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Fish physiology

**CARDIOVASCULAR AND RESPIRATORY CHANGES IN EEL,
ANGUILLA ANGUILLA L. DURING EXPOSURE TO LETHAL DOSES
OF LINDANE AT DIFFERENT WATER TEMPERATURES**

**ZMIANY W MIĘŚNIU SERCOWYM I W ODDYCHANIU U WĘGORZA,
ANGUILLA ANGUILLA L. W CZASIE EKSPOZYCJI W DAWCE LETALNEJ LINDANU
W RÓŻNYCH TEMPERATURACH**

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Heart rate and ventilation frequency were monitored in eel exposed to lethal doses of lindane at different water temperatures. A simultaneous bradycardia and hyperventilation followed by a decrease in the ventilation rate occurred after exposure to lindane. It is concluded that lindane kills fish by internal hypoxia induced by damage to the gills.

INTRODUCTION

The widespread use of pesticides has greatly benefited mankind by increasing food production and controlling vectors of serious human and animal diseases. However, we have largely overlooked the problem of environmental pollution caused by indiscriminate use of pesticides. The biological activity of pesticides is not only restricted to the target organisms but extends to non-target organisms as well (Brown, 1978). Among the pesticides, Lindane, a Gamma isomer of hexachlorocyclohexane, is more toxic than any of the other isomers. There is an abundant literature on the effects of lindane on aquatic organisms (Levain et al 1973; Jeanne, 1979; Hansen, 1980; Mendiola, et al. 1981; Łakota et al. 1983 and Reddy et al. 1986), yet the action and effects of lindane on the heart and ventilation rate have received scant attention. In view of this, the main objective of this study is to assess the effects of lindane

on the heart and ventilation frequency of the eel at different water temperatures.

MATERIAL AND METHODS

The tests were carried out on 64 healthy eel with a mean weight of 213.4 ± 73.3 gm. and length of 50.5 ± 7.6 cm. Two groups of fish were acclimated at 10°C and 18°C under appropriate experimental conditions. The heart rate of the eel was calculated from the electrocardiogram obtained with the method of Labat (1966). The respiratory rate was calculated by counting the mandibular movements. A stock solution of lindane was prepared in acetone which was used as an organic solvent since it has a low toxicity to fish (Alabaster, 1969). The fish were individually subjected to lethal doses of lindane in a glass aquarium containing 20 liters of aerated water. Changes in the heart rate and respiratory rate of the fish under the influence of lindane were recorded. Also, detoxication ability of the eel after a short exposure to the lethal dose of lindane was studied by placing the fish in aerated tapwater free of lindane.

RESULTS AND DISCUSSION

The toxicity of lindane to the eel at different concentrations and water temperatures is shown in Table 1. From this table it can be seen that the toxicity of lindane increased more than twice as the water temperature increased from 10°C to 18°C . For example, the fish died after 20h of exposure to 0.9 mg/l lindane at 10°C and a temperature increase to 18°C resulted in the survival being reduced to 9h. The effects of water temperature was also observed at different doses of lindane. The increase of lindane toxicity at the higher temperature may be attributed in part to differential uptake and in part to alteration in the susceptibility of the fish.

Table 1
Toxicity of lindane at different doses and temperatures

Doses mg/l	Toxicity of lindane/h	
	10°C	18°C
Control	Survived	Survived
0.9	20	9
1.8	8	3

Average of 8 fish.

Fig. 1. Effects of lindane and temperature on the heart rate of the eel

The results obtained are in agreement with Fisher and Wadleigh (1985). On the other hand, the data for heart rate and respiratory rate after exposure the eel to lindane at different doses and temperatures are summarized in Fig. 1 and Fig. 2. From these figures it can be seen that the lethal dose of lindane was temperature-dependent since changes in the heart rate and respiratory rate of the eel were found to be stronger at the higher than at the lower temperature. The results obtained (bradycardia and hyperventilation followed by hypoventilation) were found to be identical to the effects of hypoxia which points out to a similar mechanism of toxicity.

This result is an agreement with Basha et al. (1984); Madhu et al. (1984); Zlateva and Yurukova (1984), who demonstrated that lindane was known to cause hypoxic

Fig. 2. Effects of lindane and temperature on the respiratory rate of the eel

condition in the tissues and reduced the rate of oxidative metabolism. The increase in ventilation rate of the fish after exposure to lindane is known to maintain the delivery of oxygen to the gill surface as the oxygen content falls. There is a general agreement that the teleost fish can regulate their branchial surface function by modifying the blood circulation through the gills (Steen and Kruijsse, 1964; Hughes, 1972) and regulation of this surface to respiratory and ionic changes is related to the needs of the organism (Randall, 1972). It was found that a continuous exposure of the fish to lethal doses of lindane resulted in increasing hypoxia, eventually inhibiting the respiratory system due to anoxia of the nervous system. It has become

clear that lindane interferes with some of the mechanism involved in the uptake of oxygen by the gills and consequently can significantly affect the ability of the fish to respond to the additional stress of oxygen lack in its environment. The available studies are in an accordance with this finding since lindane was found to cause desquamation of the epithelial layer of the gills (Matei and Malgina, 1979); extensive disarray of the secondary lamellae (Dreett and Abel, 1983) and histological damages in the gill tissues (Studnicka et al. 1981).

Changes in the respiratory rate of the eel were found to be associated with a decrease in the heart rate. A decrease in heart rate after exposure to lindane has been suggested to be a mechanism that could alter the dynamics of blood flow in the vicinity of respiratory surface. Satchell (1960) and Holeyton and Randall (1967), indicated that the lower heart rate may facilitate oxygen uptake by permitting the blood to remain in the gill lamellae for a long period of time. Thus the overall effect of this mechanism would be to enable the fish respiratory apparatus to compensate for the hypoxia by exposing its blood to a greater volume of water. On the other hand, it was found that a continuous exposure of the fish to lindane results in a strong stimulation of the heart by the parasympathetic nerve, which eventually leads to a complete stop of the rhythmic contractions. It is likely that tachycardia observed during the experiments resulted from inhibition of the parasympathetic fiber and reduction in the vagal tone.

Table 2

Changes in the heart and respiratory rate of the eel after exposure to 1.8 mg/l lindane at different water temperatures and returned to clean-water

Time/min.	Heart rate/min.		Respiratory rate/min.	
	10°C	18°C	10°C	18°C
Control	30.00	35.10	29.11	34.40
5 min.	27.60	28.00	30.80	35.80
15 min.	20.40	18.20	27.30	44.20
Clean-water "15–20 min."	29.20	36.30	28.30	35.80

Average of 8 fish.

Detoxication ability of the eel after a short exposure to the lethal dose of lindane at different water temperatures is shown in Table 2. From this table it can be seen that placing the eel in aerated tap-water free of lindane resulted in a considerable detoxication ability of the eel since after about 15–20 minutes the heart and respira-

tory rate returned to normal. This rapid normalization was probably due to the fact that the eel lives in two different aquatic environments and tolerates considerable differences in ionic composition during migration (Kłyszajko et al. 1977).

CONCLUSIONS

1. The lethal concentrations of lindane was temperature-dependent.
2. Lindane alters the heart rate and respiratory rate in the manner identical to the effect of hypoxia, which points out to a similar mechanism of toxicity.
3. The survival of the eel under prolonged exposure to lindane may be dependent upon modifications in circulation and respiration and the ability of the heart and ventilation mechanism to function under the effects of lindane.
4. Placing the eel in aerated tap-water free of lindane results in return of the heart and respiratory rate to their initial form.

REFERENCES

- Alabaster J.S.**, 1969: Survival of fish in 164 herbicides, insecticides, fungicides, wetting agent and miscellaneous substances. *Int. Pest. Control*, 11: 29–35.
- Basha S., R. Prasada, R. Sambasiva and R. Ramana**, 1984: Respiratory potentials of the fish *Tilapia mosabica* under malathion, carbaryl and lindane intoxication. *Bull. Environ. Contam. Toxicol.* 32, 5: 570–574.
- Brown A.W.**, 1978: Ecology of pesticides. New York, J. Wiley & Sons, Inc.
- Drewett N. and P. Abel**, 1983: Pathology of lindane poisoning and hypoxia in the brown trout, *Salmo trutta*. *J. Fish Biol.*, 23, 4: 373–384.
- Fisher S. and R. Wadleigh**, 1985: Effects of temperature on the acute toxicity and uptake of lindane by *Chironomus riparius* "Meigen". *J. Econ. Entomol.* 78, 6: 1222–1226.
- Hansen Peter-Diedrich**, 1980: Uptake and transfer of the chlorinated hydrocarbon lindane in a laboratory fresh water food chain. *Environ. Pollut. Ser. A Ecol. Biol.* 21, 2: 97–108.
- Holeton G.F. and D.J. Randall**, 1967: Changes in blood pressure in the rainbow trout during hypoxia. *J. Exp. Biol.* 46: 297–305.
- Hughes G.M.**, 1972: Morphometric of fish gill. *Respirat. Physiol.* 14: 1–25.
- Jeanne N.**, 1979: Effects of lindane on division, cell cycle and biosynthesis in 2 unicellular algae. *Can. J. Bot.*, 57, 13: 1464–1472.
- Kłyszajko B., J. Muzykiewicz, R. Węgrzynowicz and G. Głębocka**, 1977: The effect of dieldrin "DBS" on the electrocardiogram of eel *Anguilla anguilla* L. *Acta Physiol. Pol.*, 28, 2: 179–186.
- Labat R.**, 1966: *Electrocardiologie chez les poissons téléostéens: Influence de quelques facteurs écologiques*. Toulouse Edouard Privat, Libraire-Editeur: 255.
- Levain N., F. Marano-Le Baron and C.R. Hebd**, 1973: Study of the effects of an organochlorine insecticide, lindane, on growth and structure of two unicellular algae, *Euglena gracilis* Z. and *Dunaliella bioculata*. *Seances Acad. Sci. Paris, (D)*, 276, 1: 37–40.
- Lakota S., A. Roszka, J. Roszkowski, C. Hebd**, 1973: Study of the effects of an organochlorine insecticide, lindane, on growth and structure of two unicellular algae, *Euglena gracilis* Z. and *Dunaliella bioculata*. *Seances Acad. Sci. Paris D*, 276 1: 37–40.
- Madhu C., R. Jayantha and R. Ramana**, 1984: Hematological changes in *Sarotherodon mossambicus* exposed to lindane *J. Food Sci. Technol.* 21, 1: 53–55.

- Matei V. and N. Malgina, 1979: Effect of pesticides on the branchial epithelium of a crucian carp. Inst. Biol. Vnutr. Vod., Akad. Nauk SSSR, 38, 68–80.
- Mendiola P., J. Mataix, M. Illera and G. Varela, 1981: Effect of lindane on protein nutritive utilization in trout (*Salmo gairdneri*). Rev. Esp. Fisiol., 37, 2: 141–146.
- Randall D.J., 1972: The relationship between gas and ion transfer across the gills of fish. Comp. Biochem. Physiol. 41, 629–637.
- Reedy M., Y. Venkateswarlu, P. Surendranath and Rao, 1986: Photophamidon and lindane induced changes in the hemolymph biochemistry of a penaeid prawn *Metapenaeus monoceros* "Fabricius". Natl. Acad. Sci. Lett. 9, 5: 155–157.
- Satchell G.H., 1960: The reflex co-ordination of the heart beat with respiration in the dogfish. J. Exp. Biol. 37: 719–731.
- Steen J.B. and A. Kruijsse, 1964: The respiration function of teleostean gills. Comp. Biochem. Physiol. 12: 127–142.
- Studnicka M., A. Sopińska and J. Niezgoda, 1981: Zmiany histologiczne w wątrobie i skrzelach karpia podanych działaniu DDT, lindane i HCH. Histochemical changes within liver and gills of carp exhibited to DDT, lindane and HCH influence. Roczniki Nauk Roln. SH. Med. Wet.
- Zlateva M and T. Yurukova, 1984: Effect of organochloride pesticides on cardiac muscle, a morphological assessment, Med.-Biol. Probl. 12: 159–166.

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STRESZCZENIE

Badano ilość skurczów serca oraz ilość oddechów w czasie ekspozycji węgorza w dawce letalnej lindanu w różnych temperaturach.

W wyniku badań stwierdzono bradykardię oraz początkowo zwiększenie ilości oddechów a następnie zmniejszenie.

Charakter zmian w mięśniu sercowym oraz w oddychaniu wskazuje na objawy hipoksji.

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