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EFFECT OF THE EXTREMELY LOW FREQUENCY, ELECTROMAGNETIC FIELD ON SOME BEHAVIORAL ASPECTS OF *OREOCHROMIS SPILURUS.*

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ABSTRACT

The impact of the extremely low frequency (50 Hz), electromagnetic fields (5 and 10 KV/m) on some behavioral aspects of the tilapia, *Oreochromis spilurus*, has been studied. Both fields strength showed no change in feeding behavior, however, the exposed fish were calm and tend to stay near the bottom of the aquarium. They can be very aggressive if they were stimulated (i.e. at the time of feeding). The opercular ventilation rates (OVR) decreased drastically among both field strengths exposed fish.

INTRODUCTION

It is not clear how the extremely low electromagnetic fields (EMF) affect animals. It has been found that the primary response of extremely low frequency (ELF) is related to the neural and neuro-endocrine organs (Polk and Postow, 1986; Anderson and Kaune, 1989). It was suggested that it promotes and may have association with cancer and other diseases (Wertheimer, and Leeper, 1979; Anderson, 1990; Silverman, 1990; Wood, 1993).

A great interest has increased to test the effects of such EMF on various biosystems. It has been found that the mechanism by which the EMF's can affect biosystems depends on the electric and magnetic properties of that system (Fam, 1980; El-Mashak, *et al.*, 1990). Earlier reports showed a possible relationship between exposure to EMFs and human health. Symptoms such as general malaise, headache, insomnia, upper respiratory tract infections, and fatigue are present among people exposed to electrical plants (Asanova and Radkova, 1966). Moreover, other reports showed that 50 and 60 Hz EMFs may be harmful to human health (Wertheimer and Leeper, 1979; Tomenius, 1986; Savitz *et al.*, 1988). In human studies, the principle source of information on the effects of ELF are surveys of utility workers and of people living near high voltage lines, a few laboratories and clinical studies and several epidemiological studies (Fadel *et al.*, 1994). Headaches, poor digestion, minor changes in ECG and EEG of humans have been reported (Waibel, 1975). Although the interaction of humans with EMF is the most important, many biological investigations are conducted with various animal species, because they provide integrated system that can be used in prospective studies in contrast to the retrospective studies done with human. Some reports showed a relationship between ELF-EMF and animal behavior, especially, animal activities (Waibel, 1975; Fadel *et al.*, 1994). While fewer studies reported the effects of high field intensities on animal behavior (Lovely, 1988**;** McGivern *et al.*, 1990). A decreased libido, loss of sleep, and increased irritability were observed among workers after prolonged exposure to EMF (up to 26kV/m) (Frey, 1993). Moreover,

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circadian rhythm of mammalians has been affected by electric (Wilson *et al.*, 1981, Maestroni *et al.*, 1988) or magnetic (Kavaliers *et al.*, 1984) fields.

Studies on the impact of the extremely low electromagnetic fields on fish behavior are rare. So the aim of the present study is to follow up the direct and late effects of extremely low electromagnetic fields on the behavioral responses of *Oreochromis spiluras*.

MATERIALS AND METHODS

Experimental Fish

The tilapia, *Oreochromis spilurus,* was used as the experimental species, due to its importance as one of the most popular edible commercial and cultivable fish. Juvenile tilapias (~10 cm in total length) were obtained from King Abdulaziz University hatchery and/or Ministry of agriculture hatchery.

Fish Exposure set up

Twenty five fish were kept in each glass aquaria (50 X 40 X 40 cm). They were kept under the same experimental conditions with continuous aeration (oxygen contents is 5-6 mg/l) and at room temperature (22-25 °C). One aquarium (50 X 45 X 25 cm) served as the control group and another one served as the exposure tank. Two aluminum sheets (46 X 46) put along the length of the exposure aquarium from each side and were connected to the field generator. For safety, the two aluminum sheets were wrapped carefully inside a plastic material to prevent any contact with water. The fish were fed 30% protein fish diet (RADWA, Jeddah, KSA).

The electromagnetic field was derived from a 50 Hz stabilized power supply that had a maximum 6000V output (CENCO, CAT# 87208, 115 Volts-60 cycles). The power supply input voltage was adjusted by using a Variac Lab Volt (Model # 187 AP, Buck Eng. Co., Inc, Farmingdale, N. J., USA).

Electromagnetic Field (EMF)

In this study, the impact of the extremely low frequency (ELF), electromagnetic field (EMF) on the tilapia, *Oreochromis spilurus,* were studied. The following biophysical characteristics were taken into consideration. Constant frequency of 50Hz was used. Two field strengths were used:

a. The internationally permissible field strength (5KV/m).

b. Higher field strength of 10KV/m.

The electric intensity was fixed during the exposure time (two weeks).

Experimental Groups

Table 1 show the two experimental treatments which were studied. One is the internationally permissible field strength (5KV/m) and the other is higher field strength of 10KV/m. The direct effect and the late effect of the EMF were estimated among the exposed groups as follows:

Control Group: Each treatment was assigned a control group which received no treatments.

Direct Effect Estimation Group: Fish were monitored directly (D) two weeks after exposure in order to measure the various parameters stated below.

Late Effect Estimation Groups: The fish were monitored after two (L1) and four (L2) weeks after the termination of exposure, in order to measure the different parameters stated bellow.

Behavioral Responses

The behavioral changes were monitored throughout the experimental period. For example, changes in movement, balance, feeding habits and respiration were assessed. The opercular ventilation rates per minute (OVR/min.) were determined for 12 individual fish at each experimental group (table1). Besides the monitoring of OVR every two weeks as explained above.

Statistical Analysis:

Statistical analysis was conducted by using the SPSS statistical package. One way analysis of variance was conducted to explore the impact of exposing fish to electromagnetic field (EMF) of 50 Hz and field strengths of 5kV/m and 10kV/m on the opercular ventilation rate (OVR). The strength of association which indicates the relative magnitude of the differences between means was calculated as described by Cohen (1988); and Pallant (2001). It was calculated as described in the following equation:

Eta squared = SS between groups/Total SS

The post hoc Scheffe multiple comparisons test was conducted to test the difference among the means of the various exposure groups (Zar, 1999; Pallant, 2001).

RESULTS

Behavioral Responses

Behavioral observations showed that there were no changes in swimming balance of the exposed fish (to 5kV/m and 10kV/m). Great changes in fish distribution in the water column can be observed among the directly exposed (to 5kV/m and 10kV/m). Fish which have been exposed to (5kV/m and 10kV/m) were calmer and stayed, most of the time, at the bottom of the aquarium. They move up to the surface of the water at the feeding time only. They stand at water column without any directional pattern. On the other hand, the control, L1 and L2 fish were distributed throughout the water column. The control, L1 and L2 fish were moving freely and distributed throughout the control aquarium and most of them seem as if they were holding the same direction. They gathered in the surface of the aquarium at the time of feeding. Then, they start to drop to the bottom to follow the food particles. There was no indication of imbalance in their swimming pattern.

Although the directly exposed fish (at 5kV/m and 10kV/m) showed calmness and tendency to stay in the bottom of the aquarium, they could be very aggressive and start to jump if they were stimulated at the time of feeding and cleaning of the aquarium.

The directly exposed fish maintained a normal feeding behavior. They feed aggressively at the feeding time in a nearly similar pattern as the control, L1 and L2 groups. The fish rise to the surface of the water column and feed normally. The experimental subjects fed aggressively on the diet. They picked up the food while it was drooping through the water column. They also grazed upon the food which reached the aquarium bottom and stopped feeding after satiation.

Opercular Ventilation Rates (OVR)

Respiration (opercular movement) among the control fish were a steady and regular movement of the operculum. However, the movements of the operculum among the exposed fish were not steady nor could be described as regular. The exposed fish had to move the operculum slowly once or twice then it stopped its movement for a few seconds. Then, a sudden two or three opercular movement was observed.

Respiration can be represented quantitatively as the opercular ventilation rates (OVR) per minute. Among the 5 kV/m directly exposed fish, a drastic decrease in the mean OVR (M= 14.00, SD=1.800) has been shown after one week of exposure. After two weeks of exposure, the rate was almost the same (M=13.75, SD=1.055). One week after cessation of the EMF exposure the rates jumped up to almost the control group levels and stayed at this level until the termination of the experiment, throughout the L1 and L2 period. A similar trend were observed among the 10 kV/m exposed fish where the OVR decreased to about (M=17.7, SD=1.500) one week of exposure and (M=17.00, SD=1.595) after two weeks of exposure. One week after stopping the EMF exposure, the rates jumped up to the levels comparable to the control group and stayed at this level until the termination of the experiment, throughout the L1 and L2 period.

A one way between groups analysis of variance was conducted to explore the impact of exposing fish to electromagnetic field (EMF) of 60 Hz and field strength of 5kV/m on the opercular ventilation rate (OVR). There was a statistically significant difference at the $p<.05$ level in OVR for the four experimental groups [F (3, 44) =1601.07, p=.000] as seen in table 2. A large effect size (effect size=.991) was detected by calculating the eta squared which indicates that the actual difference in mean scores between the groups. Post hoc comparisons using the Scheffe test indicated that the mean OVR for the D5 (M=13.75, SD=1.055) group was significantly different from C5 (M=37.7, SD=.888), L5.1 (M=38.00, SD=.853) and L5.2 (M=36.83, SD=1.267) groups (see Table 2 and Table 3).

Table 4 shows one way analysis of variance that conducted to explore the impact of exposing fish to electromagnetic field (EMF) of 50 Hz and field strength of 10kV/m on the opercular ventilation rate (OVR). There was a statistically significant difference at the p<.05 level in OVR for the four experimental groups [F (3, 44) =833.44, p=.0005]. A large effect size (effect size=.982) was detected by calculating the eta squared. Post hoc comparisons using the Scheffe test indicated that the mean OVR for the D10 (M=17.00, SD=1.595) group was significantly different from C10 (M=35.33, SD=1.155), L10.1 (M=38.00, SD=1.044) and L10.2 (M=36.33, SD=.778) groups as can be seen in Table 4 and Table 5.

Mortality

No mortalities were recorded along the experimental period.

Table1. The experimental groups, treatments and abbreviations used in the study.

Treatments	Groups	Abbreviations
5kV/m field strength		
	Control	C5
	Direct effect	D5
	First late effect	L1.5
	Second late effect	L2.5
10kV/m field strength		
	Control	C10
	Direct effect	D10
	First late effect	L1.10
	Second late effect	L2.10

Table2. One way ANOVA and Eta square test results of Opercular Ventilation Rates (OVR) for the different studied treatments at 5KV/m.

S.O.V.	Sum of Squares	df	Mean Square	F	Sig.	Eta Squired
Between Groups	5085.229	3	1695.076**	1601.074	000	.991
Within Groups	46.583	44	1.059			
Total	5131.813	47				

S.O.V.: Source of Variations.
df: degrees of freedom.
**: significant at 0.01
Eta squared = SS between groups/Total SS (Pallant, 2001)

Table3. Descriptive statistics of the Opercular Ventilation Rates (OVR) for the different studied treatments at the 5KV/m.

Groups	N	Mean*	Std. Deviation	Std. Error
C5	12	37.67 b	.888	.256
D5	12	13.75 a	1.055	.305
L5.1	12	38.00 b	.853	.246
L5.2	12	36.83 b	1.267	.366

* Means followed by the same letter are not significantly different according to Scheffe multiple comparisons test at 0.05 level of probability.

Table4. One way ANOVA and Eta square test results of Opercular Ventilation Rates (OVR) for the different studied treatments at 10KV/m.

S.O.V.	Sum of Squares (SS)	df	Mean Square	F	Sig.	Eta Squired
Between Groups	3485.333	3	1161.778**	833.449	.000	.982
Within Groups	61.333	44	1.394			
Total	3546.667	47				

S.O.V. : Source of Variations.
df : degrees of freedom.
** : significant at 0.01
Eta squared = SS between groups/Total SS (Pallant, 2001).

Table5. Descriptive statistics of the Opercular Ventilation Rates (OVR) for the different studied treatments at 10KV/m.

S.O.V.	N	Means	Std. Deviation	Std. Error
C10	12	35.33 b	1.155	.333
D10	12	17.00 a	1.595	.461
L10.1	12	38.00 c	1.044	.302
L10.2	12	36.33 b	.778	.225

* Means followed by the same letter(s) are not significantly different according to Scheffe multiple comparisons test at 0.05 level of probability.

DISCUSSION

The impacts of the extremely low frequency (ELF), electromagnetic field (EMF) [5 kV/m and 10 kV/m EMF field strength] on the behavior of the tilapia (*Oreochromis spilurus*) were studied. Both fields strength showed no change in feeding behavior. However, the exposed fish were calm and tend to stay near the bottom of the aquarium. They can be very aggressive if they were stimulated. The opercular ventilation rates (OVR) decreased drastically among the EMF exposed fish (Both field strength). The directly exposed fish maintained a normal feeding behavior. They feed aggressively at the feeding time in a similar pattern as the control, L1 and L2. Fish rise to the surface of the water column and feed normally. The experimental subjects fed aggressively on the diet. They picked up the food while it was drooping through the water column. They also grazed upon the food which reached the aquarium bottom and stopped feeding after satiation.

Although the directly exposed fish (at 5kV/m and 10kV/m) showed calmness and tendency to stay at the bottom of the aquarium, they could be very aggressive and start to jump if they were stimulated at the time of cleaning the aquarium. This was in agreement with the effect of EMF on mice and Rats behavior (El-Mashak *et al.*, 1992; El-Mashak and El-Gebaly, 1994; Kumosani *et al.*, 1996). In humans, varied behavioral effects have been shown, such as Sleepness. Such variations in behaviour may be related to effects of the EMF on the brain (; Dumanski and Shandala, 1974; Belokrinitskiy, 1982; Von Klitzing, 1995; Kolodynski and Kolodynska, 1996).

Respiration among the control fish were steady and with a regular movement of the operculum. However, the movements of the operculum among the exposed fish were not steady nor could be described as regular when compared with the control. The exposed fish had to move the operculum slowly once or twice then it stopped its movement for a while. Then, sudden two or three opercular movements were observed. Among the 5 kV/m directly exposed fish, a drastic decrease in the mean OVR (13.75) has been shown after two weeks of exposure. One week after cessation of the EMF exposure the rates jumped up to almost the control group levels and stayed at this level until the termination of the experiment, throughout the L1 and L2 period. A similar trend was observed among the 10 kV/m exposed fish where the OVR decreased to (17.00) after two weeks of exposure. One week after stopping the EMF exposure, the rates jumped up to the levels comparable to the control group and stayed at this level until the termination of the experiment, throughout the L1 and L2 period. Previous studies indicated a decrease in opercular ventilation rate when fish was exposed to a stressor. Omoregie *et al.*, (1998), reported a decrease a decrease in the operculer ventilation rate, when fingerlings of the Nile tilapia, *Oreochromis niloticus*, were exposed to various levels of malachite green, an anti-fungal agent. Another study indicated that opercular ventilation rate has been affected severely when catfish fry, *Plecostomus commersoni*, were exposed to Paraquat, a commercial herbicide (Tortorelli *et al.*, 1990).

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