the floating garden (A1 and B1) and weaving factory (C9) points and which were all above the WHO MRLs of 0.01 µg/l for endosulfan-sulfate in drinking water. The U.S.EPA has not specified standard levels for Endosulfan sulphate pesticide residue. It was not detected in the rest of water sample collection sites. The high occurrence of endosulfan sulfate in the water samples suggests the continual usage of illegal pesticide in the study area. It may also be attributed to previous contamination as well as environmental persistence from past usage of the chemical. The occurrence of endosulfan sulphate in the water samples most likely reflects the current use of the pesticide. The use of endosulfan I was banned in Myanmar (in 2006), farmers may still have access that pesticide. As endosulfan sulfate is a metabolite of endosulfan, it may have adverse health effects such as endocrine disruptions, reproductive and developmental damage in animals and humans, like endosulfan.

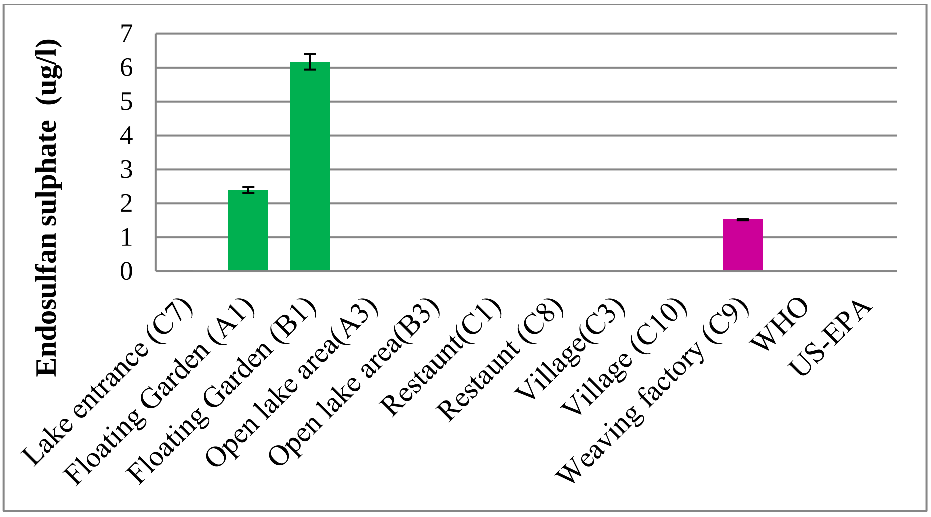

Figure 19. Endosulfan sulphate content in Inlay Lake

5.19 Methoxychlor

The World Health Organization's standard limit for methoxychlor is 20 ug/l and United States Environmental Protection Agency does not set a maximum acceptable level for Methoxychlor. According to the result, it was found that Methoxychlor pesticide residue was not detected in all the water sampling locations of Inlay Lake. Methoxychlor, a pesticide, is primarily concerning due to its potential to disrupt the endocrine system, causing reproductive effects in both males and females, including reduced fertility, abnormal reproductive development, and altered hormone balance; other adverse effects may include liver and kidney damage, neurological issues like tremors and convulsions, and potential skin irritation with high exposure levels.

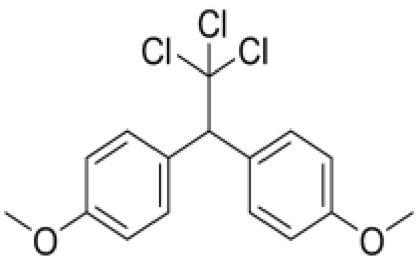

Figure 20. Structure of 4,4'-DDE (Aislabie, *et al.*, 2000)

5.20 Endrin ketone

There is no WHO and U.S.EPA standard limits for Endrin ketone pesticide residue. According to the laboratory finding, the water sample collected from A1 (near Inn Oo village), A3 (Inn entrance/Nam Lat Stream entrance), B1 (the middle of the lake), B3 (near the camp in the middle of the lake and Inpawgoun Village near Khitsanyin weaving factory) did not contain Endrin ketone pesticide residue. Endrin ketone, a breakdown product of the pesticide endrin, can cause a range of adverse effects in humans, primarily impacting the central nervous system, including symptoms like headaches, dizziness, nervousness, confusion, nausea, vomiting, and convulsions, potentially leading to seizures and even death in cases of high exposure; due to its neurotoxic nature, long-term exposure may also affect concentration, memory, and muscle coordination.

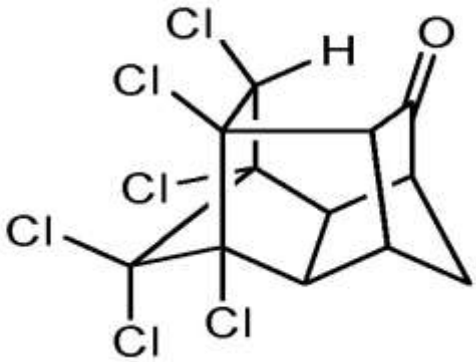

Figure 21. Structure of Endrin ketone (Purnomo, 2017)

6. Conclusions

Trans-chlordane pesticide residues were detected at the sampling sites of C7 (lake entrance), B1 (floating garden), A3 (open lake area), C1 and C8 (Restaurants) and C3 (village). Moreover, all the water sampling sites in the Inlay Lake were found to contain endrin pesticide residue, which were all above the WHO MRLs and U.S.EPA standard limits. Floating garden (A1) contained dieldrin, endrin aldehyde, dichlorodiphenyldichloroethane (4,4'-DDD) dichlorodiphenyl trichloroethane (4,4'-DDT) and endosulfan sulphate pesticide residues, while floating garden (B1) also contained residues of endosulfan I, endosulfan II, endrin aldehyde and endosulfan sulphate, which were exceeding the standard limits. Similarly, the content of endosulfan I, endosulfan II, endrin aldehyde, 4,4'-DDD, 4,4'-DDT and endosulfan sulphate pesticide residues found near Khit SanYin weaving factory (C9). From water quality results, the concentration of pesticide residues at the lake entrance (C7) is significantly lower than in other areas inside the lake. whereas the levels of pesticide residues in floating gardens were higher than in other areas.

Kyaw (2014) pointed out that the farmers in Inlay Lake always afraid of the pest and disease infestation so that they always spray the pesticide, fungicide and hormone even no or minor infestation of the pest and disease. The excessive use of fertilizers and pesticides in floating gardens, which are the main agricultural activity in Inlay Lake, is considered to be the main reason for the high levels of pesticide residues in the lake water. The presence of organochlorine pesticide residues in the Inlay Lake areas may be attributed to the current illegal use or historic use of the pesticides in the study area since organochlorine pesticides are prohibited from agricultural use in Myanmar. In addition, organochlorine pesticide residues content in all sampling areas could be due to drift during pesticide application, direct overspray, direct spillage, pesticides misuse, improper disposal of left over spray solution, sprayer wash water and pesticide containers, runoff from treated areas, many other factors.

The high levels of pesticide residues in the lake water can be due to reasons such as uncontrolled manual spray, poor management in the process of pesticides using in the floating gardens, low knowledge about the application of pesticides and unnecessary and inappropriate application of pesticides. According to the results, pesticide residues were found more than the WHO MRL standard value and U.S.EPA maximum permissible levels at all sampling points in the lake. Many OCPs and their metabolites are highly toxic and have been implicated in a wide range of adverse health effects such as cancer, neurological damage, reproductive system deformities, birth defect, and damage to the immune system (Ahlborg *et al.* 1995; Sosan *et al.* 2008; Leena *et al.* 2012), hence their presence is of serious concern. It can therefore be concluded that water pollution due to high concentration of OCPs poses a threat to local people and aquatic lives in the study area. The immediate attention should also be paid on the management of floating gardens if the open lake area and water quality are to be preserved. Government and relevant organization should address pesticide importers and users with effective laws on the import and use of banned pesticide because some farmers in Inlay Lake thought that this banned pesticide was more efficient than other.

Moreover, trainings and education program on proper use of pesticide chemicals, such as avoiding repeatedly spraying pesticide, using only the recommended amount of pesticide, avoiding the use of banned pesticides and incorrect mixing of pesticides would be the important for the decreasing concentration of pesticide residues in the Lake. Good Agricultural Practices (GAP), Integrated Pest Management (IPM) and the natural combating means for agricultural pests can be effective in decreasing the concentration of pesticides in aquatic resources and environment. The continuous monitoring of pesticide residues in the Inlay basin is necessary for the prevention, control and reduction of environmental pollution in the future.

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