J.Pest Control & Environ.Sci. Vol:5 No:2 pp 91 - 102 (1993).

COMPARATIVE TOXICITY OF FOUR HEAVY METALS TO *Gambusia affinis* AND *Daphnia magna* IN AQUEOUS SYSTEMS

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Recived 7/7/1993 Accepted 29/7/1993.

ABSTRACT

Cadmium , lead , mercury and tin in the form of water soluble cations were compared for their acute toxicity 96 h LC_{50}'s against the mosquito fish *Gambusia affinis* and the water flea *Daphnia magna*. Daphnids were more sensitive to all the tested heavy metals than the mosquito fish with 85-300 fold differences. Mercury was the strongest toxic cation, followed by tin, cadmium, and lead in a decreasing order.

The high susceptibility of *Daphnia magna* supports its use for detection of heavy metals in polluted aquatic ecosystems. On the other hand, the relatively tolerant behaviour of the mosquito fish *Gambusia affinis* qualifies it for its essential role as a biological larvivorous fish to control the disease.

Transmitting mosquito larvae particularly in stognant water systems. The data indicated also that cadmium and tin are more hazardous to aquatic biota than lead.

INTRODUCTION

Many species of fishes have been used for the biological control of mosquito larvae with

special emphasis on malaria vectors. Gambusia affinis has been used as a mosquito larvivorous fishes in North America since the turn of the century (Haas and Pol,1984). Generally, fish are more susceptible to environmental variations than terrestrial animals. Water quality is thus a limiting factor which should be considered in culturing fish including the mosquito fish, when introducing them to mosquito breeding areas. Heavy organic and inorganic pollutants released with industrial on agricultural water wastes can be thus lethal to the beneficial Gambusia affinis mosquito fish and other aquatic biota.

El-Basyouni (1988 a) reported that Tilapia zilli fish proved to be more sensitive than the mosquito fish (Gambusia sp.) to organic pesticides with about 5-20 folds in the LC_{50} values This finding favours the mosquito fish to be more qualified as a relatively more tolerant biological control agent against the mosquito larvae. This trend was supported by El-Basyouni (1988 b) who compared the toxic effect of dimethoate , methomyl , and fenvalerate insecticides on the mosquito fish Gambusia affinis and the Culex pipiens mosquito larvae. A selectivity factor of 125 fold was demonstrated for dimethoate , followed by methomyl which showed only a safety factor of 10 fold , while fenvalerate was the best selective.

Moffett and Yarbrough (1972) proved the correlation between development of resistance in Gambusia affinis to insecticides and the succinic dehydrogenase activity which was more responsive for inhibition by DDT , Toxaphene , and Dieldrin in the susceptible strain of the mosquito fish.

Motabar (1978) and Alio et al.(1985) reported that the mosquito fish Gambusia affinis is the most outstanding ammivorous fish useful in controlling the mosquito larvae in aqueous

ecosystems. In the literature there are few data on the toxic impact of heavy metals on the Gambusia fish. Kenaga and Moolenaar(1979) compared the acute sensitivity of fish,daphinids, aquatic vascular plants and algae to thousands of chemicals of heterogenous structures. They found that animals were more sensitive indicators of toxic effects than were vascular plants or algae. They concluded that toxicity data for fish and daphnids should be sufficiently restrictive to protect algae and aquatic vascular plants. Maki (1979) demonstrated the correlation between the sensitivity of Daphnia magna or the fathead minnow fish to a variety of chemicals. They found that daphnids are very suitable for toxicity prediction to aqueous organisms. U.S. EPA (1978) recommended that species indigenous to the receiving water could be used as a biological marker for detection of toxicity levels.

Enslein et al.(1989) described a structure-activity model of Daphnia magna median effective concentration (EC_{50}) based on rat oral median lethal concentration (LD_{50}) and structural parameters. They considered daphnid a suitable organism for reproducible toxicity data.

The use of acute toxicity tests for assessing the potential hazard of chemical contaminants to aquatic organisms is well documented(Johnson and Finley,1980).Static acute toxicity tests provide rapid and reliable concentration-response curves for estimating toxic effects of chemicals on aquatic organisms. These tests provide a data base for determining relative toxicity of a large number of chemical pollutants. Acute toxicity tests usually provide estimates of the exposure concentration causing 50% mortality (LC_{50}) to a test organism during a specific period of time. The application of LC_{50} has gained acceptance among toxicologists and is generally the most highly rated test for assessing potential adverse effects of chemical constituents to

aquatic life. Few data were reported about the effect of heavy metals on both daphnids and gambosia. Accordingly , this study was planned to compare the acute toxicity of the four heavy metals: cadmium , lead , mercury and tin on the mosquito fish Gambusia affinis and the water flea Daphnia magna in aqueous systems.

MATERIALS AND METHODS

Gambusia affinis culture:

The mosquito fish Gambusia affinis were collected from untreated irrigation canals and transferred to the lab. The fish was kept for acclimitization 10 days in dechlorinated tap water before experimentation. Commercial fish feed was used to feed the culture. Any dead fish was removed to reduce infections. The water tanks containing the stock culture were aeriated with a pump system. The water was changed after 2 - 3 days to avoid accumulation of wastes. Ten similarly-sized active Gambusia were transferred to each glass jar one liter capacity containing 500 ml of dechlorinated water. Three replicates were used for each treatment including the control, from average mortality counts, LC_{50} values were recorded.

Daphnia imagna culture:

A culture of water flea Daphnia magna from the Zoology Dept.,Faculty of Science was used in this study. They were fed a suspension of food (1 ml / liter) twice weekly for rearing and once for testing. The suspension food contained the algal culture of Chlorella pyrenoidoea.

For acute tests , 10 daphnids 12 $\pm$ 2 hr old were placed in the testing vials, 250 ml beakers each containing the feed. Each treatment had 3

replicates and the average 96 hr mortalities were plotted on the log / probit paper and from the fitted regression lines the LC_{50} values were deduced.

Chemicals used:

Cadmium chloride, lead nitrate, mercuric chloride, and stannrus chloride were the heavy metal salts used to prepare the stock aqueous solutions. All the salts were of the pure chemical grade quality. The freshly prepared solutions were used in the acute toxicity tests.

RESULTS AND DISCUSSION

The data in Table(1) show the LC_{50} values of the four tested heavy metals to Gambusia affinis. Mercury and then tin were the higher effective cations followed by cadmium and then lead in a descending order. The higher toxic cations (tin and mercury) showed higher slope values suggesting higher rates of penetration and uptake. On the contrary , lead showed the lower slope suggesting slower uptake.

Table (2) prresents the LC_{50} values for four heavy metal cations on Daphnia magna.Mercury,tin followed by cadmium and then lead in a descending order showed the relative acute toxicity to daphnids. Again,the more potent cations: mercury and tin showed the higher slope values suggesting rapid penetration and uptake. On the other hand , lead the least toxic had the least slope suggesting slower uptake.

This relative pattern is alnmost repeated for the same cations against both gambusia and daphnid. However , by comparing the LC_{50} values in both cases, it was clear that Daphnia is more susceptible than the gambusia fish. A fact which

Table (1)

Acute Toxicity of Four Heavy Metals to the Mosquito Fish Gambusia affinis

The Heavy metal	96 hr LC_{50} mg / ml (ppm)	Confidence Limits	Slope of Regression Line
Cadmium	16.32	16.14-16.50	3.64
Lead	194.28	194.08-194.48	2.842
Mercury	0.69	0.61-0.78	4.836
Tin	9.58	9.54-9.63	4.284

Table (2)

Acute Toxicity of Four Heavy Metals to the Water Flea Daphnia magna

The Heavy metal	96 hr LC_{50} ug / liter (ppm)	Confidence Limits	Slope of Regression Line
Cadmium	60.0	58 - 63	3.420
Lead	3400.0	3000 - 3900	3.204
Mercury	5.6	4.8 - 5.9	4.946
Tin	55.8	55.4 - 56.2	4.836

supports the recommendation of Daphnia as a sensitive bioindicator for detection of water pollution incidents.

Biesinger and Christensen (1972) reported 48 hr LC_{50} for mercury and cadmium on Daphnia magna to be 5 and 65 mg/liter, respectively. The corresponding figures for 96 hr LC_{50} values in the present study were 5.6 and 60 ug/liter , respectively. Elsebae et al.(1981) reported LC_{50} of 8 mg/liter for 72 hr $HgCl_2$ to mosquito fish. This indicates similarity in order and magnitude of toxicity. No other comparable data were reported in the literature for the acute toxicity of heavy metals on Gambusia affinis. Danielli and Davis (1951) suggested that the metal ions exert their toxic effect by covalent binding at cell surfaces , and that the difference in electronegativity of the various ions is a toxicity determining factor. However, it seems that the limiting factor is the affinity between the metallic cations and the reactive sites in the biological systems which indicate the ability to bind with proteins through SH group sites and the other chemical bands with other cytotoxic targets.

The low susceptibility of the mosquito fish Gambusia affinis is an advantage to this larvivorous fish to be a successful tolerant biological control organnism of the mosquito-transmitted diseases. Gambusia affinis is characterized by being tolerant to pollutants and capable of building resistant strains.Ferguson et al.(1966) described the mechanism of endrin resistance and the dynamics of uptake and release by resistant and susceptible strains of mosquito fish. They concluded that this fish has an unique tolerant systems. Gambusia affinis therefore can live in adequate numbers in relatively polluted aquatic ecosystems. It can be concluded that the water flea Daphnia magna is the recommended biological indicator for detection of aquatic pollution

with very low costs.Besides,Gambusia affinis the mosquito fish is less sensitive as a biological indicator but it is well qualified to tolerate pollutants and to be more tolerant in the aquatic environment capable of controlling the mosquito larvae. The data also throw the light on tin and cadmium as more hazardous pollutants than lead to the aquatic systems.

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الملخص العربي

مقارنة السمية الحادة لاربعة من المعادن الثقيلة على سمك الجامبوزيا و الدافنيا فى الانظمة المائية

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استخدمت المحاليل المائية لاملاح كل من الكادميوم - الرصاص - الزئبق - النحاس فى دراسة مقارنة للسمية الحادة بقياس التركيز المتوسط للموت بعد تعرض لفترة ٩٦ ساعة لكل من سمك الجامبوزيا وحيوان الدافنيا.

وقد أظهرت النتائج أن الدافنيا أعلى فى حساسيتها للتاثر بتلك المعادن الثقيلة بفروق تتراوح بين ٨٥-٣٠٠ ضعف ، وهذا يؤكد صلاحية الدافنيا ليس فقط فى التنبؤ بسمية المركبات العضوية بل تصلح ايضا للتنبؤ بسمية المعادن الثقيلة بنفس الكفاءة. وقد تبين ان سمية املاح الزئبق كانت أعلى المركبات المختبرة يليه النحاس ثم الكادميوم وكان الرصاص اقلها سمية لكل من سمك الجامبوزيا و الدافنيا. وتشير النتائج الى التحمل العالى النسبى لسمك الجامبوزيا فى تاثره بتلك السموم المعدنية مما يجعله يتحمل مثل هذه التركيزات فى البيئة فى مناطق انتشار البعوض فى أماكن المياه الراكدة لتلوثه وبذلك تستمر الجامبوزيا فى أداء وظيفتها فى المكافحة الحيوية ليرقات البعوض الناقلة للامراض.

كما تنبه النتائج الى المخاطر البيئية لكل من مركبات الزئبق و النحاس و الكادميوم و التى تفوق فى شدتها مركبات الرصاص.