Effect of Electromagnetic Field on Mass of Earthworms

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Accepted on July 4, 2013

Abstract
Various experiments have been conducted on the effect of both high and low electromagnetic radiations on man and animals especially rabbit and rats. However, much work has not been done on fauna and flora with fragile systems. This work centres on the short term effect of low frequency electromagnetic field on earthworms (Lumbricus sp.). The experiment was carried out using a population of earthworms exposed to electromagnetic field of frequency of 36kHz and 42kHz for four hours daily for a period of nine days. Statistical analysis showed that there was a decrease in the mass of earthworms exposed to fields at 42 kHz and 36 kHz while the control experiment showed no such decrease.

Keywords: *earthworms, electromagnetic field, magnetic field,*

Introduction
Technological advancement despite its advantages has some downsides, one of which is the exposure of living systems to various fields. Unconsciously, we are continually inundated with electromagnetic waves on a daily basis. However, to date, there is an inadequate knowledge on the effect of these radiations on biological systems by devices emitting these radiations.

When an organism is exposed to an electromagnetic field, some of the electromagnetic energy is absorbed by the body and converted to heat. Excessive heat load and elevated body temperature can be detrimental to health. This is termed thermal effect. Although there non-thermal effects exist, yet there are no biophysical mechanisms to satisfactorily explain them. (Oresegun, 2003).

The radio spectrum of the electromagnetic field can be classified into four broad categories according to frequency range: Radio frequency (RF) (100 kHz $< f \leq$ 300 GHz), intermediate frequency (IF) (300 Hz $< f \leq$ 100kHz), extremely low frequency (ELF) ($0< f \leq$ 300 Hz), and static (0 Hz). These frequencies are emitted from devices such as visual display units (monitors, televisions etc), anti theft devices, hands free access control systems, card readers and metal detectors, Magnetic Resonance Imaging, Welding devices. Bone growth stimulation is used as a therapeutic application in the IF range. In this case coils are applied where the fracture is located to stimulate the healing process. Other applications include Transcranial Magnetic Stimulation, wound healing, or pain treatment. A diagnostic application is the bioimpedance measurement for cancer detection (SCENIHR 2007).

With various regulations and reports on the effect of electromagnetic waves on man ICNIRP (1998); IEGMP (2000); RSC (1999) and HCN (2002), very few researches have been conducted on sensitive and fragile but economically important animals such as earthworms, insects, etc.

Earthworms play **important** role in soil ecology. Soil is made more fertile through the activities of earthworms by continual soil loosening, stirring up and aerating (Sarojini T.R, 2007). Earthworms also form a source of food for many animals, and constitute the principal food of moles and shrews (Microsoft Encarta, 2009). The earthworm has well-developed nervous and circulatory system. They have moist skin and stay near moist environment Sarojini T.R (2007). Earthworms must live in moist soil containing organic matter. They usually live in the upper layers of the soil, but in winter, they penetrate more deeply to escape frost. These characteristics make them ideal specimen for the measurement of electromagnetic effect on fragile animals.

Sakurai *et al*., (2010) investigated the effect of Extremely Low Frequency (ELF) magnetic fields on Insulin-secreting cells. In short time exposure to ELF magnetic fields at 5 mT, glucose-stimulated insulin secretion was decreased and prevention of the increases in cellular ATP/ADP, membrane depolarization, and cytosolic free calcium ion concentration were observed. Uloziene *et al*., (2005), studied the effect of EMF on Hearing Threshold Levels (HTL) on Pure Tone Audiometry (PTA) and Transient Evoked Otoacoustic Emissions (TEOAE's) of young adults for a short duration of 10 minutes. The highest change observed was 10dB in TEOAE. Repacholi (1997) exposed a mouse strain that has been genetically modified to spontaneously develop lymphomas to RF for 30 minutes a day during an 18 months period. The overall effect was doubling of the number of tumors. Lilienfeld *et al*., (1978); ICNIRP (1998) proposed that body temperature does not rise by more than 1K after exposure to radiation. Further investigations on the effect of ELF on living things has revealed effects such as DNA damage (Lai and Singh, 2004), leukaemia in humans (Ahlbom *et al*., 2000; Greenland *et al*., 2000), skin tumors in rats (Kumlin *et al*., 1998), accelerated development of mammary tumors (Baum *et al*., 1995; Fedrowitz *et al*., 2004) and increase in cell proliferation workers in rat mammary gland (Fedrowitz *et al*., 2002).

Materials and Method

In order to determine the effect of electromagnetic field (EMF) on earthworms, the following experimental setup was employed. Copper coils of diameter 11.5mm was wound round two (2) containers A and B with radius 9cm and 6cm respectively. In the first container labeled (A), there were two hundred and fifty turns while on the second container (B), were wound one hundred turns. Signals from a frequency generator were applied to both coils. The resistance of the coil used was measured as 19 ohms. A third container (C) was also utilized with no coil as the control experiment. This was placed at a considerable distance from containers A and B to prevent stray EMF from interfering with it. The field in container A was determined to be at 42 kHz while the field in container B was measured as 36 kHz using a search coil.

Soil samples containing organic matter (top soil with 25cm^3 humus) was collected and carefully placed in the three containers (A, B, and C). Ten earthworms, considered suitable, were selected at random. Each earthworm was carefully washed and the individual mass determined using a digital balance to an accuracy of 0.001g. They were placed in the three containers in groups of threes. The containers A and B were kept at a distance of 20 metres apart while container C was completely removed from the effect of the electromagnetic field.

The experiment was carried out for a period of nine days. Fresh water was sprinkled equally to the soil sample containing the earthworms in all the containers everyday to keep the earthworms moist. Also, fresh soil samples of top layered humus soil were sourced and introduced into the containers every three (3) days to allow for proper feeding and nutrients of the earthworms. The electromagnetic field was switched on in the containers (A and B) for a period of four hours continuously and once every day after which observations were made. The earthworms in each container were taken out in turn once a day for the period of the experiment for weighing. Each earthworm was washed and weighed before placing it back in the container.

To measure the effect of electromagnetic on the mass of the earthworms with respect to time the correlation, rate of mass loss/gain and total mass difference are computed. *Correlation* quantifies the strength of a linear relationship between two variables (Equation 1).

$$Correl(X,Y) = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}} \qquad (1)$$

where x and y are the sample means.

When there is no correlation between two variables, then there is no tendency for the values of the variables to increase or decrease in tandem. The correlation coefficients range from -1 to 1, where

- Values close to 1 indicate that there is a positive linear relationship between the data columns.
- Values close to -1 indicate that one column of data has a negative linear relationship to another column of data (*anticorrelation*).
- Values close to or equal to 0 suggest there is no linear relationship between the data columns.

The rate of mass loss/gain shows how fast the mass of the earthworms increase/decrease with respect to time (Equation 2). A negative value shows a mass loss while a positive number indicates mass gain. Rapid mass loss/gain is easily seen from the high value of the rate of mass loss/gain.

$$\text{Rate of mass loss/gain} = \frac{\text{final mass - initial mass}}{\text{time difference}} \qquad (2)$$

The total mass difference is the difference between the initial mass and final mass while the mean mass is the average of the experimental mass for each sample.

Results and Discussion

A1, B1 and C1 are the masses of earthworm 1 in container A, B and control containers C respectively. Similarly, A2, B2 and C2 refer to masses of earthworm 2 in containers A, B and C respectively. A3, B3 and C3 refer to the third earthworm in containers A, B and C respectively. The mean of the three earthworms in each container was also evaluated and presented in Table 1.

Table 1: Masses of Earthworm exposed to 42 kHz, 36 kHz and control experiment.

DAY	A1	A2	A3	Mean	B1	B2	B3	Mean	C1	C2	C3	Mean
Correlation	-0.984	-0.974	-0.978	-0.967	-0.629	-0.938	-0.980	-0.828	0.862	0.828	0.966	0.901
Total mass difference(kg)	0.110	0.052	0.009	0.057	0.111	0.033	0.032	0.059	-0.133	-0.103	-0.019	-0.085
Rate of mass change(kg/day)	-0.014	-0.007	-0.001	-0.007	-0.008	-0.004	-0.004	-0.005	0.017	0.009	0.002	0.010
Mean (kg)	0.211	0.054	0.006	0.091	0.256	0.057	0.030	0.115	0.651	0.152	0.063	0.289

The mean mass of the three samples is seen to be highest for the control experiment while the samples exposed to 42kHz field showed the lowest mean. Total mass difference is negative for earthworms exposed indicating loss of mass.

From the experiment, at a frequency of 42 kHz, the earthworms show a significant reduction in mass for the period under investigation. A1 showed a marked decrease in mass from an initial mass of 0.272kg to 0.162kg. This is confirmed with a correlation coefficient of -0.9843. Other earthworms (A2 and A3) showed the same trend with mean mass decrease of 0.052kg and 0.009kg respectively. Other earthworms in container A (A2 and A3) also exhibit strong correlation coefficients of -0.974 and -0.978 respectively. The mean of the total mass difference and mean rate of change of mass of all earthworms in container A were calculated as 0.057kg and -0.007kg/day respectively. On the average, the analysis showed that the relationship between the mass of the earthworm and days of exposure at a frequency of 42 kHz has a strong negative correlation coefficient.

At a frequency of 36 kHz, there was also a marked decrease in mass with the highest decrease noticed in earthworm B1 (0.111kg). The average mass loss was calculated as 0.059kg. This experiment group (36 kHz) also showed a fairly strong negative correlation of -0.6289, -0.6289 and -0.9797 for B1, B2 and B3 respectively. Rate of mass change was also negative for all the earthworms with a mean rate of mass change given as -0.005kg/day.

However, the control experiment (C1,C2 and C3) did not show the mass decrease experienced in the 42kHz group and 36kHz group. The total mass difference for all earthworms were negative while positive correlation and rate of change were obtained.

Negative correlations are observed for samples exposed to electromagnetic fields while the control experiment showed positive correlation. The negative correlation seen in the test sample are close to -1 showing strong anticorrelation. As time of exposure of the earthworm increases, the masses of the earthworm decreases.

The effect of the strength of the electromagnetic field on the masses of the earthworms can be inferred from the rate of mass change. Earthworms exposed to 42kHz electromagnetic field showed higher values for rate of change than earthworms exposed at 36kHz. It can be inferred that the higher electromagnetic field causes a more rapid rate of mass loss than the lower electromagnetic field. The control experiment showed positive rate of change which implies mass gain with respect to time (normal mass gain).

It is well recognized that there are established biophysical mechanisms that can lead to health effects as a consequence of exposure to sufficiently strong fields. For frequencies up to, say, 100 kHz the mechanism is stimulation of nerve and muscle cells due to induced currents and, for higher frequencies, tissue heating is the main mechanism IARC (2002).

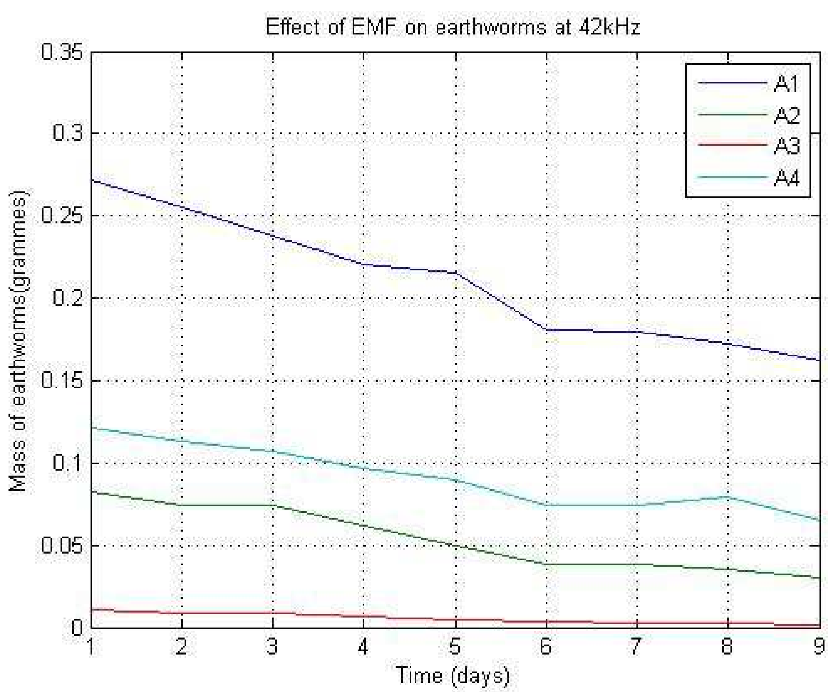

Figure 1: Effect of EMF on mass of earthworms at 42kHz.

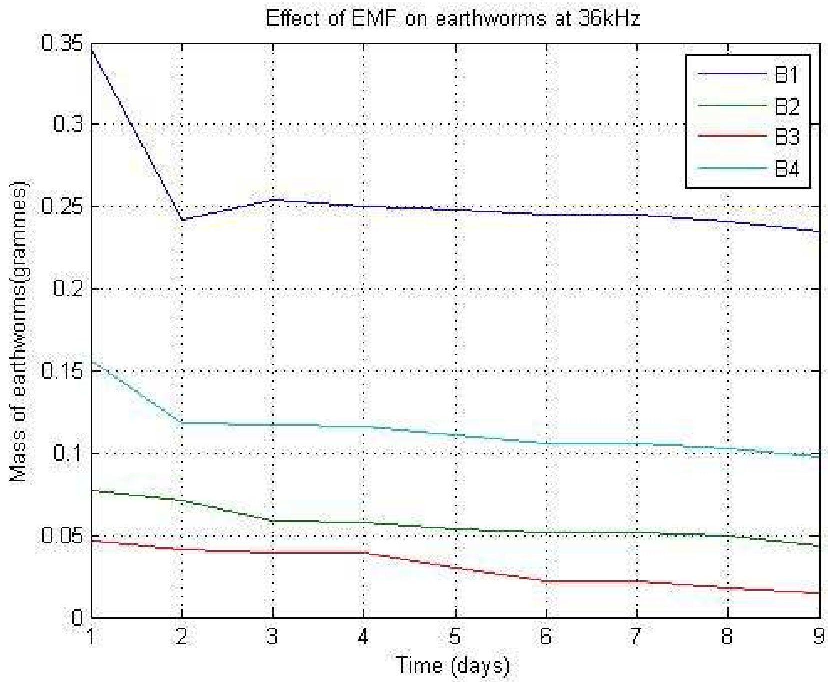

Figure 2: Effect of EMF on mass of earthworms at 36kHz.

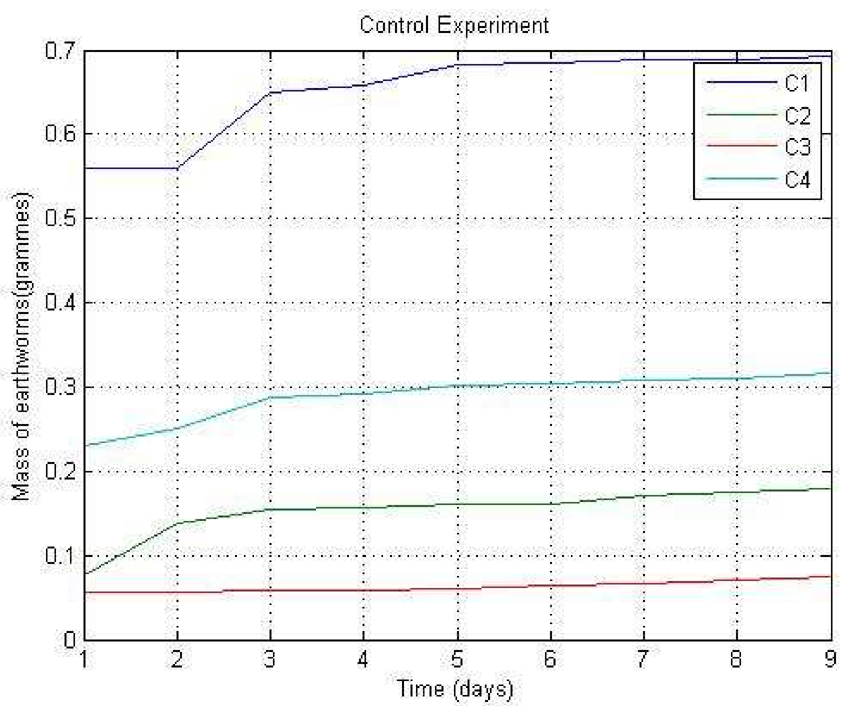

Figure 3: Variation of mass of earthworms with time in the control experiment.

Conclusion

It can be inferred that at frequencies 42 kHz and 36 kHz there is a negative effect on the mass of earthworms. Experiments to measure the effect of EMF on larger population of earthworms for longer period should also be considered. It is also imperative that more research work be done not only on earthworms but other fragile but economically viable animals.

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