ปริมาณโลหะหนักในพืชน้ำและสัตว์น้ำ จากระบบบำบัดน้ำเสียเทศบาลนครขอนแก่น
Bioaccumulation of Heavy Metals in Aquatic Biota from Khon Kaen City Wastewater Treatment System

วรางคณา สังสิทธิสวัสดิ์ Warangkana Sungsitthisawad*
ธวัชชัย เนียรวิฑูรย์ Thawatchai Nienvitoon**
อุไรวรรณ อินทร์ม่วง Uriwan Inmuang*
ถิรพงษ์ ถิรมนัส Thirapong Thiramanus***

บทคัดย่อ

เทศบาลนครขอนแก่น มีระบบบำบัดน้ำเสียรวมของเมืองขอนแก่น แบบบ่อผึ่ง สามารถรับน้ำเสียจากบ้านเรือนและโรงงานอุตสาหกรรม ประมาณ 25,500 ลูกบาศก์เมตร/วัน ประชากรในเขตเทศบาลมีจำนวน 142,926 คน จากจำนวนหลังคาเรือน 35,585 หลังคาเรือน และโรงงานอุตสาหกรรม 568 โรงงาน มีประชาชนที่อาศัยอยู่โดยรอบระบบบำบัดนำเอาปลา ผักบุ้งและพืชน้ำอื่นๆ ไปบริโภคและจำหน่าย โลหะหนักที่ปนเปื้อนอยู่ในน้ำเสียและตะกอนดินมีโอกาสแพร่กระจายเข้าสู่ปลา พืช ห่วงโซ่อาหารได้ งานวิจัยนี้จึงได้พิจารณาตรวจวัดปริมาณโลหะหนัก แคดเมียม ทองแดง ตะกั่ว และสังกะสีในตัวอย่างน้ำเสีย 30 ตัวอย่าง ดินตะกอน 15 ตัวอย่าง ปลานิล 20 ตัวอย่าง และผักบุ้ง 20 ตัวอย่าง ในช่วงเดือนมกราคมถึงเดือนพฤษภาคม พ.ศ. 2541 ผลการวิจัยมีค่าความเป็นกรดด่างในน้ำเสีย 7.2 - 8.8 ออกซิเจนละลาย 3.5 - 6.2 มก./ล. บีโอดี 16.5 - 51.2 มก/ล ซีโอดี 66 - 87 มก./ล. และน้ำเสียมีตะกั่ว 0.014-3.075 มก./ล. ทองแดง 0.007 - 2.285 มก./ล. สังกะสี 0.272 - 0.696 มก./ล. และแคดเมียมน้อยที่สุด 0.002 - 0.583 มก./ล. ดินตะกอนมีสังกะสี 4.893 - 284.300 มก./กก. ทองแดง 0.06 - 16.385 มก./กก. ตะกั่ว 0 - 9.15 มก./กก. และแคดเมียม 0 - 1.325 มก./กก. ตรวจพบโลหะหนักทุกชนิดในปลานิลและผักบุ้งมีการปนเปื้อนของโลหะหนักที่หนังปลานิลมากที่สุด มีสังกะสีสูงถึง 36.31 มก./กก. และทองแดงสูงถึง 6.14 มก./กก. ส่วนที่เหงือกมีแคดเมียมมากที่สุด 9.84 มก./กก. เมื่อเทียบการปนเปื้อนโลหะหนักในอวัยวะต่างๆ ของปลานิลแล้วพบว่ามีโลหะหนักที่หนังปลา > เหงือก > กระดูก > ทุกส่วนผสมรวมกันและในเนื้อปลาพบน้อยที่สุด ส่วนโลหะหนักในผักบุ้งพบที่ส่วนก้านอ่อนและยอด มีสังกะสีสูงถึง 7.62 - 26.394 มก./กก. แคดเมียม 2.54 - 10.944 มก./กก. ทองแดง 0.46 - 1.253 มก./กก. และตะกั่ว 0.01 - 0.746 มก./กก. มากกว่าโลหะหนักในทั้งต้นของผักบุ้ง (สังกะสี 5.11 - 14.546 มก./กก. แคดเมียม 0.05 - 0.347 มก./กก. ทองแดง 0.3 - 0.582 มก./กก. และตะกั่ว 0.07 - 0.264 มก./กก.) เมื่อเทียบกับมาตรฐานสารโลหะหนักปนเปื้อนในผลิตภัณฑ์อาหารที่ร่างกายได้รับใน 1 วัน ปลานิลและผักบุ้งมีค่าสูงจนอาจก่อให้เกิดอันตรายต่อผู้บริโภคได้

Abstract

Khon Kaen City wastewater treatment system receives almost all domestic and industrial sewage approximately daily loading 25,500 m3/day, serving 142,926 population or at least 35,585 houses and including 568 industries. A lot of people come to catch fishes and take vegetables from wastewater treatment system. So this research aims to determine heavy metals concentration because substance in wastewater can accumulate heavy metals into its components, which in long term intake those aquatic biota may give rise to health problems. Cd, Cu, Pb and Zn, were examined in wastewater 30 samples, sediment sludge 15 samples, Tilapia 20 samples, morning glory 20 samples from January to May 1998. The result showed characterstics of wastewater pH range from 7.2-8.8, DO 3.5-6.2 mg/L, BOD5 16.5-51.2 mg/L, COD 66-87 mg/L, the concentration of heavy metals in wastewater were high (Pb > Cu > Zn > Cd). Pb, Cu, and Cd concentration were decreased after wastewater was treated, however the concentration of Zn was rather constant. The sediment accumulated heavy metals varied from the highest to lowest; for Zn (4.893-284.3 mg/kg), Cu (0.06-16.385 mg/kg), Pb (0-9.15 mg/kg), and Cd (0-1.325 mg/kg). The Tilapia generally was found to have higher content of heavy metals, Tilapia's organs having heavy metals in skin > grill > bone > mix > fillet. Concentration of Zn in fish-organs was the highest, while the Cu and Pb were relatively lower. Heavy metal concentrations in morning glory indicated heavy metals of the tip and leaf were higher than the whole (Zn 7.62-26.394 mg/kg, Cd 2.54-10.944 mg/kg, Cu 0.46-1.253 mg/kg and Pb 0.01-0.746 mg/kg), almost morning glory concentration exceed the standard. Hence, fishes and vegetables can give rise to the health problems to consumers. It is necessary to be awareness.

คำสำคัญ : โลหะหนักในพืชน้ำและสัตว์น้ำ
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* ผู้ช่วยศาสตราจารย์ คณะสาธารณสุขศาสตร์ มหาวิทยาลัยขอนแก่น
** รองศาสตราจารย์ คณะสาธารณสุขศาสตร์ มหาวิทยาลัยขอนแก่น
*** ผู้ช่วยศาสตราจารย์ คณะสาธารณสุขศาสตร์ มหาวิทยาลัยบูรพา

Introduction

Most municipal wastewater treatment systems in Thailand are stabilization pond systems. Khon Kaen City has also applied such the stabilization pond in treatment its raw wastes since 1989. This system composed of 2 facultatives and 3 maturation ponds, located in the East of Thung-Sang Lake. Almost all domestic and industrial sewage flow into the system with approximately daily loading 25,500 m^3/day, served 142,926 population or at least 35,585 houses and including 568 Industries. (Environmental care center, 1995) Many kinds of fishes and aquatic plants grow abundantly in the system, and thus becoming a food source for the locals for daily consumption and even earning selling them for money. (Fig.1) Heavy metals in waste water may dramatically cause toxic effects on aquatic life, even more subtle, but the effects remain chronic damaging over a long period of time. Aquatic system has its ability to recover from contaminants damaged if not seriously overloaded with irreversible pollutants.

Sediment with a high organic or clay composition usually has some contents of toxicants and trace metals. These enriched sediments, once deposited and if environmental conditions suitable, can be remobilized which to posing an additional risk to benthic and other aquatic life. Aquatic is capable of fixing plant carbon from the air and absorbing essential macro-and micronutrients from the sediment, which include heavy metals. (Kumar Nanda, et. al, 1995) Plants accumulated metals for a long time were considered as detrimental trait at the bottom of the food chain. Metal-accumulating plants are directly or indirectly responsible for a large proportion of dietary uptake of toxic heavy metals by human and animal.

The objectives of this research are to determine heavy metal contents; there are cadmium (Cd), copper (Cu), lead (Pb), and zinc (Zn). These traces were chosen as they are ubiquitous pollutants present in industrial, agricultural and municipal wastes. Comparison was made between concentrations of heavy metals in wastewater, sediment, vegetables and fishes in order to identify how much heavy metals in food stuff which likely to effect on human health.

Materials and Methods

Collection of samples

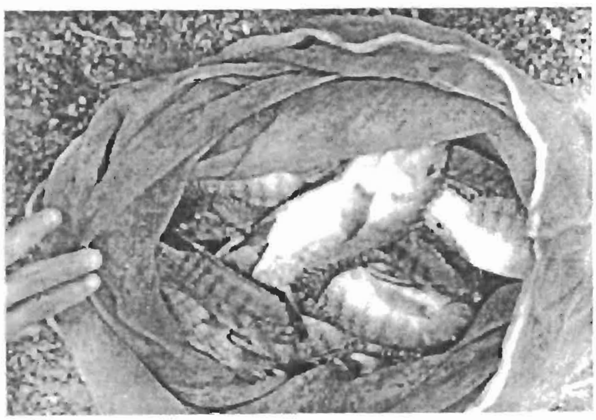
Samples were collected for physical and chemical analysis during the critical time for 4 months from January to May 1998, this examination was chosen as the organic content period tend to be critical in summer months, as the water level in ponds was low, so as the dissolved oxygen. There are 4 main kinds of selected samples to be examined; there are wastewater in each pond, sediment sludge, aquatic vegetables and fishes.

Wastewater samples were collected, totaling 30 samples from municipal wastewater treatment system from 5 stabilization ponds arranged in series representing a wide range of contents of chemical properties and heavy metals. These samples were analyzed for pH, dissolved oxygen (DO), biochemical oxygen demand (BOD_5), total contents of Cd, Cu, Pb and Zn. Details of laboratory analyses followed the Standard Methods for Examination of Water and Wastewater (APHA; AWWA and WEF, 1992). Sampling equipment used Van Dorn Sampler with single grab sample to collect wastewater from the middle of the pond at mid-depth. The water samples were preserved in polypropylin bottle, which kept in 4°C ice container a nitric acid to pH below 2.0. Then the samples were analyzed as quickly as possible on arrival at the Environmental Health Laboratory, Department of Sanitary Science, Faculty of Public Health, Khon Kaen University.

Heavy metal were examined by digesting 100 ml-sample in 5 ml conc. HNO_3, boils slowly until digesting completed as shown by clear solution contents (light colored) and the lowest volume about 25 ml. The samples were next filtered through a 0.45-µm cellulose nitrate filter membrane and then determined by a flame atomic absorption spectrophotometer. There were three replicates for each determination.

Sediment sludge samples were collected by Ekman Grab, totaling 15 samples from the bottom of 5 ponds, combining 4 points into one sample. The sediment samples were measured for total heavy metal contents of Cd, Cu, Pb, and Zn. The method digest 1 gram dry weight (105°C, 48 h) with nitric acid-perchloric acid-Hydrofluoric acid technique, then determining trace elements by the flame atomic absorption spectrophotometer.

Fish samples were Tilapia (*Tilapia nilotica* Linn.) by catching 20 samples from the plant with gill net. Fishes with medium size were chosen with their body weight about 200-400 gram and a total length about



15-25 cm. These specimens were frozen at 4°C. Heavy metals were examined in 5 organs ; fillet, skin, grill, bone (Spinal cord + Hemal spine), and mix. Using nitric acid-perchloric acid associated with hot plate technique as cited above weighing about 5 gram by wet weight. These solutions were determined for metal contents by the flame atomic absorption spectrophotometer.

Aquatic vegetable samples were morning glory (*Imponoea aquatica*), 20 samples totaling collected from the system. Morning glory with roots attached to the mud and free floating plants, were chosen. The samples were kept cool in container with ice at 4°C. Heavy metals were examined from 2 portions of the whole, tip+leaf. Pre-examination was made by digesting vegetables with nitric acid-perchloric acid technique. These solutions were then examined for Zn, Cu, Pb and Zn by the flame atomic absorption spectrophotometer.

Results and Discussion

A five-pond wastewater treatment system received municipal wastewater from commercial, industrial and storm water sources. Wastewater was continuously discharged in to the five series stabilization ponds in an area of 143 Rai (57.2 acre) which surface water 119 Rai (47.6 acre). The five ponds were interconnected with a large culvert as to allow waters overflowed to next ponds when the amount of wastewater exceeds the design level (Fig.2). Each pond has details of approximate surface area, average depth, and detention time as shown in table 1.

The weather during study period from January to May 1998, was hot and dry, the water in ponds was swamp with average low depths, between 1.5-2.0 metres. The wastewater had range of pH 7.2-8.8 (the pH of wastewater quality criteria & standard in Thailand has been reported as between 5-9), DO 3.5-6.2 mg/L, BOD_5 16.5-51.2 mg/L, COD 66-87 mg/L, and the concentrations of heavy metals were shown in Table 2. The DO may also increase as transferring to atmospheric carbon dioxide. The dissolved carbon dioxide then provides a carbon source for carbon fixation during the photosynthetic process. If low dissolved oxygen occurred, the fish reacted by pumping more water over the grills surfaces. When ever toxic pollutants such as Zn are introduced, an additional stress is created at a critical time. When dissolved oxygen is low, caused this the fish uptaking in more DO through the grill, and thus they absorbed more Zn, which eventually led to higher heavy metal poisoning during a period of dissolved oxygen stress.

The concentrations of metals in wastewater were relatively high, where the concentration of Pb > Cu > Zn > Cd. Pb, Cu and Cd concentration were decreased when treated by the plant, but the concentration of Zn was rather constant.

Concentration of metals in sediment sludge. Heavy metals in sediment sludge were shown in Table 3. These concentrations were reported as milligram of heavy metal per kilogram dry weight of sediment sludge. The data indicated that accumulated heavy metals varied from the highest to lowest; for Zn (53.46 mg/kg), Cu (6.38 mg/kg), Pb (3.28 mg/kg), and Cd (0.14 mg/kg). The deposition level of all metals declined from first to the fifth pond as because of the degradable of organic wastewater in the first pond by receiving the raw wastewater with high organic loading, while the fifth pond has already biological digested. Fishes and vegetables also tended to accumulated the metals.

Concentration of metals in Tilapia (*Tilapia nilotica* Linn.) and morning glory (*Ipomoea aquatica*) were shown in tables 4 and 5. These concentrations were reported as milligram of metal per kilogram wet weight of sample. The concentration factors of heavy metals in the fish ranged from not found to 36.31 mg/kg. The magnitude of heavy metals concentration in *Tilapia's* organs were skin > grill > bone > mix > fillet. Concentration of Zn in fish-organs was the highest, while of the Cu and Pb were relatively lower. These results showed that the fish accumulated much more Zn and Cd than the other two metals, and the lowest metal concentration found in the fillet. This result then suggested that ones for eating fish should take only the fillet. Fish was an important food source for human and was a key unit in the natural food web. Toxication from the ponds may be best judged by examined the fish as its role interrelate with all other aquatic biota; e.g., plankton macrophytes etc.

Heavy metal contents in morning glory. Heavy metal concentrations in the tip and leaf were higher than the whole (roots associated with old leaf and stem). There was no vivid indication that physical nature of the tip and leaf was risky at toxic concentrations at a high level of heavy metal. Damage to consumer always happens for their life because people prefer to eat the tip and leaf than the whole. Plants always accumulate heavy metals from their ambient environment through physiochemical adsorption at the cell surface and adsorption by protein. This implied that the rather high levels of heavy metals may pose adverse effects on higher tropic organisms. Plant growth in water is limited by some physical and or chemical factors, for example, sunlight provides energy for aquatic plants. Nutrients are generally limiting growth factors, but in side the oxidation ponds are abundant.

Zinc in sediment sludge can transfer in to unsaturated soil (study in a soil column) ranged from 3-30 cm (mean 10 cm.). Most of the Zn applied to the unsaturated columns remained in the sludge-amended soil layer 96.1 to 99.6% (mean 98.1%). The major portion of Zn leached from sludge-amended soil layer accumulated in the 0-3 cm depth 35.7-100% (mean 73.6%). So when sludge were applied to the agricultural land, such heavy metals will accumulate in the soil and can be taken up by crops or leached to groundwater. (Welch and Lund, 1989)

The sixteenth meeting of the Joint FAO/WHO (WHO, 1993) expert committee on food additives and food contaminants recommended the provisional tolerable intake of heavy metal which contaminated in food should not exceed the amount listed in table 6.

Conclusion

Food (Fish and Vegetable). This study found that the most fish and vegetable, (*Tilapia* and morning glory) contain trace of Cd, Cu, Pb and Zn in polluted wastewater as its habitat. People who eat these food items will tend to ingest more heavy metals than those who do not. According to FAO/WHO proposed acceptable daily intake heavy metal in food for Cd 0.068-0.085 mg/kg food/day, Cu 35.71 mg/kg food/day, lead 0.510 mg/kg food/day and Zinc 21.429-71.429 mg/kg food/day expectedly (WHO, 1993).

From this point of view the data shown in table 6 almost exceed the standard acute effects have been seen where food has been contaminated by heavy metals.

Wastewater and sediment sludge. Prevention should be made for beneficial reuse of wastewater an sediment sludge as agricultural. Elevated concentrations of heavy metal on land receiving sludge are of public health concern because of phytotoxicity or increased movement of metals into the food-chain. (Heckman; Angle and Chaney, 1987)

Data on which these estimated from table 2 and table 3 have shown the health effects significance. The solubility of heavy metal in water and sediments are influence by the nature of source of heavy metals and the acidity of water. A few microgram of metal per litre have probably been contaminated to which wastewater or sediment sludge has been added. It should be realized that most food stuffs contain heavy metals that grown in polluted wastewater and sediment sludge are used as fertilizer.

For a short cut to minimize the thread of food-chain concentration accurate estimation of movement and potential for vegetable accumulation of wastewater borne trace metals is important.

References

APHA; AWWA and WEF. 1992. ***Standard methods for the examination of water and wastewater: part 3000 metals.*** 18th ed. Maryland: American Public Health Association.

Environmental Care Center Co., LTD. 1995. ***The study design Khon Kaen municipal wastewater treatment systems.*** Final report. Bangkok.

Heckman, JR; Angle, JS and Chaney, RL. 1987. Residual effects of sewage sludge on soy bean: I. Accumulation of heavy metal. ***J. Environ. Qual.*** 16 (1) : 113-117.

Kumar Nanda, PBA ; Dushenkov, V ; Motto, H and Raskin, I. 1995. Phytoextraction: the use of plants to remove heavy metals from soils. ***Environmental Science & Technology*** 29 (5) : 1232 -1238.

Welch, JE and Lund, LJ. 1989. Zinc movement in sewage-sludge-treated soil as influenced by soil properties, irrigation water quality, and soil moisture level. ***Soil Science*** 147(3): 208-214.

WHO. 1993. ***Guidelines for Drinking-water quality: health criteria and other supporting Information.*** 2nd ed. Geneva : WHO.

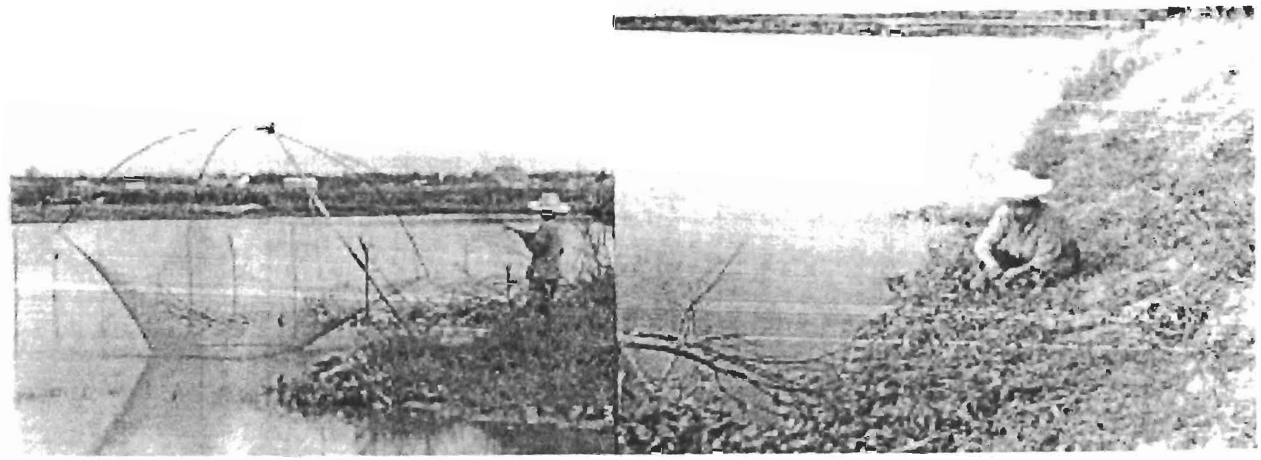


Fig. 1 We always see people come to catch fishes and take vegetables from wastewater treatment system.

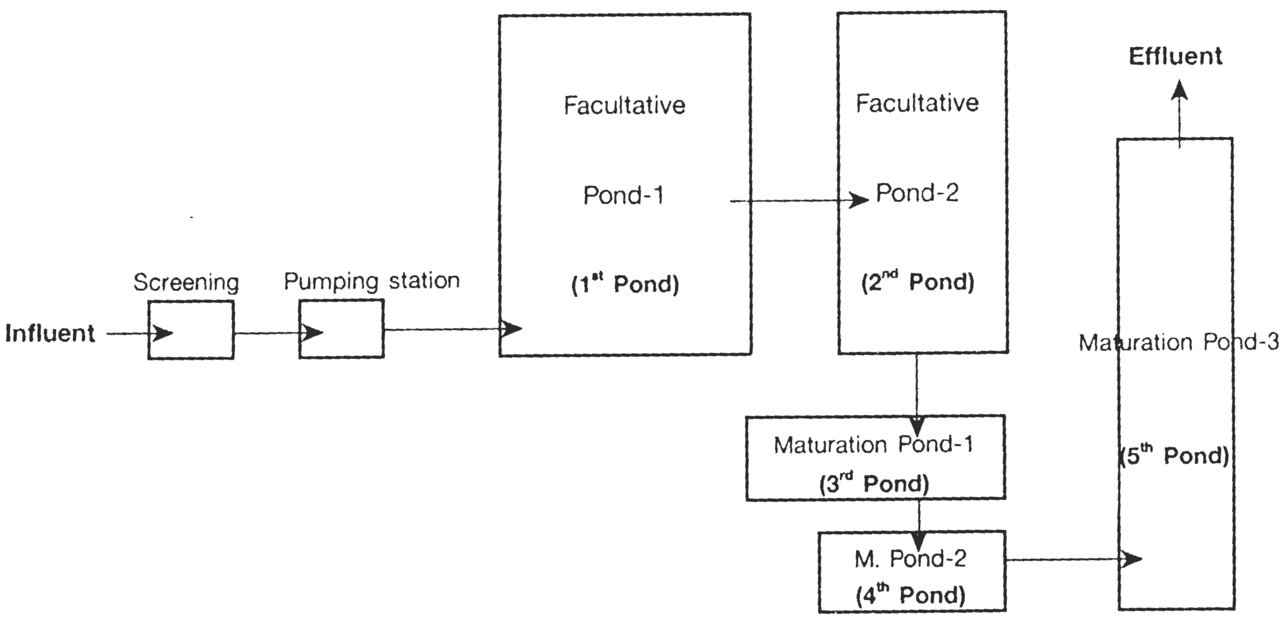


Fig.2 Flow diagram of Khon Kaen Municipal Wastewater Treatment Systems

Table 1 Approximate surface area, average depth, and detention time in each stabilization pond

pond	surface water (Rai)	depth (m)	detention time (day)
1. Facultative Pond-1	82.0	2	7.72
2. Facultative Pond-2	20.0	2	1.88
3. Maturation Pond-1	8.75	1.5	0.82
4. Maturation Pond-2	3.13	1.5	0.92
5. Maturation Pond-3	5.06	1.5	0.48

Table 2 Mean concentration of metals in wastewater

metals		mean concentration of metals in wastewater (mg/l)					
		1 st Pond	2 nd Pond	3 rd Pond	4 th Pond	5 th Pond	conclusion
Cd	Mean	0.39	0.39	0.39	0.20	0.19	0.31
	Min	0.0025	0.0045	0.0050	0.0025	0.0025	0.0025
	Max	0.5795	0.5765	0.5770	0.5830	0.5830	0.5830
Cu	Mean	1.52	1.52	0.76	0.76	0.76	1.07
	Min	0.0095	0.0075	0.0115	0.0070	0.0096	0.0070
	Max	2.2770	2.2855	2.2675	2.2695	2.2755	2.2855
Pb	Mean	1.95	1.99	1.75	1.49	1.269	1.69
	Min	0.0875	0.03750	0.0865	0.01375	0.01375	0.0137
	Max	3.3125	3.07526	2.7542	3.1375	2.4762	3.07526
Zn	Mean	0.47	0.53	0.52	0.55	0.45	0.50
	Min	0.4124	0.5043	0.2719	0.3944	0.3300	0.2719
	Max	0.5243	0.5407	0.6962	0.6739	0.5381	0.6962

Table3 Mean concentration of metals in sediment sludge*

metals		mean concentration of metal in sediment sludge (mg/kg)*					
		1 st Pond	2 nd Pond	3 rd Pond	4 th Pond	5 th Pond	Conclusion
Cd	Mean	0.153	0.085	0.056	0.052	0.51	0.14
	Min	0.1400	0.0350	0.0375	NF	0.0450	NF
	Max	0.1650	0.1456	0.0856	0.1075	1.3252	1.3252
Cu	Mean	7.72	6.82	5.46	5.65	5.20	6.38
	Min	0.0700	0.3403	3.2985	0.2450	0.0600	0.060
	Max	13.2800	16.3850	7.2508	8.9003	7.8123	16.3850
Pb	Mean	6.76	2.63	2.13	2.05	1.25	3.28
	Min	5.240	0.0654	0.05	NF	0.3748	NF
	Max	9.150	5.00	4.008	3.90	2.9118	9.15
Zn	Mean	103.97	54.10	36.07	25.68	24.15	53.46
	Min	42.8795	20.0500	4.8925	7.6310	21.0060	4.8925
	Max	284.300	78.2500	61.4194	54.200	29.2365	284.300

* The values are on a dry weight basis

Table 4 Heavy metal concentrations in organs of *Nile Tilapia*

Nile Tilapia		heavy metal concentrations (mg/kg)			
		Cd	Cu	Pb	Zn
meat	Mean	2.48	0.33	NF	13.89
	Min	0.0096	0.0615	NF	NF
	Max	8.1700	0.7524	0.0917	37.3319
skin	Mean	6.14	0.61	0.03	36.31
	Min	0.0238	0.1087	NF	NF
	Max	31.9296	1.3537	0.2774	145.2890
grill	Mean	9.84	2.00	0.10	31.36
	Min	0.0063	0.2397	NF	NF
	Max	45.2412	8.5027	0.7514	105.6652
bone	Mean	5.52	0.74	0.01	23.42
	Min	0.0255	0.2199	NF	NF
	Max	18.8041	2.2565	0.0993	51.7017
mix	Mean	2.54	0.46	0.01	19.32
	Min	0.0094	0.1188	NF	NF
	Max	10.9444	1.2529	0.7464	41.0235

Table 5 Heavy metals concentration in components of morning glory

metals		concentration in components of morning glory (mg/kg)*											
		1 st Pond		2 nd Pond		3 rd Pond		4 th Pond		5 th Pond		conclusion	
		Tip leaf	Whole	Tip leaf	Whole	Tip leaf	Whole	Tip leaf	Whole	Tip leaf	Whole	Tip leaf	Whole
Cd	Mean	0.56	0.034	0.02	0.03	0.039	0.04	0.03	0.03	0.04	0.03	0.13	0.05
	Min	0.0169	0.0236	0.0140	0.0114	0.0186	0.0114	0.0170	0.0042	0.0245	0.0127	0.0110	0.0042
	Max	3.3031	0.0444	0.0254	0.0499	0.1009	0.0930	0.0381	0.0669	0.0618	0.0537	3.3031	0.3467
Cu	Mean	0.48	0.432	0.38	0.26	0.23	0.25	0.22	0.38	0.21	0.14	0.31	0.30
	Min	0.3038	0.3285	0.1627	0.1117	0.0807	0.1666	0.1104	0.3105	0.1450	0.0686	0.0807	0.0686
	Max	0.9820	0.5816	0.6251	0.5626	0.5743	0.3418	0.4290	0.5273	0.2315	0.2263	0.9820	0.5816
Pb	Mean	0.12	0.15	0.30	0.066	0.035	0.06	0.02	0.05	0.02	0.04	0.09	0.07
	Min	NF	0.0423	NF	0.0334	NF	NF	NF	0.0310	NF	NF	NF	NF
	Max	0.3917	0.2642	1.8160	0.1212	0.0857	0.1182	0.0374	0.1078	0.0514	0.0853	1.8160	0.2642
Zn	Mean	14.397	7.096	5.04	6.72	7.86	5.11	5.49	6.60	6.47	3.96	7.62	5.11
	Min	4.3963	3.6388	2.5903	2.8676	4.2735	0.4068	3.0598	4.7441	4.1295	3.4532	NF	NF
	Max	26.394	14.547	13.551	13.548	14.532	12.710	6.2995	7.7785	9.1318	4.4489	26.394	14.546

*The mean and range from all sections in 10 samples morning glory, The values are on a wet weight basis.

Table 6 The comparison of standard level and items detected in laboratory

Items	The acceptable daily intake standard level (mg/kg food/day)	Amount of detection in Laboratory		
		Fish (Mix) (mg/kg)	Vegetation (mg/kg)	
			Tip leaf	whole
Cd	0.068-0.085	2.54-10.944	0.13-3.303	0.05-0.347
Cu	35.71	0.46-1.253	0.31-0.982	0.3-0.582
Pb	0.51	0.01-0.746	0.09-1.816	0.07-0.264
Zn	21.429-71.429	19.32-41.024	7.62-26.394	5.11-14.546