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Assessment of Toxic Organic Contaminants in Mekong River Basin of Myanmar

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Assessment of Toxic Organic Contaminants in Mekong River Basin of Myanmar

1. Introduction

Assessment of toxic organic contaminants in Mekong River Basin of Myanmar project (MLC toxic project) is a type of grant supported by the Mekong-Lanchg Copperation Special Fund 2020 of the People's Republic of China. The project period is from April 2021 to September 2023. The place where the project implemented is Myanmar, Easten Shan State, which is the Mekong River Basin region: It is the area of the Mekong River and the tributaries that flow into the Mekong River in Tacheleik District. The Mekong River originates in the People's Republic of China. It is a cross-border river flow through Myannmar, Laos, Thailand, Cambodia and Vietam. The Mekong River is the twelfth longest river in the world and the third longest river in Asia. It is 3050 miles long. The catchment area of the Mekong River is 307,000 square miles. It covers 9,266 square miles, which is 3% of the total watershed area in Myanmar. The Mekong River flows for about 82 miles along the border between Myamar and Laos, contributing about 2% of the Mekong's water input from Myanmar's tributaries. The livelihoods and socioeconomics of the millions of people in the countries of the Mekong region depend on the Mekong River. Today, the basin serves for a variety of water-related activities - watershed management, agriculture, fisheries, navigation and transport, hydropower development, tourism and recreation, which support the livelihood of more than 60 million people living in the basin. In addition, Myanmar's Mekong River basin is suffering from the environmental effects of increased population and intensive agricultural development. The community relies on the application of pesticides for the management of pests and diseases. So it can be suspected that the use of pesticides by local farmers will contribute to the input of pesticide residues in the waters of the Mekong River. Excessive use of chemical fertilizers and pesticides is occurring around the river basin, which impacts the ecology of the river system and has potentially serious human health consequences. The use large amounts of pesticides and herbicides in agriculture are particularly dangerous to life in rivers, streams and lakes, where toxic substances can build up over a period of time.

Moreover, Pesticides are divided into many classes, the most important being organochlorine pesticides (OCPs) and organophosphorus pesticides (OPPs). Organochlorines (OC) are a group of chlorinated compounds widely used as pesticides. These chemicals belong to the class of persistent organic pollutants (POPs) with high persistence in the environment. As a result of their toxicity and ability to bioaccumulate, they are a possible risk both to human health and the environment (Santhi et.al, 2012). Organophosphates (OP) are esters of phosphoric acid. The OP group of pesticides asserts its effects through irreversible inactivation of the enzyme acteylcholinesterase, which is essential for nerve function in humans, insects and many other animals. OP samples degrade rapidly by hydrolysis on exposure to light, air and soil, however small amounts are detected in food and drinking water.While organophosphate compounds are not stable in the environment and are not bio-concentrated (Karazafiris E et.al, 2011). The contamination of water due to extensive uses of pesticides for agricultural purposes a serious threat to the environment and human health. Contamination from OCPs is particularly significant, due to their persistence in the environment for a long time, and the high toxicity to aquatic life and human health. Contamination of water by pesticides may occur due to direct run off, careless disposal of empty containers, leaching, misuse, equipment washing, etc.(Sankararamakrishnan et.al., 2005). Along with the dangers for environmental and human health posed by their bioaccumulation and biomagnifying effects in the food chain, OCPs also produce

reproductive and carcinogenic impacts in animals and human beings (Di Bella et.al., 2006). 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. However in many developing countries they are still in use making the ban ineffective.

To assess the water quality status based on physical, chemical, heavy metals and persistence organic pollutant contents of Mekong River and its branches is the one of the main objectives of the MLC toxic project. This paper focuses on the presence of toxic organic contaminants, especially organochlorine pesticides (OCPs), that is also called the POPs and organophosphorus pesticides (OPPs) residuces in Mekong River and stream water samples. In the present study, we identify pescide residues of approximately 20 types of OCPs and 12 types of OPPs in surface water samples from Mekong River and its branches, through the use of solid phase micro-extraction (SPME), in combination with gas chromatograph (GC) with electron capture detection (ECD) and nitrogen-phosphorus etection (NPD). Some of these OCPs are banned and not produced in Myanmar, but are being used unofficially.The OCPs and OPPs organic pollutants tested results of the water samples were compared with the Mekong Member States' water quality standards for domestic use of water, for Protection of Human Health (WQGH), the World Health Organization (WHO) guideline values and the United States Environmental Protection Agency (U.S. EPA) maximum permissible level.

2. Literature review

Persistent Organic Pollutants -POPs is usually organochlorine pesticides (OCPs) residues that created by people. POPs are toxic substances, predominately human-made, that persist within the environment and accumulate within living organisms, including humans. Human exposure from POPs can lead to many health effects including increased cancer risk, reproductive disorders, alteration of the immune system, neurobehavioral impairment, endocrine disruption, genotoxicity and increased birth defects. POPs Pesticides (Organochlorine) can be classified into four categories: (i) dichlorodiphenylethanes (such as DDT, DDE), (ii) cyclodienes (such as dieldrin, endosulfan, and heptachlor) (iii) chlorinated benzenes (such as hexachlorobenzene), and (iv) cyclohexanes (such as hexachlorocyclohexane or lindane). The use of most organochlorine pesticides has been banned or severely restricted around the world, although endosulfan, is still widely used in some countries.

Pesticides can discharge into water bodies by direct application through spray drift, aerial spray, atmospheric fallout, soil erosion, runoff from agricultural areas, industrial discharge and domestic sewage. In water bodies, pesticides can affect water quality, sediment and ultimately threat non-target organisms that are connected to the food chain (Kaushik et al 2010). Almost all types of pesticides are poisonous of varying category and can be a source of pollution for aquatic resources and the environment. Some organochlorine pesticides are volatile or can adhere to soil or particles in the air. In aquatic systems, organochlorine pesticides are adsorbed into sediments in water that can then bioaccumulate in fish and other marine mammals. Because these chemicals are soluble in fat, they are found at higher concentrations in fatty foods. The main source of exposure to organochlorine pesticides is through eating fatty foods, such as milk, dairy products, or fish that are contaminated with these pesticides. It has lipophilic properties and can contain up to 70,000 times more of the original compound (biomagnification) in the fatty tissues. It is also possible to pass these pesticides through the placenta to the unborn child or by breastfeeding, or to absorb them through the skin. Organochlorine pesticides affect the nervous system and can harm the liver. Potential adverse effects include reproductive effects, endocrine disruption, and cancer. Organochlorine pesticides can build up in a person's body over time, but the health effects associated with low exposure are still

uncertain. Organochlorine pesticides have been linked to adverse reproductive effects in wildlife. Organochlorine pesticides can cause damage to the lungs, nervous system, liver, and kidneys, and may even cause death. It is thought to be a potential carcinogen in humans. Therefore, in 2001, the Soockholm Connvention of the United Nations banned the use of Organochlorine pesticides as Persistent Organic Pollutants - POPs. In Myanmar, a new pesticide law was enacted in 2006, which banned the use of 41 pesticides, including POPs, in cccordance with the Soockholm Connvention. POPs banned in Myannmar are Alpha-hexachlorocyclohexane (α-BHC), Gamma-hexachloro cyclohexane (γ-BHC (Lindane), Beta-hexachlorocyclohexane (β-BHC), Heptachlor, Aldrin, Trans-Chlordane, Cis-Chlordane, Endosulfan I, Dieldrin, Endrin, Endosulfan II, 4,4'-Dichlorodiphenyl trichloroethane (4,4'-DDT). the improper use and/or disposal of agrochemicals (agricultural Farms) industrial chemicals, elevated temperatures, and combustion processes (Chemical produced Industries) and unwanted byproducts of industrial processes or combustion (Wastes of Industries), POPs can be released into water and soil. Aldrin, chlordane, DDT (Dichlorodiphenyl trichloroethane), dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, polychlorinated biphenyls, polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans, toxaphene are highly persistent and toxic POPs.

The adverse effects of exposure to organophosphate pesticides can be categorized based on the duration of exposure, as mentioned below.

- Acute effects: Occur within minutes to 24 hours
- Subacute effects: Occur between 24 hours and 2 weeks
- Chronic effects: Extend beyond weeks to years

Exposure to these compounds can be harmful. Poisoning can come from these compounds after exposure to these compounds for the long term. The poisoning can cause nerve damage and disrupt hormone production in humans and animals. Exposure to certain organophosphates has been associated with a potential risk of cancer. According to a report from the International Agency for Research on Cancer, OPPs pesticides such as malathion, diazinon, tetrachlorvinphos, and parathion are categorized as possible carcinogens. More recent statistics and WHO data since 2008 show that, annually, 346,000 people die worldwide due to unintentional pesticide poisonings, two-thirds of them in developing countries (WHO: Geneva, Switzerland, 2008)

3. Objectives

Objectives of the present study are:

- To assess the water quality status based on physical, chemical, heavy metals and persistence organic pollutant contents of Mekong River and its branches
- To provide the water quality standards of Mekong River and its branches
- To strengthen the capacity building of staffs from Forest Research Institute especially in the areas of water quality monitoring.

4. Materials and Methods

4.1 Water Sampling

In December 2021, according to the recommendations from the project introduction and recommendation meeting held at the meeting hall of the Forest Department, Tacheleik Township,3 locations from the Mekong River and 12 streams flowing into the river were selected for water sampling. M-04 and M-16 water sampling sites are Mekong River, Golden Triangle Area: in front of Paradise Hotel and Mekong River from the Won Phong Port, M-11 water sample was also collected from the Mekong River near the Laos-Myanmar Friendship Bridge. On the Myanmar side of Mekong

River, water sampling site M-11 is the upstream area, M-04 is the middle site of the river and M-16 is the downstream area. M-01 water sample was collected from the Maesai stream near the Thai-Myanmar Friendship Bridge, No (1), M-03 and M-05 water sampling points are also Maesai stream, Golden Triangle Area: near Paradise Hotel and Nar Thar Leek Village. M-06 sampling point is from Maesai Nwet stream which is one of the tributaries, Tacheleik Township near Hay Way Village and M-07 sample was collected from Nant Lay stream, one of the tributaries, Mai Yu Township, on the other side of the Mai Yu Special Region 4. Nant Hmaung stream water sample M-08 was collected from Mai Yaung Township, Southeast of Mai Yaung, Htet Lon Padago and near floating market. The water sample of Mone Leik stream was M-09, which is one of the tributaries, near Mone Leik Bridge, on the road of Mai Yaung-Mai Phyet within 61-62 Km. M-10 Nant Linn stream water sample was collected from near Tar Lay Bridge under construction. The locations M-12 and M-13 are on the Mai Phyet-Keng Tung Border, Nant Lo stream, Yae Kyi stream and Nant Ma stream, Yae Noet stream, M-14 Nant Lay stream water sample was collected from the Tar Pone, North of the Keng Tung (13) miles, before reaching the resort. The sampling point M-15, Wun Tar Pone steram, which is one of the tributaries, North of the Keng Tung. The point M-17 is Mae Hope stream in Tarcheleik. The places where the water samples were collected and the map are described below.

Water sampling was conducted 9 times from 2021 December 20th to 29th, from 2022 Feburuary 21st to 25th, July 10th to 14th, October 27th to Novmember 5th, December 10th to 18th, Jauary 7th to 13th, from 2023 March 7th to 13th and Auguest 25th to 28th, respectically.

Sr.No	Sampling Points	Name	Description
1	M-11	Mekong River	Myanmar-Lao Border ,near Myanmar -Lao friendship Kyelet Bridge
2	M-16	Mekong River	Wunpon Port
3	M-04	Mekong River	Myanmat-Thai -Lao Border (Golden Triangle) in front of the Paradide Hotel
4	M-05	Maesai Stream	One of the tributaries, Tacheleik Township near Nar Thar Leek Village
5	M-01	Maesai Stream	Thai-Myanmar Border ,near Thai-Myanmar No (1) Bridge
6	M-03	Maesai Stream	Myanmat-Thai -Lao Border (Golden Triangle) in front of the Paradide Hotel
7	M-06	Maesai Nwet Stream	One of the tributaries , Tacheleik Township near Hay Way Village
8	M-07	Nant Lay Stream	One of the Tributary, Mai Yu Township, on the other side of Mai Yu Special Region 4
9	M-08	Nant Hmaung Stream	One of the tributaries , Mai Yaung Township,Southeast of Mai Yaung, Htet Lon Padago, near floating market
10	M-09	Mone Leik Stream	One of the tributaries , Near Mone Leik Bridge, on the road of Mai Yaung-Mai Phyet within 61-62 Km
11	M-10	Nant Linn Stream	One of the tributaries , Near Tar Lay Bridge under construction
12	M-12	Nant Lo Stream, Yae Kyi Stream	One of the tributaries , Mai Phyet - Keng Tung Border

13	M-13	Nant Ma Stream, Yae Noet Stream	One of the tributaries , Mai Phyet - Keng Tung Border
14	M-14	Nant Lay Stream	One of the tributaries , Tar Pone, North of the Keng Tung (13) miles, before reaching the resort
15	M-15	Wun Tar Pone Steram	One of the tributaries , Tar Pone, North of the Keng Tung
16	M-17	Mae Hoep Stream	One of the tributaries, Tarcheleik City

Table (1) Sampling points and general description

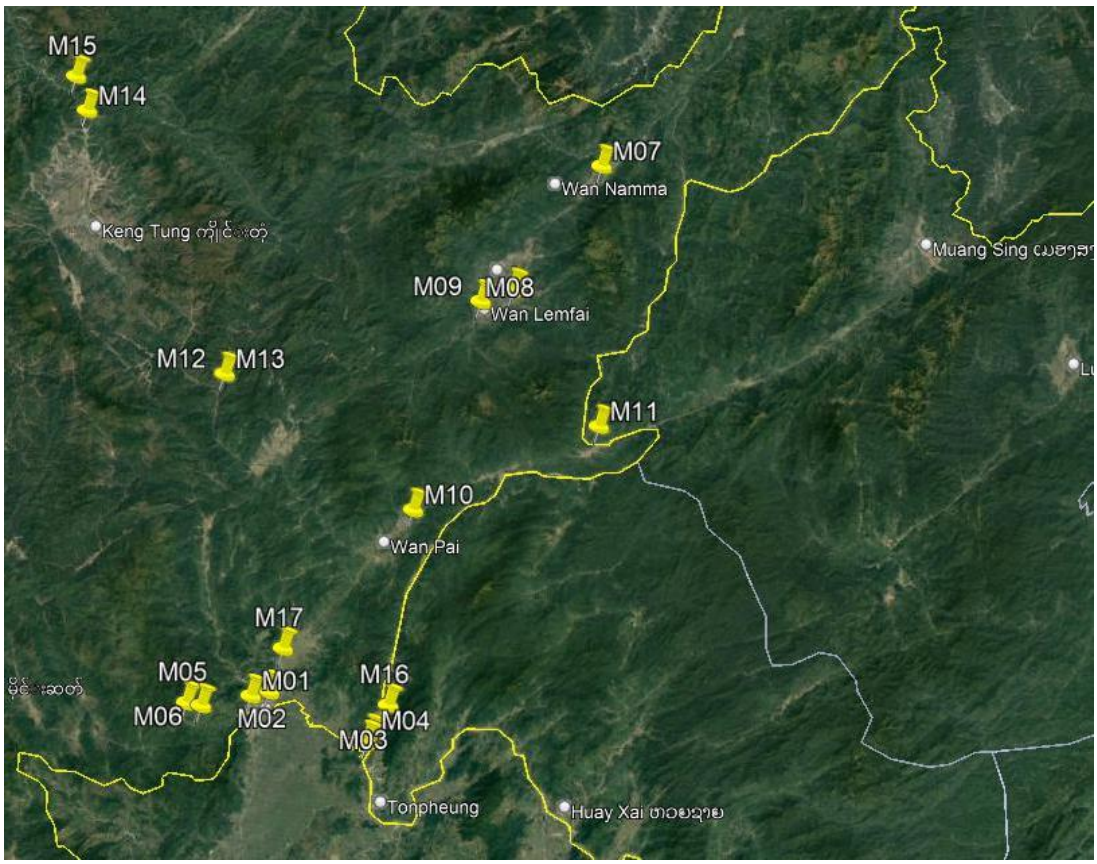

Figure (1) Map of the Sampling points

4.2. 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.

4.3. Standards and Reagents

The organochlorine and organophosphorus pesticide mixture (standards) with >99% purity and organic solvents, methanol, n-xexane, and acetone (HPLC grade) were purchased from NANOVA Co., Ltd. All the chemical reagents used were high-purity analytical grade reagents. All aqueous solutions were prepared in ultra-pure water. A Milli-Q water purification system (Millipore, Bedford, MA, USA) was used for ultra-pure water. High purity, (99.99% purity) Nitrogen gas, Air Zero gas and Hydrogen gas were used in the present study.

4.4. Solutions Preparation

Stock solution (8 ppm) containing each of the 20 organochlorine pesticides and stock solution (20 ppm) also involving 12 organophosphorus pesticides were prepared from 2000 ppm (1 ml) standard solution and 200 ppm (25 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 and fresh standard working solutions of various concentrations i.e., 0.01, 0.05, 0.1, 0.5 and 1 ppm were also prepared from (200 ppm) stock solution which contain 12 organophosphorus pesticides. For calibration, calibration plots were used for quantitative analysis of both pesticides in water samples.

4.5 GC/ ECD and NPD Conditions

All chromatographic analysis of chlorinated pesticides and phosphate pesticides were carried out on an Agilent gas chromatograph (6890 N series, Agilent Technologies, Palo Alto, CA, USA) equipped with ECD (electron capture detector) and NPD (Nitrogen phosphorus 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. For GC/NPD, air zero, nitrogen and hydrogen were used as carrier gas at a rate of 1.2 mL/ min. A 1μL aliquot of the sample extract or standard was injected in splitless mode by an autosampler. The operating GC conditions for the analysis of organochlorine and organophosphate pesticides in water samples were as follows:

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

Aspect	Setting	Aspect	Setting
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.
Injection temperature	250°C	Flow rate	1.5 ml min-1 (99.99% purified nitrogen gas)
Detector	temperature	250°C	Make up flow 25 mL

Table.3. Instrument setting for analysis of 12 organophosphorus pesticides with GC-NPD

Aspect	Setting	Aspect	Setting
Injection volume	1μL	Oven program	Initial 80°C to 290°C (ramped with 10°C min^{-1}), Hold time 10 min. Total runtime is 24 min.
Injection temperature	300°C	Flow rate	1.5 ml min-1 (99.99% purified nitrogen, hydrogen and air zero gases)
Detector	temperature	250°C	Make up flow 25 mL

4.6 Water Sample Analyses

Organochlorine Pesticides - OCPs (Persistent Organic Pollutants - POPs) and Organophosphorus Pesticides - OPPs content of water samples were analyzed at the Water Quality Laboratory of Forest Research Institute (FRI), Yezin. The OCPs and OPPs tested results of the water samples were compared with Mekong Member States' water quality standards for domestic use of water, for Protection of Human Health (WQGH), the World Health Organization (WHO) guideline values and the United States Environmental Protection Agency (U.S. EPA) maximum permissible level.

5. Results and Discussion

5.1 Organochlorine Pesticides - OCPs (Persistent Organic Pollutants - POPs)

The concentration of OCPs pesticide residues in all water samples collected from the Mekong River Basin is showe below.

5.1.1 Alpha-hexachlorocyclohexane (α-BHC)

In order to protect human health, the highest acceptable values of the Mekong Member States' water quality standards for domestic use of water states the total organochlorine pesticides as 50 ug/l, but the amout of α –BHC pesticide residuce is not specified separately. The World Health Organization (WHO) guideline values and the United States Environmental ProtectionAgency (U.S. EPA) maximum permissible level do not specify a standard level for α –BHC. According to the following graph, the amount of α –BHC content of M-01 (Maesai stream, Thai-Myanmar Border, near Thai-Myanmar No (1) Bridge) water sample is 152.34 ug/l and the amount of α –BHC residuce in the M-12 water sample (Nant Lo stream, Yae Kyi stream, one of the tributaries, Mai Phyet-Keng Tung Border) is 145.74 ug/l. In the analysis of Mekong River and other stream water samples, Gas Chromatography (GC) showed not detected (ND), and no indication of α-BHC pesticide residuce content was found. It is considered that such occurance may be due to their low application of pesticide in the mentioned places and the high hydrolysis rates of the pesticides used.

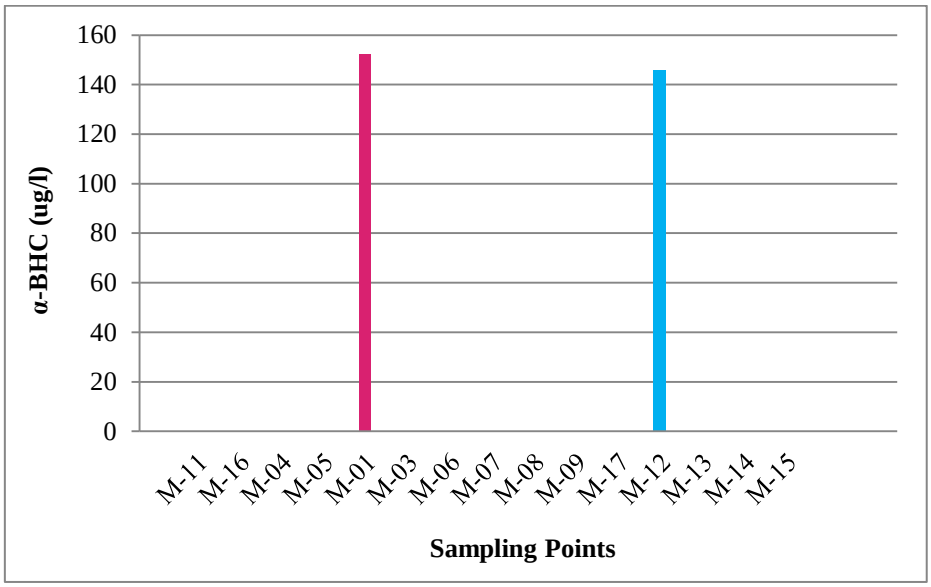

Fig (2) Comparison of α –BHC content of water samlpes

Mekong River Mae Sai stream Streams from Keng Tung Township Streams from Tacheleik Township

5.1.2 Gamma-hexachlorocyclohexane (γ-BHC - Lindane)

The proposed WHO Limit for γ-BHC - Lindane is 2ug/l. The U.S. EPA's maximum permissible level for γ-BHC is 0.2ug/l. All water samples collected from 3 locations of Mekong River and 12 streams flowing into that river were found to be free of γ- BHC - Lindane Orgaochlorine Pesticide (OCPs) residue.

5.1.3 Beta-hexachlorocyclohexane (β-BHC)

Mekong Member States' water quality standards for domestic use of water for protection of human health specifies the total organochlorine pesticide content as 50 ug/l. However, the concentration level for β-BHC pesticide residuces is not specified separately. The World Health Organization (WHO) and the United States Environmental Protection Agency (U.S. EPA) have not proposed a maximum acceptable concentration level for β-BHC. The concentration of β-BHC residue in the water samples of Mekong River M-11, Myanmar-Lao Border, near Myanmar-Lao Friendship Kyelet Bridge and M-04, Myanmar-Thai -Lao Border (Golden Triangle) in front of the Paradide Hotel, Maesai stream M-05, one of the tributaries, Tacheleik Township near Nar Thar Leek Village and M-01, Thai-Myanmar Border, near Thai-Myanmar No (1) Bridge and Maesai Nwet stream M-06, one of the tributaries, Tacheleik Township near Hay Way Village were extremely higher than the standards, and the analysis found that there was no β-BHC residue in the water samples from Mekong River M-16, Wunpon Port and the rest of the stream water samples.

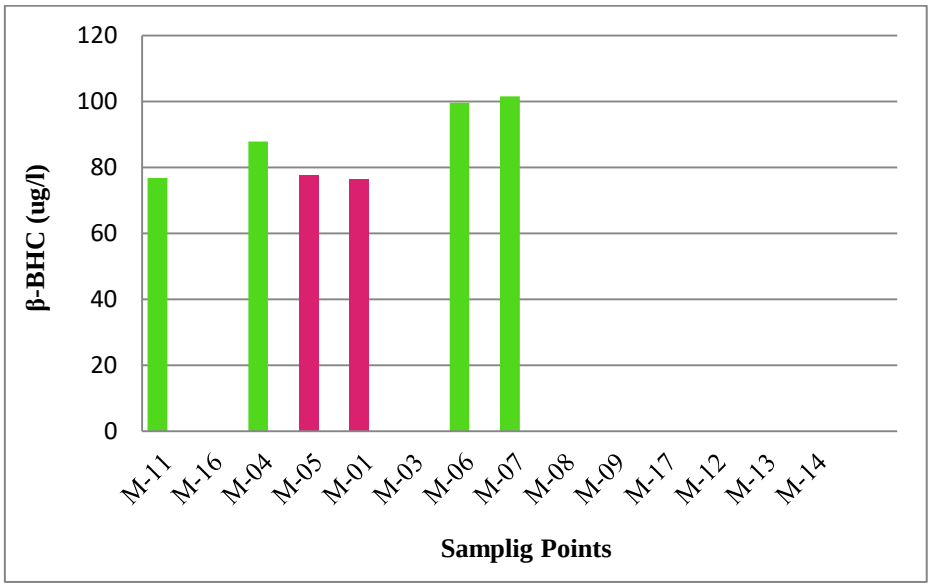

Fig (3) Comparison of β-BHC content of water samlpes

Mekong River Mae Sai stream Streams from Keng Tung Township Streams from Tacheleik Township

5.1.4 Delta-hexachlorocyclohexane (δ–BHC)

There is no standard for δ–BHC in the WHO setting and U.S. EPA's statement of maximum acceptable concentration. Although the highest acceptable values of the Member States' Water Quality Standards for domestic use of water, do not specify the concentration level of δ–BHC, it was found that the the total organochlorine pesticide concentration is stated as 50 ug/l. The concentration of δ–BHC pesticide residue of Mekong River, M-04 was 127.92. The δ–BHC pesticide residue level of water samples from Maesai Nwet stream M-06, and Nant Lay stream M-07 were 127.48 and 126.85 ug/l. All these concentration are higher than the Mekkong Member States' Water Quality Standards. The remaining 2 Mekong River sites and 11 stream water samples did not contain δ–BHC pesticide residue.

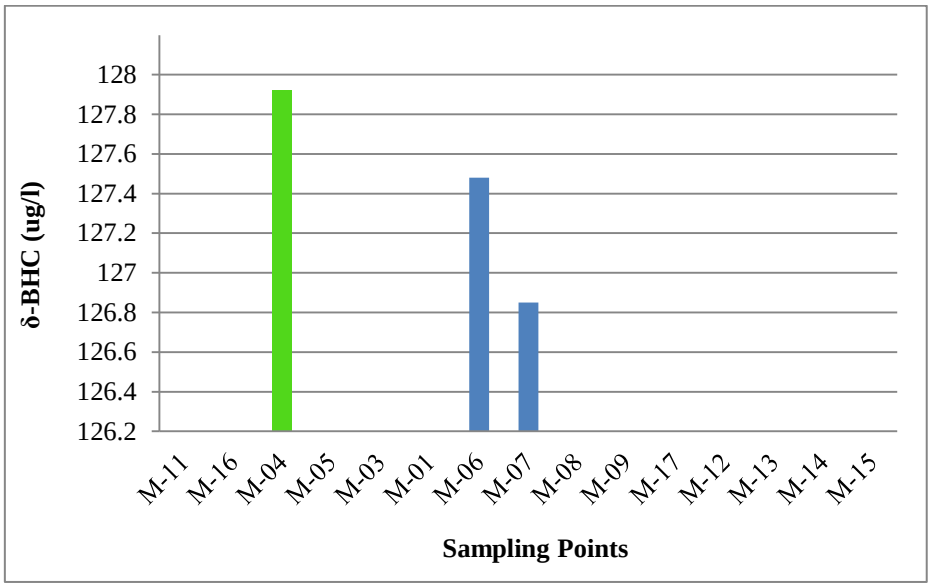

Fig (4) Comparison of δ–BHC content of water samlpes

5.1.5 Heptachlor

The World Health Organization standard for heptachlor is 0.03 ug/l and the United States Environmental Protection Agency's maximum acceptable concentration of heptachlor is 0.4 ug/l. Heptachlor pesticide residue content is not mentioned separately in the Member States' Water Quality Standards for domestic use of water for the protection of human health (WQGH), but total organochlorine pesticide content is 50 ug/l. The amount of heptachlor pesticide residue in the water sample from the downstream area of Mekong River M-04 was 80.05ug/l. The heptachlor pesticide residue content of the middle site of Maesai stream water sample was 74.99ug/l. The heptachlor content of M-06 Maesai Nwet stream and M-07 Nant Lay stream, water sampler were 75.27ug/l and 75.8ug/l respectively. According to the laboratory analysis, Heptachlor pesticide residue content of these water samples were above the WHO, U.S.EPA and Member States' Water Quality Standards. However, the remaining 2 Mekong River locations and 11 stream water samples were found to contain no heptachlor pesticide residue.

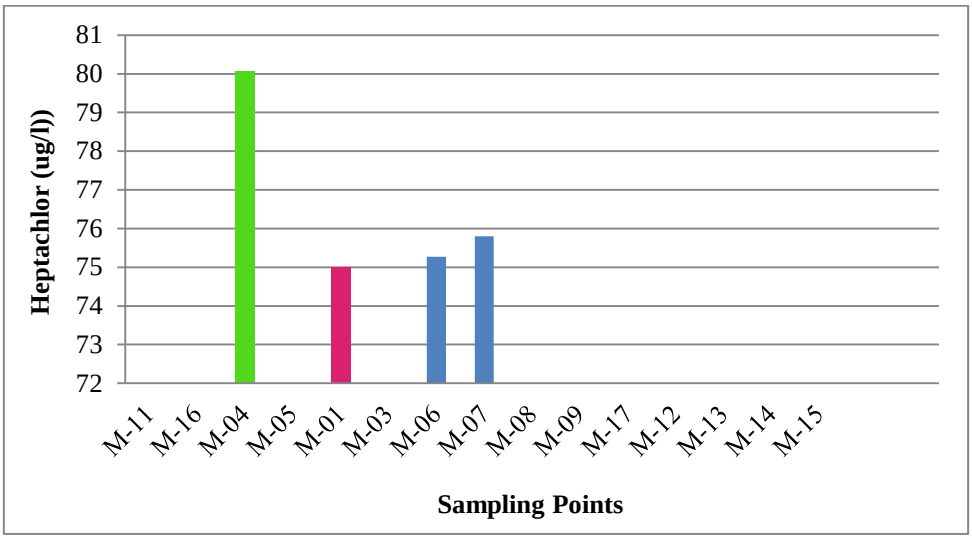

Fig (5) Comparison of heptachlor content of water samlpes

Mekong River | Mae Sai stream | Streams from Keng Tung Township | Streams from Tacheleik Township

5.1.6 Aldrin

The proposed WHO stamdard limit for aldrin is 0.03ug/l. There is no U.S. EPA standard limit for aldrin pesticide. Aldrin pesticide residue content is not mentioned separately in the Member States' Water Quality Standard for domestic use of water, but total organochlorine pesticide content is 50ug/l. Aldrin pesticide residue levels of all water sampling sites in the Mekong River Basin were above the WHO and Member States' Water Quality Standards. The aldrin residuce content of the upstream area M-11 and downstream area M-04 of Mekong River were higher than that of M-16 the middle site.

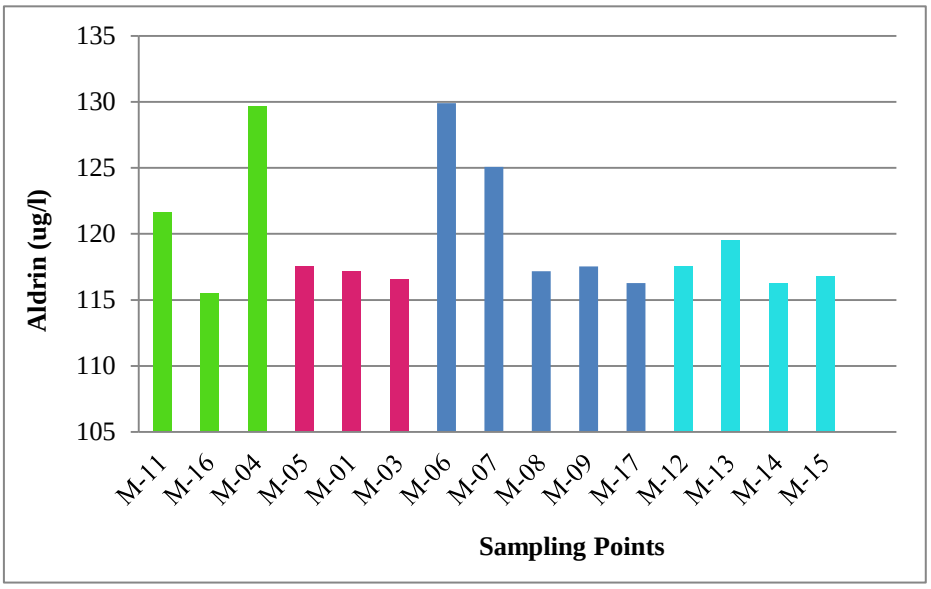

Fig (6) Comparison of aldrin content of water samlpes

Mekong River | Mae Sai stream | Streams from Keng Tung Township | Streams from Tacheleik Township

5.1.7 Heptachlor epoxide

WHO standard for heptachlor epoxide is 0.03ug/l and U.S.EPA's the maximum acceptable concentration for heptachlor is 0.2ug/l. Like other pesticide, heptachlor epoxide pesticide residue content is not mentioned separately in the Member States' Water Quality Standard for domestic use of water for protection of human health, but total organochlorine pesticide content is defined as 50ug/l. According to the laboratory finding, the heptachlor epoxide pesticide residue content of the 2 locations of Mekong River M-11 and M-04, Maesai stream M-05 and Nant Lay stream M-07 water samples were higher than the specified standards. However, it was found that there was no heptachlor epoxide in the Mekong River M-16 and the rest of the stream water samples. Heptachlor epoxide pesticide residue was not found in M-16 in the middle site of Mekong River.

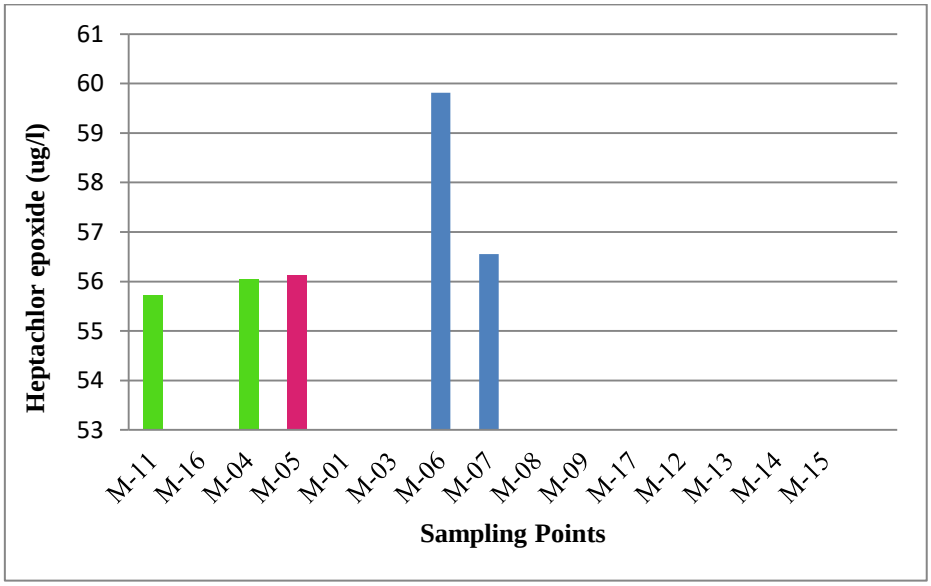

Fig (7) Comparison of heptachlor epoxide content of water samlpes

5.1.8 Trans-Chlordane

The total organochlorine pesticide content is set at 50ug/l in Member States' Water Quality Standard for domestic use of water. The presence of Trans-Chlordane alone is not specified. The World Health Organization standard limit for Trans-Chlordane is 0.2ug/l and the United States Environmental Protection Agency has set a maximum acceptable limit of 2ug/l. According to the results, the water sample of Maesai stream M-01did not contain Trans-Chlordane residue and the amount of Trans-Chlordane pesticide residue in the rest of the Mekong River and all streams was found to be much higher than the standard limits. It was found that the concentration of Trans-Chlordane pesticide residue in the downstream area of the Mekong River M-04 was lower than that of the upstream ares M-11 and the middle site M-16.

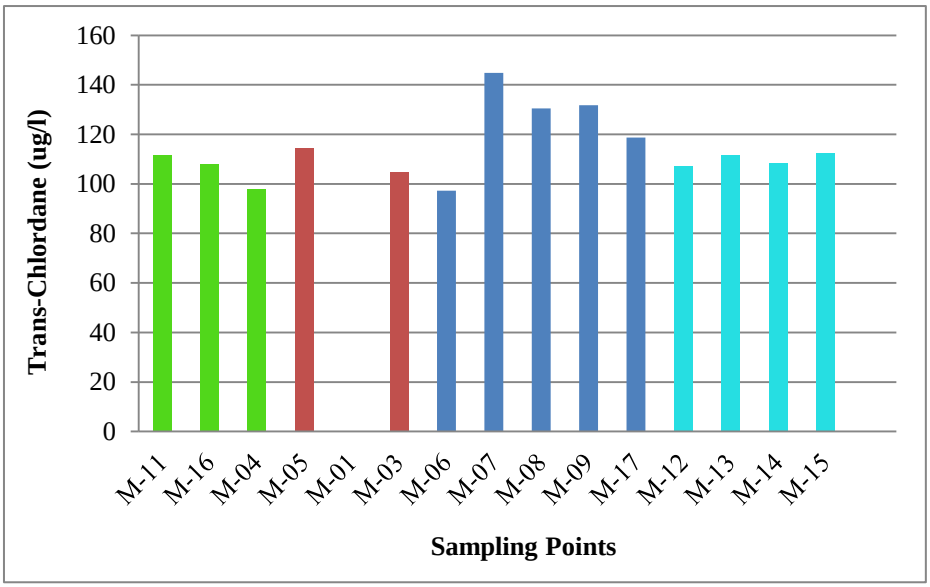

Fig (8) Comparison of Trans-Chlordane content of water samlpes

Mekong River | Mae Sai stream | Streams from Keng Tung Township | Streams from Tacheleik Township

5.1.9 Cis-Chlordane

The proposed Member States' Water Quality Standard for domestic use of water for protection of protection of human health for total organochlorine pesticide is 50ug/l. But the presence of Cis-Chlordane alone is not specified. The standard for Cis-Chlordane concentration by WHO is 0.2ug/l and the maximum acceptable concentration level set by U.S.EPA is 2 ug/l. Mekong River M-16, Nant Hmaung stream M-08, Mone Leik stream, M-09, Wun Tar Pone steram M-15 and Mai Hope stream M-17 water samples did not contain Cis-Chlordane residue. The content of Cis-Chlordane residue in the rest of the Mekong River and streams was found to be in high to extremely high condation above the mentioned standards. Moreover, it was found that there was no Cis-Chlordane residue in the Mekong River middle site M-16, but it was found to be much higher than the standard limits in the upstream M-11 and downstream M-04.

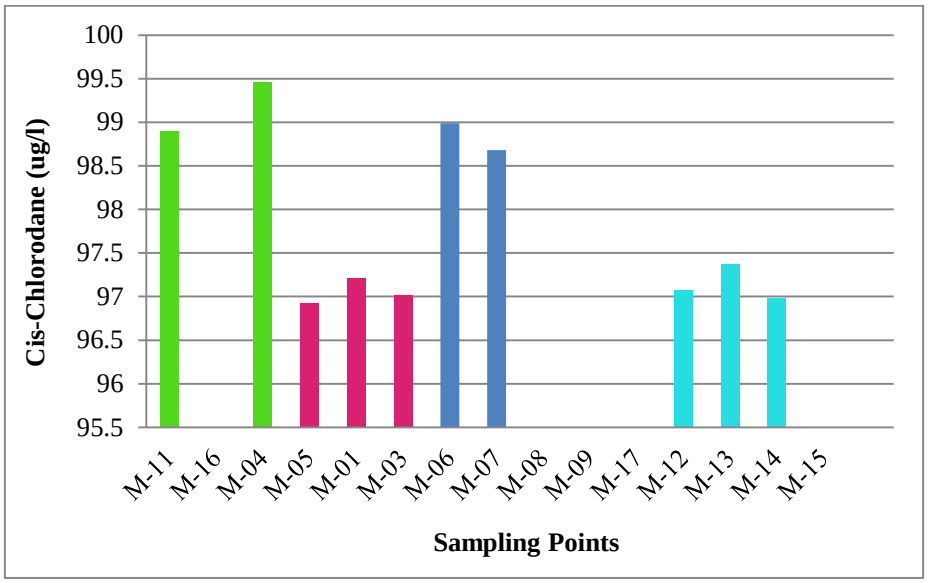

Fig (9) Comparison of Cis-Chlordane content of water samlpes

5.1.10 Endosulfan I

The Mekong Member States do not mention the content Endosulfan I pesticide residue, but the total organochlorine pesticide content is set at 50ug/l. For Endosulfan I, WHO and U.S.EPA did not specify the standard amount. Nant Lay stream M-14 water sample was found to contain no Endosulfan I residue, while the remaining 3 Mekong River sites and 12 streams contained Endosulfan I residue. It was found that the concentration of Endosulfan I in the downstream site of Mekong River M-04 was higher than that of the M-11 upstream and the M-16 the middle sites.

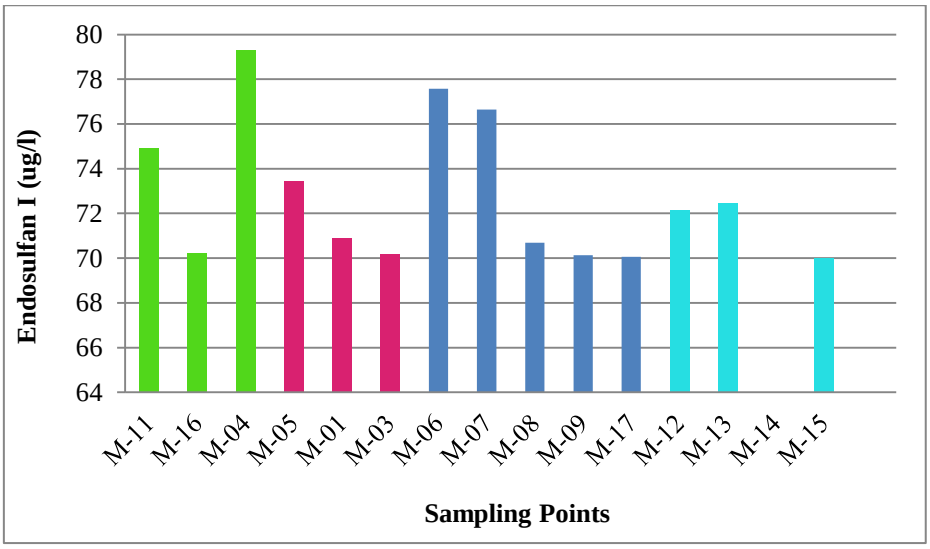

Fig (10) Comparison of Endosulfan I content of water samlpes

5.1.11 4,4'-Dichlorodiphenyldichloroethylene(4,4'-DDE)

The Mekong Member States do not mention the content 4,4'-DDE pesticide residue, but The total organochlorine pesticide content is set at 50ug/l. WHO and U.S.EPA did not specify the standard amoun for 4,4'-DDE. M-11, M-01and M-03, M-12 and M-13 water samples were found to contain no 4,4'-DDE pesticide residue, while the remaining 2 Mekong River sites and streams contained 4,4'-DDE residue, which were higher than the Mekong Member States standard limit (50ug/l).

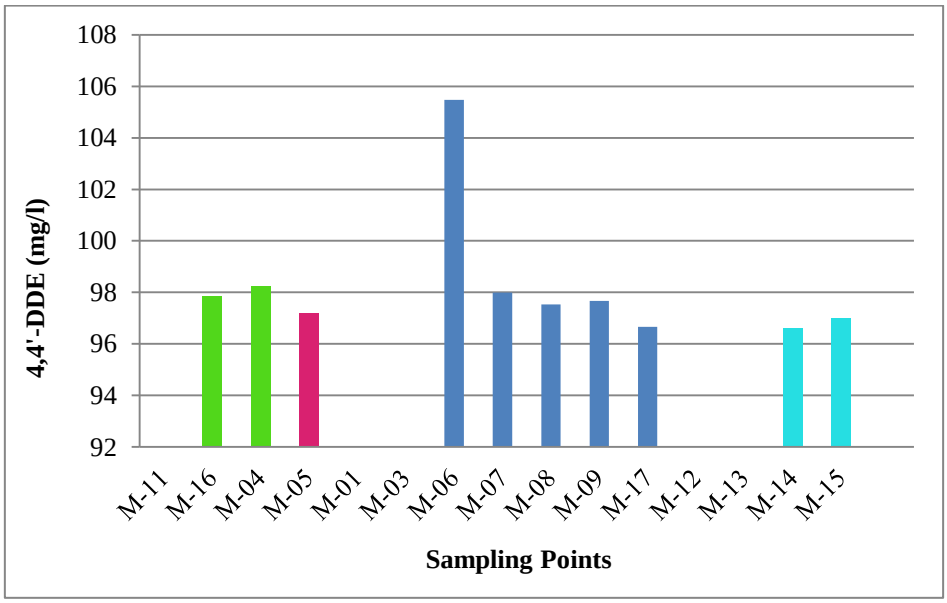

Fig (11) Comparison of 4,4'-DDE content of water samlpes

5.1.12 Dieldrin

The World Health Organization standard limit for Dieldrin is 0.03ug/l and the United States Environmental Protection Agency has not set a maximum acceptable limit for Dieldrin.The total organochlorine pesticide content is stated as 50ug/l in the domestic water quality standard for human health protection by the Mekong Member States. Mekong River M-11, Maesai stream M-01, Nant Hmaung stream M-08, Mone Leik stream M-09 and Mai Hope stream M-17 water samples were found to be free of Dieldrin pesticide residue, while the rest of the 2 Mekong River sites and streams were foud to contain Dieldrin residue, which were exceedingly higher than the standard values.

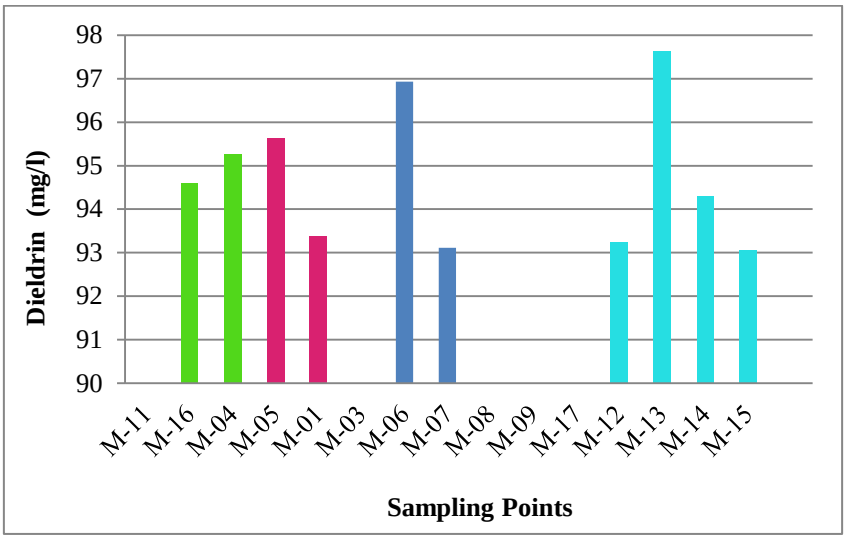

Fig (12) Comparison of Dieldrin content of water samlpes

Mekong River | Mae Sai stream | Streams from Keng Tung Township | Streams from Tacheleik Township

5.1.13 Endrin

The domestic water quality standard for WQGH of Mekong Member States set the total organochlorine pesticide content as 50ug/l. No indication of endrin pesticide residue content was found. The U.S.EPA standard limit for endrin pesticide residue is 2ug/l. and the WHO water quality standard does not specify the limit. Accordig to the laboratory findings, water samples from 3 locations of Mekong River and 12 streams contained endrin residues, which were exceedingly higher than the U.S.EPA and Member States standard limits. It was found that the concentration of endrin pesticide residue in the upstream area M-11 of the Mekong River was significantly higher than that of the rest of the middle site M-16 and the downstream area M-04.

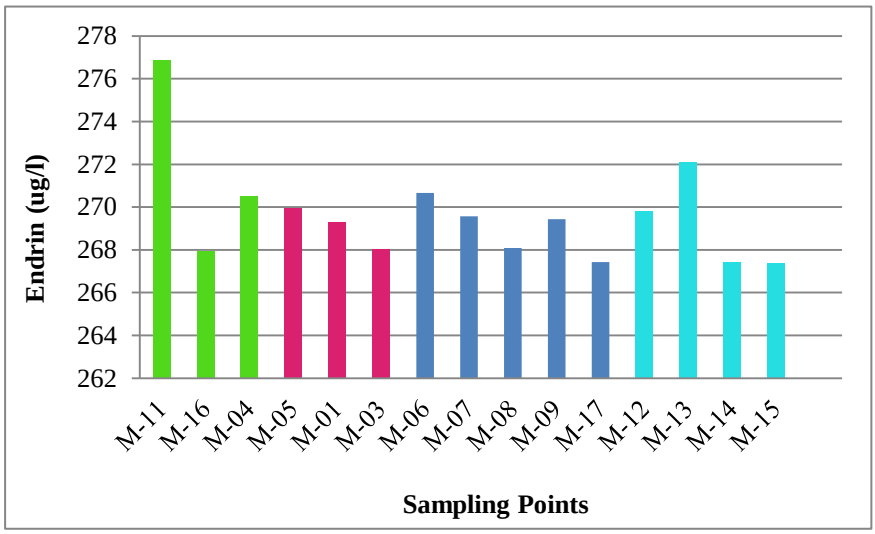

Fig (13) Comparison of Endrin content of water samlpes

Mekong River | Mae Sai stream | Streams from Keng Tung Township | Streams from Tacheleik Township

5.1.14 4,4'-Dichlorodiphenyldichloroethane (4,4'-DDD)

The water quality standard limit for 4,4'-DDD pesticide residue set by WHO is 2ug/l, which is not listed as a maximum acceptable concentration level by the U.S.EPA. The total organochlorine pesticide content is stated as 50ug/l in the domestic water quality standard for human health protection by the Mekong Member States. All sampling points of of Mekong River and 12 streams did not contain 4,4'-DDD pesticide residue.

5.1.15 Endosulfan II

To protect human health, The domestic water quality standard of the Mekong Member States do not mention the content Endosulfan II pesticide residue, but The total organochlorine pesticide content is set at 50ug/l. The U.S.EPA and WHO water quality standards also do not specify levels of Endosulfan II pesticide residue. In accordance with the results, all the sampling sites in the Mekong River basin contain Endosulfan II pesticide residue, which were high to very high condition compared with the stansard values.M-11 Mekong River and M-06 Maesai Nwet stream water sampling sites are higher than other significantly.

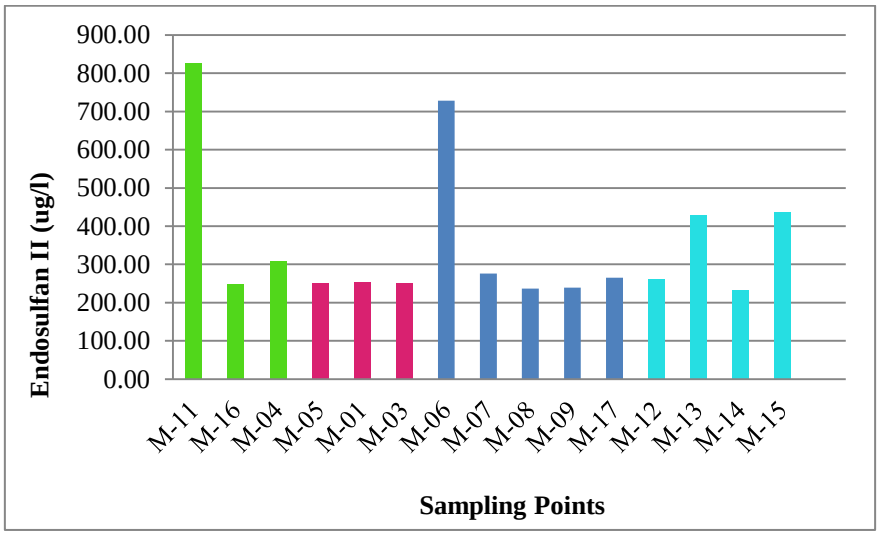

Fig (15) Comparison of Endosulfan II content of water

Mekong River | Mae Sai stream | Streams from Keng Tung Township | Streams from Tacheleik Township

5.1.16 Endrin aldehyde

The Mekong Member States do not mention the content Endrin aldehyde residue, but the total organochlorine pesticide content is set at 50ug/l. U.S.EPA and WHO water quality standards do not mention the amount of Endrin aldehyde pesticide residue. According to the results, except for water samples of Mekong River M-11 and Mae Hoep stream M-17, water samples collected from the rest of the 2 Mekong River sites and streams were foud to contain Endrin aldehyde residue, which were extremely higher than the Member States standard limit. The Endrin aldehyde content of the water sampling sites M-04 and M-06 were also found to be higher than the other sites.

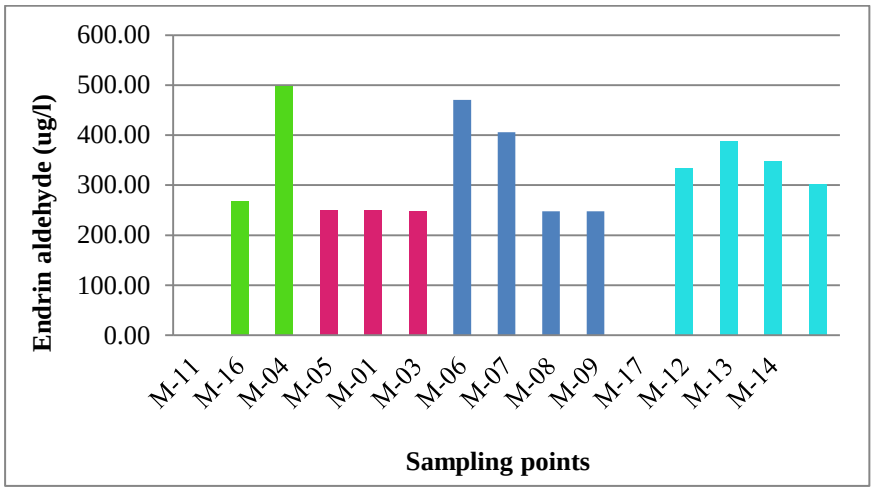

Fig (16) Comparison of Endrin aldehyde content of water samlpes

Mekong River | Mae Sai stream | Streams from Keng Tung Township | Streams from Tacheleik Township

5.1.17 4,4'-Dichlorodiphenyltrichloroethane (4,4'-DDT)

According to the laboratory finding, all the water sampling sites in the Mekong Basin, except for the water sample of Nant Ma stream M-13 were found to contain 4,4'-DDT pesticide residue. It was also found that the concentration of 4,4'-DDT residue in the water samples collected from Maesai stream M-03 and Mae Hoep stream M-17 were higher than the rest. The WHO water quality standard for 4,4'-DDT is 2ug/l. There is no U.S.EPA standard limit for 4,4'-DDT pesticide residue. The Member States' water quality standard for domestic use of water specifies the total organochlorine pesticide content as 50ug/l.

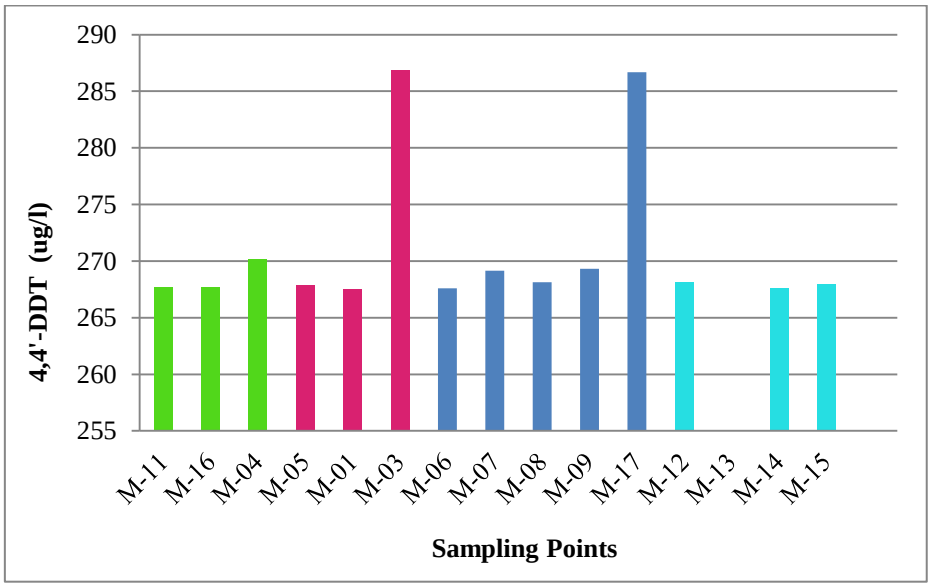

Fig (17) Comparison of 4,4'-DDT content of water samlpes

Mekong River | Mae Sai stream | Streams from Keng Tung Township | Streams from Tacheleik Township

5.1.18 Endosulfan sulphate

Endosulfan sulphate pesticide residue content is not mentioned separately in the Mekong Member States' Water Quality Standard for domestic use of water for protection of human health specify the total organochlorine pesticide content as 50ug/l, but do not mention Endosulfan sulphate alone. The U.S.EPA and WHO water quality standards do not specify levels of Endosulfan sulphate pesticide residue. According to the results, the water sample collected from Mae Hoep stream M-17 did not contain Endosulfan sulphate pesticide residue, while all other water sample collection sites in Mekong River Basin contained Endosulfan sulphate pesticide residue. It was found that the concentration of Endosulfan sulphate in the downstream area of Mekong River M-04 was higher than that of the upstream M-11 and the middle site M-16.

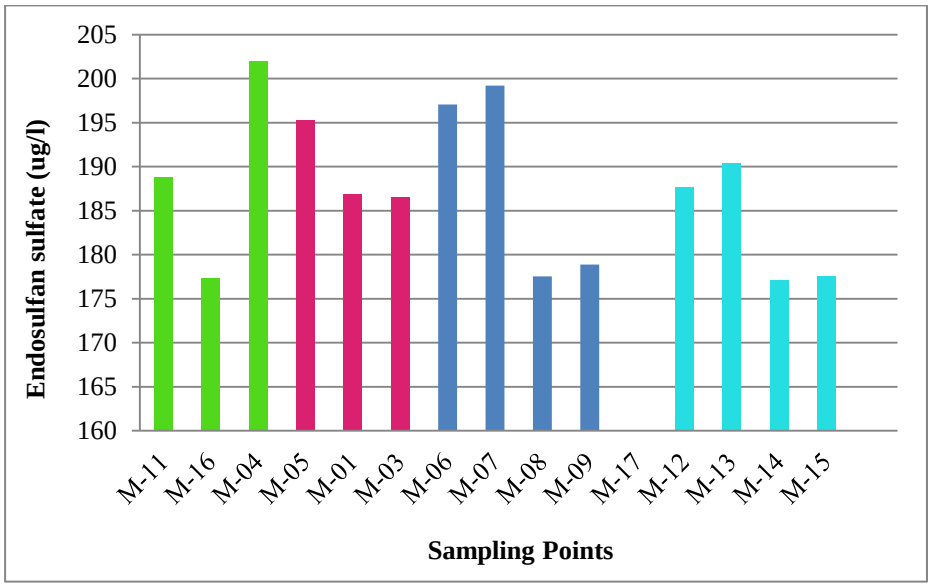

Fig (18) Comparison of Endosulfan sulphate content of water samlpes

Mekong River | Mae Sai stream | Streams from Keng Tung Township | Streams from Tacheleik Township

5.1.19 Methoxychlor

The WHO standard limit for Methoxychlor is 20ug/l and U.S EPA does not specify a maximum acceptable limit for Methoxychlor. The total organochlorine pesticide content is stated as 50ug/l in the domestic water quality standard for human health protection by the Mekong Member States. According to the following graph, Methoxychlor residue were found in all the water sampling sites in the Mekong River Basin, which were much higher than the WHO and Member States standards. Methoxychlor pesticide residue content of M-11, was higher than the M-16 and M-04.

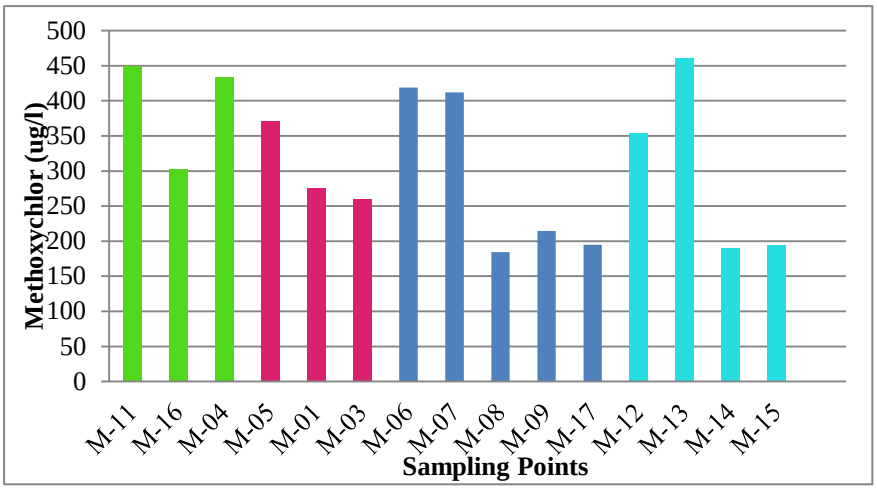

Fig (19) Comparison of Methoxychlor content of water samlpes

Mekong River | Mae Sai stream | Streams from Keng Tung Township | Streams from Tacheleik Township

5.1.20 Endrin ketone

There is no WHO and U.S.EPA standard limits for Endrin ketone pesticide residue. To protect human health, the highest acceptable values of the Member States' water quality standards for domestic use of water states the total organochlorine pesticides as 50 ug/l, but the amout of Endrin ketone pesticide residuce is not specified separately. According to the laboratory finding, the water sample collected from Mae Hoep stream M-17 did not contain Endrin ketone pesticide residue, but all the water samples collected in the rest of the Mekong River Basin contained Endrin ketone residue. Endrin ketone residue contents of these water samples are below the standard of domestic water limit proposed by Member States. It was found that M-14 Nant Lay stream water sample have highest levels of Endrin ketone residue than the Mekong River and other streams.

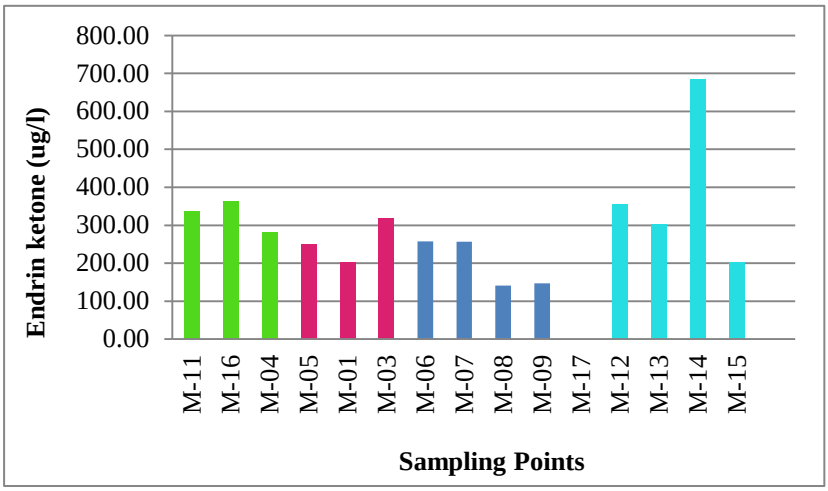

Fig (20) Comparison of Endrin ketone content of water samlpes

Mekong River | Mae Sai stream | Streams from Keng Tung Township | Streams from Tacheleik Township

5.2 Organophosphorus Pesticide - OPPs

The concentration of Organophosphorus Pesticides - OPPs residue in all water samples collected from the Mekong River Basin is described below.

5.2.1 Dichlorvos (DDVP)

There is no standard limit for total organophosphorus pesticide-OPPs in the Mekong Member States' Water Quality Standards for domestic use. The World Health Organization's water quality standard set the concentration of Dichlorvos (DDVP) pesticide residuce as 20ug/l. Like Member States; U.S EPA does not specify a maximum acceptable limit for Methoxychlor. According to laboratory findings, the water samples collected from Mekong River M-11 and Maesai stream M-05 and Mae Hoep stream M-17 did not contain Dichlorvos (DDVP) pesticide residuce, and all the other water sample collection sites contained DDVP residuce, which were above the WHO standard.

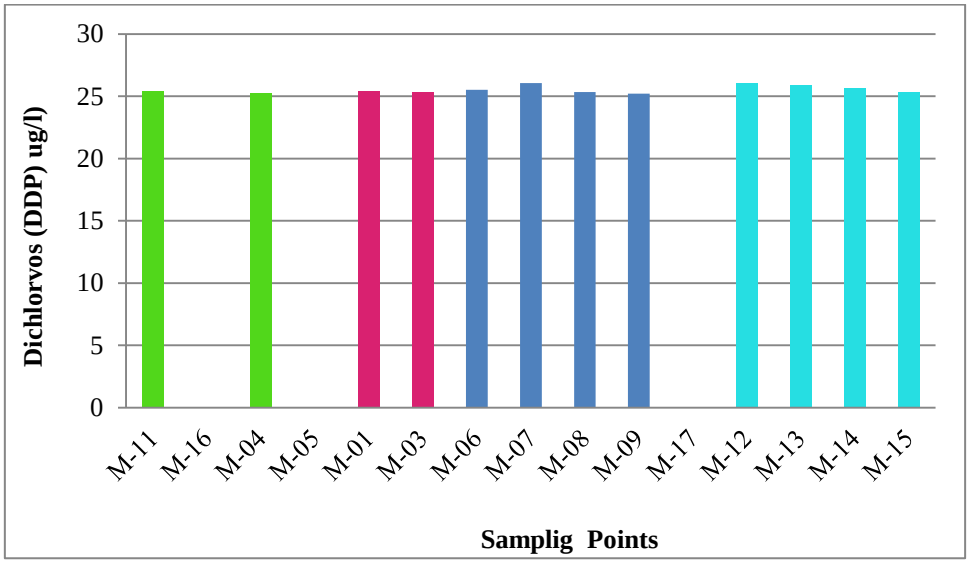

Fig (21) Comparison of Dichlorvos (DDVP) content of water samlpes

Mekong River | Mae Sai stream | Streams from Keng Tung Township | Streams from Tacheleik Township

5.2.2 Dimethoate

The standard limit for Dimethoate cotent by the World Health Organization is 6ug/l. All the water sampling sites in the Mekong River Region, except for the M-14 Nant Lay stream, were found to contain Dimethoate pesticide residuce, which were much higher than the standard set by WHO. Dimethoate content of the the middle site M-01 Maesai stream was lower than that of the beginning site M-05 and the end site M-03.

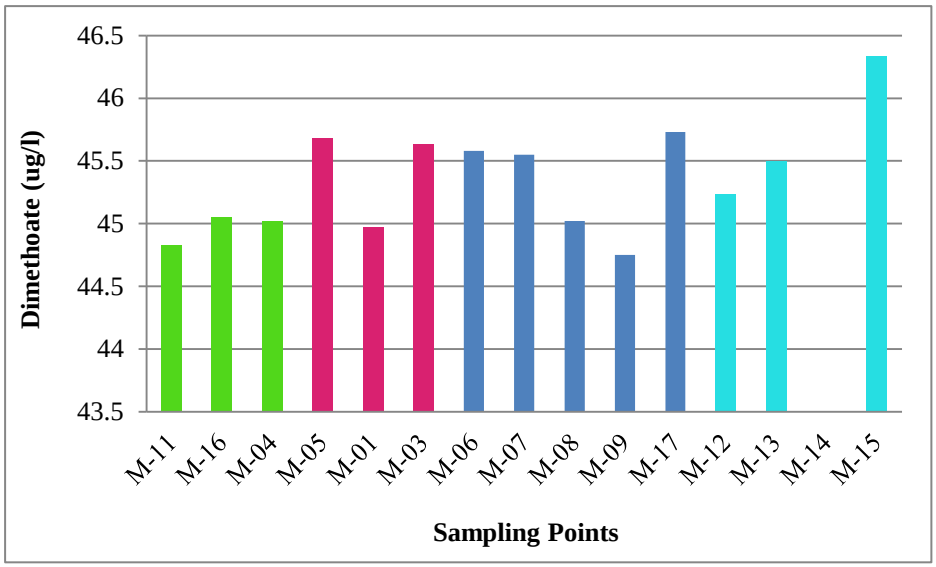

Fig (22) Comparison of Dimethoate content of water samlpes

Mekong River | Mae Sai stream | Streams from Keng Tung Township | Streams from Tacheleik Township

5.2. 3 Turbufos

The standard limit for Turbufos cotent by the World Health Organization is 6ug/l. There is no maximum acceptable limit for Turbufos from the U.S.EPA. There are no total organophosphorus pesticide-OPPs in the domestic water quality standards of Mekong Member States to protect human health. Except for the M-14 Nant Lay stream, all the water sampling sites in the Mekong River Region were found to contain Turbufos pesticide residuce, which is much higher than the standard set by WHO. Turbufos content of the M-01 Maesai stream was much higher than that of the M-01 and M-03 Maesai stream.

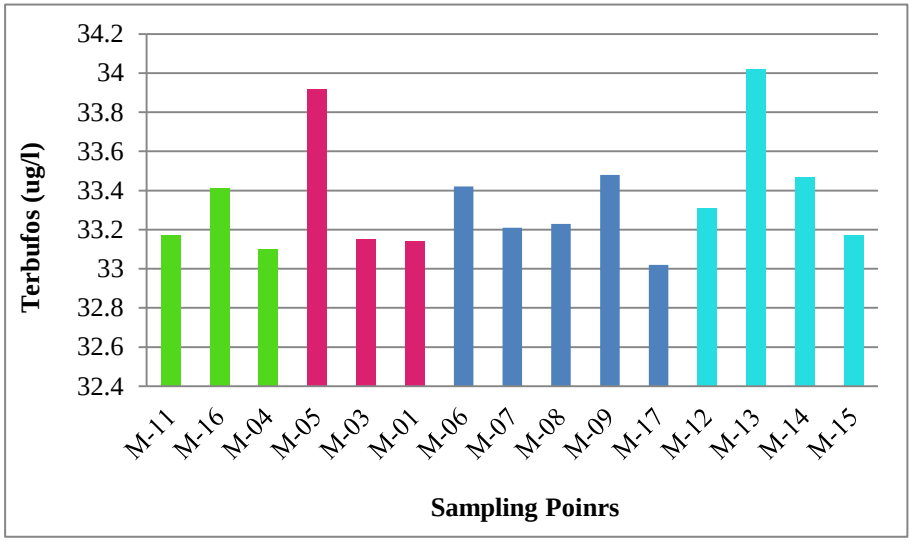

Fig (23) Comparison of Terbufos content of water samlpes

Mekong River | Mae Sai stream | Streams from Keng Tung Township | Streams from Tacheleik Township

5.2.4 Diazinon

The World Health Organization stansard setting for diazinon and the maximum acceptable concentration set by the United States Environmental Protection Agency are 20ug/l. According to the results, water sample of Mekong River M-04 did not contain diazinon pesticide residue, and that residue content of all the rest of the Mekong River and streams was found to be higher than the specified standards. Diazinon residue was found in the upstream area M-11 and the middle site M-16 of the Mekong River, but there was no presence in the downstream area M-04. Simillarly, it was found that the content of diazinon residue in M-05 at the beginning of Mae Sai stream was higher than M-01 in the middle and M-03 at the end of the stream.

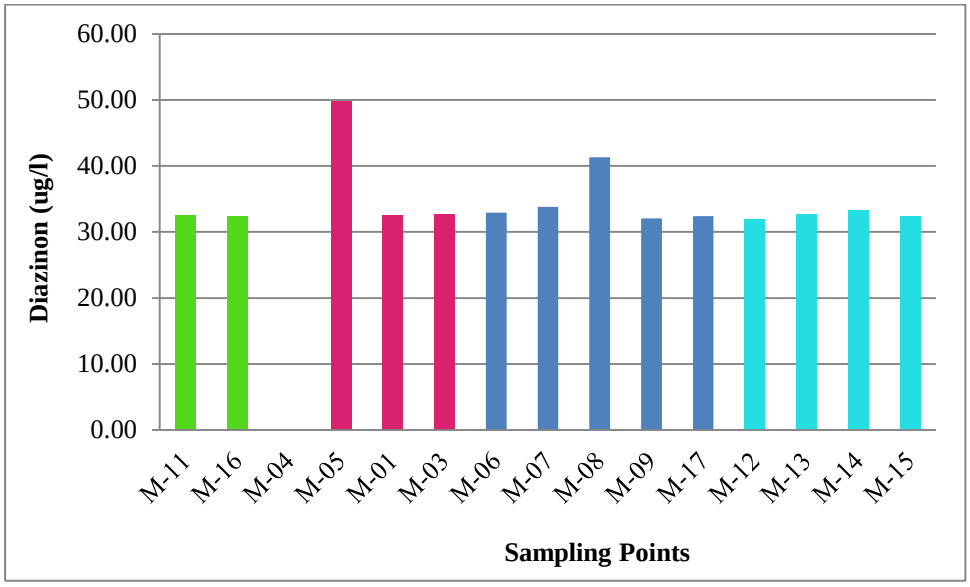

Fig (24) Comparison of Diazinon content of water samlpes

Mekong River Mae Sai stream Streams from Keng Tung Township Streams from Tacheleik Township

5.2. 5 Fenitrothion

WHO water quality stansard for fenitrothion is 8ug/l. It was found that there was no fenitrothion pesticide residue in the water samples of Mone Leik stream M-09 and Nant Lay stream M-14, but there were pesticide residues in the rest of the Mekong River and streams, which were higher than the WHO standard. Fenitrothion content of the Mae Sai stream M-05 was significantly higher that of the Mekong River and other streams.

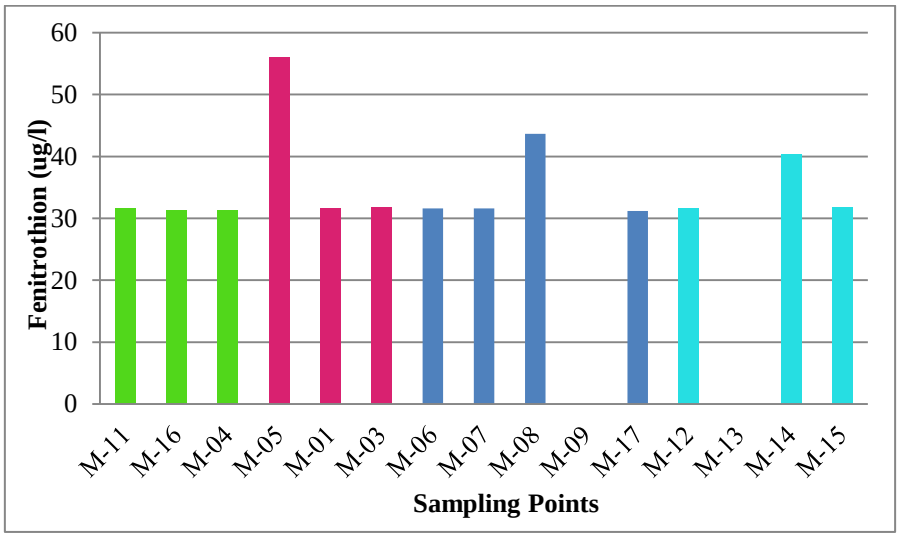

Fig (25) Comparison of Fenitrothion content of water samlpes

Mekong River | Mae Sai stream | Streams from Keng Tung Township | Streams from Tacheleik Township

5.2.6 Malathion

The US.EPA maximum acceptable level of malarthion in drinking water for chlddren and adults is 100-200ug/l and the WHO's maximum acceptable level of malarthion in drinking water is 0.1 ug/l. There was no malarthion pesticide resdisue in Mae sai stream, M-05 water sample but the concentration of malarthion residue in the rest of the Mekong River and streams was below the US.EPA standard and much higher than the WHO standard. The content of the malarthion residue in the middle site M-16 is higher than in the upstream M-11 and downstream M-04 sites. Simillarily, malarthion residue content of the Mae Sai stream M-05 was higher that of the Mekong River and other streams.

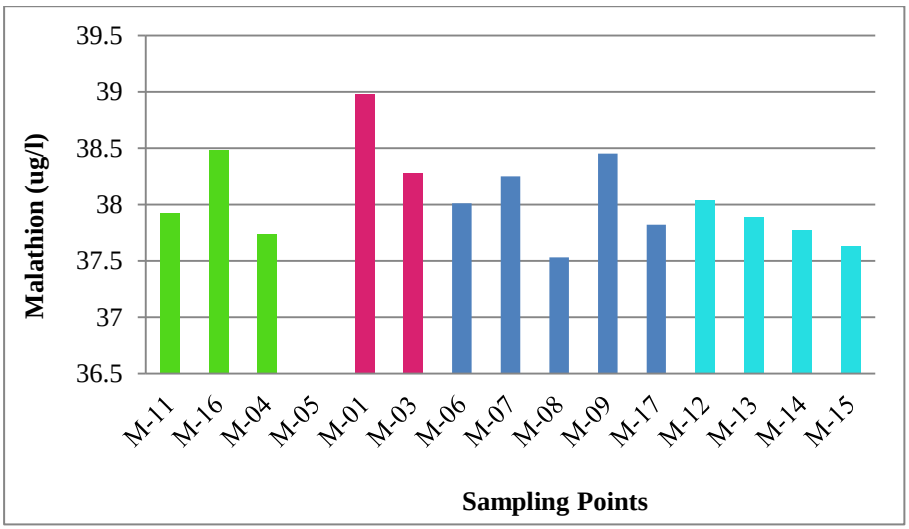

Fig (26) Comparison of Malathion content of water samlpes

5.2.7 Fethion, Chlorpyrifos

The US.EPA maximum acceptable level for Fethion, Chlorpyrifos is 0.1ug/l. Fethion, Chlorpyrifos pesticide residues were present in all the water sampling sites in the Mekong River Basin and were higher that the US.EPA standard. It was found that the concentration of Fethion, Chlorpyrifos residues in Mae Hoep stream M-17 water sample was higher than that of the Mekong River and streams.

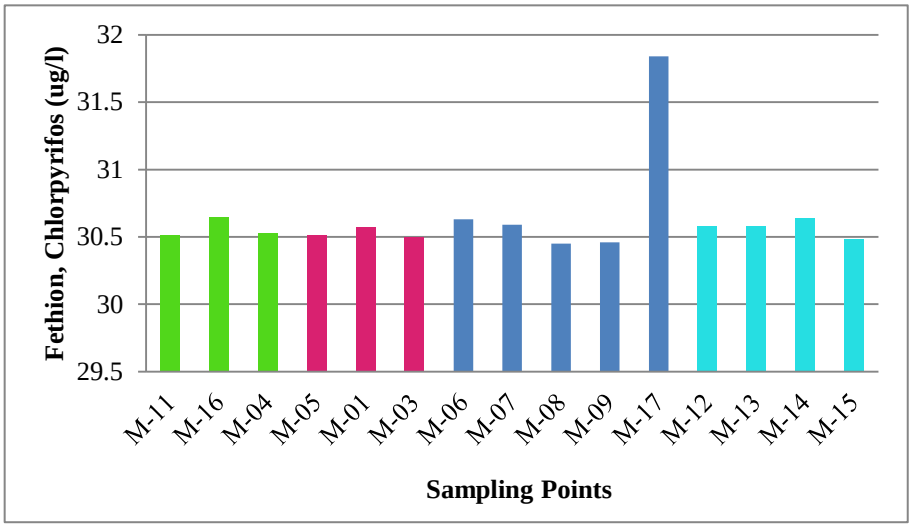

Fig (27) Comparison of Fethion, Chlorpyrifos content of water samlpes

5.2.8 Phenthoate

There is no specification for phenthoate pesticide rescidue from WHO and U.S.EPA. Mekong River M-04 and Mae Sai stream M-05 water samples did not contain penthoate rescidue, while all the rest of the Mekong River and streams contained that rescidue.

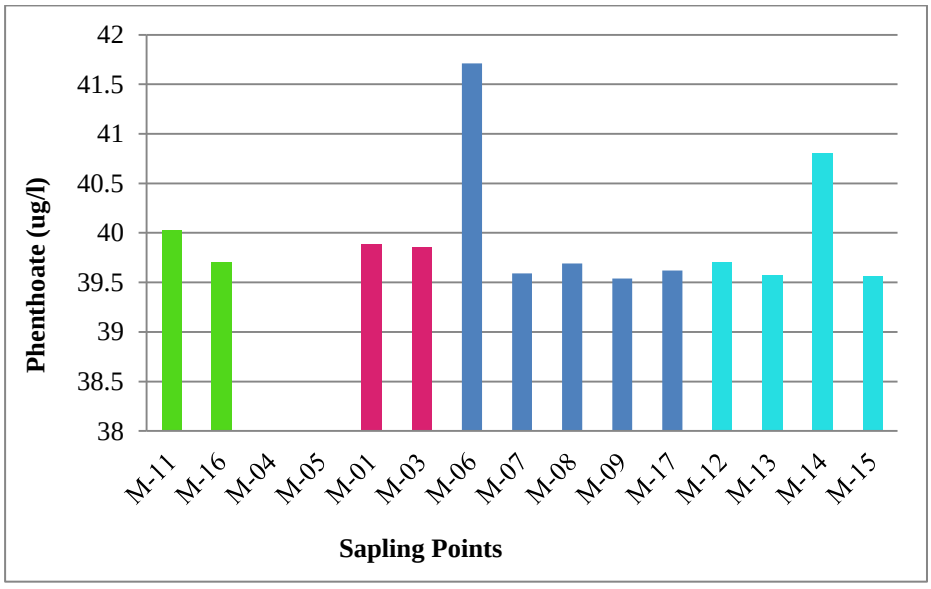

Fig (28) Comparison of Phenthoate content of water samlpes

Mekong River Mae Sai stream Streams from Keng Tung Township Streams from Tacheleik Township

5.2.9 Prothiofos

All sampling points, Mekog River and streams contrain prothiofos pesticide residue. The concentration of prothiofos pesticide residue in the middle site M-16 of the Mekong River was higher than that in the upstream area M-11 and downstream ares M-04. Simillarily, it was found that the content of prothiofos residue in the middle area M-01 of the Mae Sai stream was higher than that in the beginning M-05 and M-04 end areas. The World Health Organization and the United States Environmental Protection Agency water quality standards do not find criteria for the present of prothiofos.

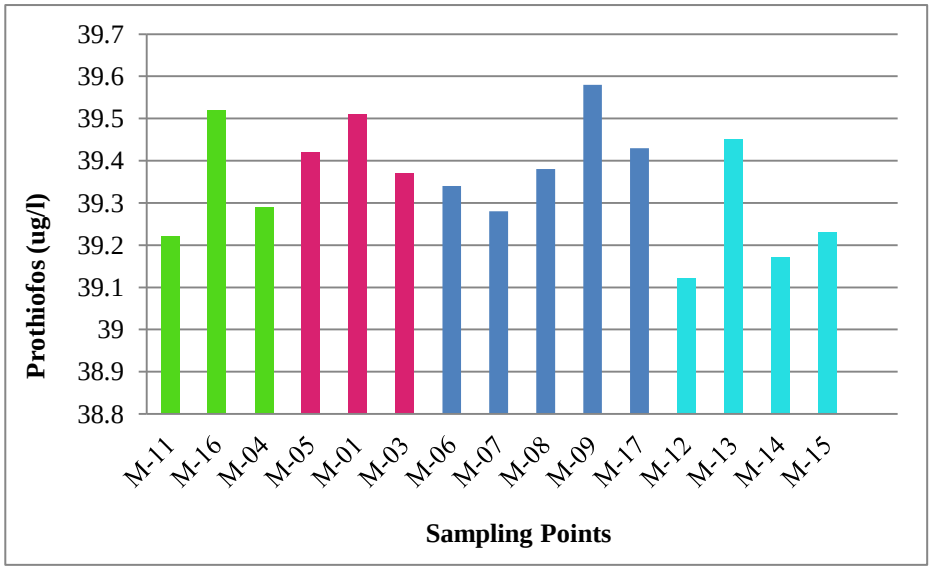

Fig (29) Comparison of Prothiofos content of water samlpes

5.2.10 Profenofos

Like prothiofos, The WHO and U.S.EPA water quality standards do not find criteria for the present of profenofos. Profenofos pesticide residue were not found in the water samples collected from Mekong River M-11, Maesai Nwet stream M-06 and Mone Leik stream M-09, but profenofos pesticide residue were foud in the rest of the water sample collection sites. The presence of the profenofos residue in the middle Mekong site M-16 was higher than in the upstream M-11 and downstream M-04 areas. Simillarily, profenofos residue content of the Mae Sai stream M-05 was higher than that of the inlet M-05 and M-03 outlet points of the streams.

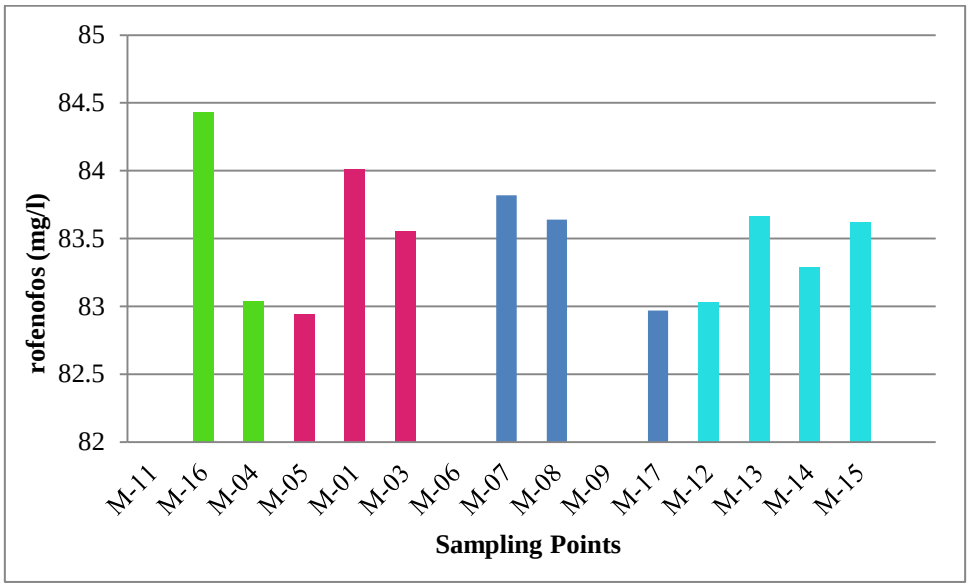

Fig (30) Comparison of Profenofos content of water samlpes

Mekong River | Mae Sai stream | Streams from Keng Tung Township | Streams from Tacheleik Township

5.2.11 Triazophos

Triazophos pesticide residue was found in all the Mekong River and streams. It was found that the amount of pesticide residue in the M-16 sampling point was higher than in M-11 and M-04 sampling points, and triazophos residue content of the Mae Sai stream M-01 middle point was higher than that of the inlet M-05 and M-03 outlet points of the stream. WHO and U.S.EPA water quality standards do not specified the present of triazophos.

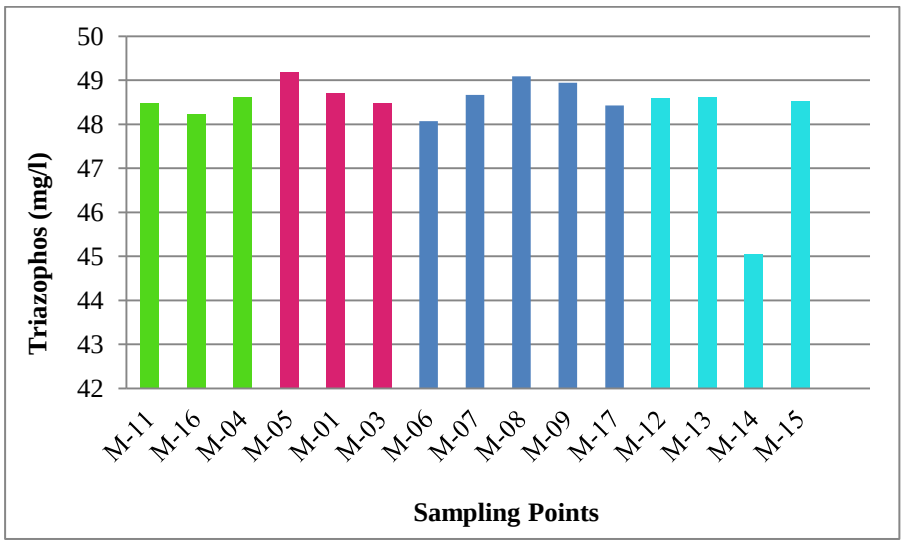

Fig (31) Comparison of Triazofos content of water samlpes

Mekong River | Mae Sai stream | Streams from Keng Tung Township | Streams from Tacheleik Township

6. Conclusions

In the present study, The Maesai and Nant Lo stream water samples contain the α–BHC pesticide residue, which were exceedingly higher than the standard values. The remaining sampling points did not contain that residue. All water samples collected from 3 locations of Mekong River and 12 streams flowing into that river were found to be free of Gamma-hexachlorocyclohexane (γ-BHC - Lindane) and 4,4'-Dichlorodiphenyldichloroethane (4,4'-DDD) pesticide residuces. Moreover, Nant Hmaung, Mone Leik, Nant Lo, Nant Ma, Nant Lay, Wun Tar Pone and Mae Hoep streams were found to be free of β-BHC, δ-BHC, heptachlor and heptachlor epoxide pesticide residues. Simillarily, there were no Cis- Chlordane, Dieldrin residues in the water sampling sites of Nant Hmaung , Mone Leik, Nant Lo streams. In addition, Nant Ma, Nant Lay stream water samples did not contain 4,4'-DDE and 4,4'-DDT pesticide residues, while Nant Lo stream water sample did not contain Endrin aldehyde, Endosulfan sulphate and Endrin ketone pesticide residues. It is considered that such occurance may be due to their low application of pesticide in the mentioned places and the high hydrolysis rates of the pesticides used.

According to the results, the remaining water samples collected from the Mekong River Basi were found to be contaminated with the organochlorinated pesticides α-BHC, β-BHC, δ-BHC, heptachlor, aldrin, heptachlor epoxide, trans chlordane, cis chlordane, Endosulfan I, dieldrin, 4,4' DDD, endrin, 4,4' DDT, Endosulfan II, Endrin aldehyde, endosulfan sulfate, metoxychlor and endrin ketone with maximum concentrations of 152.34, 101.55, 127.98, 80.05, 129.91, 59.81, 144.87, 99.46, 79.29, 105.47, 97.62, 232.13, 276.86, 286.89, 825.03, 498.07, 201.94, 460.88 and 684.59 μg/l, respectively. All these concentrations were high to very high condition compared with the the Member States' water quality standards for domestic use of water for protection of human health, the World Health Organization (WHO) guideline values and the United States Environmental Protection Agency (U.S. EPA) maximum permissible level. Similarly, all water sampling sites in the Mekong River basin were polluted with the organophosphorus pesticides Dimethoate, Fenitrothion and Profenofos with maximum values of 46.33, 55.99, 38.98 and 84.43, ug/l, respectively. It was found that the organophosphorus pesticides residue exceeded the standard limits.

The amount of OCPs and OPPs pesticide residues (organic pollutants) in the water resources depend on different factors, such as topography, steepness of the location, soil humidity, rainfall and types of pesticides used, proximity of agricultural land to the river, extensive agricultural and horticultural activities, metabolism of pesticides to other compounds, absorption of pesticides into organic matter in water and soil, accumulation rate, concentration, solubility, volatility, polarity of each pesticides, water temperature and pH. For this reason, the residual concentrations of diverse types of pollutants pesticides are various in different sources. The presence of the OCPs and OPPs pesticides in the water resources can be due to reasons such as uncontrolled manual spray, poor management in the process of pesticides using, low knowledge of farmers about the application of pesticides and unnecessary and inappropriate application of pesticides. Due to many problems of pesticides on the environment and human health, increasing farmers' awareness about the proper use of

pesticides at the right time and preventing the entrance of pesticides into the water, the correct way of cultivation, amount of pesticides, and the natural combating means for agricultural pests can be effective in decreasing the concentration of pesticides in aquatic resources and environment. The presence of organic pollutants in surface waters may indicate acute exposure of humans and wildlife, and consequently requires continuous monitoring of these pollutants in water resources.

Because of organic pollutants can affect the water quality and the health of local people who use river and stream waters, relevant governmental departments and organizations should work together to reduce ennviromental pollution and prevent water pollution caused by waste materials and waste waters from the village, houses, hotels and restaurants located on the banks of the river and streams, from mining, farming, livestock and industrial operations. In addition to farmers education activities, awareness and education activities for local peoples should also be carried out. Furthermore, as the water quality can change the people actions and the weather conditions, continuous monitoring and measuring of pesticides should be carried out to protect the health of the community and the environment.

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