Journal of the Nigerian Association of Mathematical Physics
***Volume* 14 (May, 2009), pp 159 – 164**
© J. of NAMP

The effect of extreme-low-frequency electromagnetic field on air borne particles concentration

L. Bamidele
Department of Mathematics and Statistics,
Osun State College of Technology, Esa-Oke, Nigeria

Abstract

Electromagnetic fields produce alternating electric fields and modify static electric fields in the vicinity. These electric fields, if large enough, can alter the concentration or transport of airborne particles (including particles harmful to health). In this study, the concentration of radioactive materials (gamma radiation) was monitored around transmission power lines. The result of this study shows that there is an increase in concentration of air borne articles but not high enough to cause health hazard.

1.0 Introduction

The electromagnetic field is a physical field produced by electrically charged objects. It extends indefinitely through space and describes the electromagnetic interaction. Electromagnetic field is one the four fundamental forces of nature (the others are gravitation, the weak interaction, and strong interaction). The field can be viewed as the combination of an electric field and a magnetic field. The electric field is produced by stationary charges and magnetic field by moving charges (currents). These two are often described as sources of the field. Electromagnetic field affects the behaviour of charged objects in the vicinity of the field.

Electromagnetic fields are present everywhere in our environment though invisible but they can be measured. Naturally, electric fields are produced by the local build–up of electric charges in the atmosphere associated with thunderstorm. The earth's magnetic field causes a compass needle to orient in a North-South and is used by birds and fish for navigation. Besides natural sources, the electromagnetic spectrum also includes field generated by human sources, x-rays are employed in medical diagnosis, the electricity that come out of every power socket WHO, [1].

The time-varying electromagnetic fields produced by electrical appliances are an example of extreme low frequency (ELF) fields. ELF fields generally have frequencies from 300Hz to 10MHz and radio frequency (RF) fields with frequencies of 10MHz to 300GHz. Electricity power supply, all appliance and lightning from local home and workplace, distribution wiring from major national electric grids are the main sources of extreme low-frequency (ELF) fields.

For nearly two decades there had been speculations that electric and magnetic fields produced by power system may be harmful, to health. The suggestions had largely stemmed from epidemiological studies Nancy Wertheimer and Edleeper [2]; Savits [3]; Nair et al [4];

---

e-mail: bam07ng@yahoo.com
Telephone: 08067912315

Davis, Mirick et al [5], but the consensus scientific opinion is that such a link has not been established. Doll [6], Portier and Wolfe [7]; Swanson et. al [8]. Henshaw et al, [9], suggested that a candidate for such harmful effect may be “the attraction of radon daughter nuclei in normal domestic room air to every day source of low frequency electromagnetic fields” and their observations show that electromagnetic fields can concentrate in their vicinity a cocktail of radon daughter nuclei, a known carcinogen and presumably other potentially harmful agents. They also suggested that this evidence may help explain the link between exposure to electromagnetic fields and the incidence of certain types of cancer.

In this study, the concentration of radioactive elements around electric power lines were monitored and the results obtained were compared with the International Atomic Energy Agency (IAEA) minimum value of ionizing backgrounds radiation to cause health hazard.

2.0 Theoretical basis

In this section, an expression for the polarization force on a particle near a long straight wire is obtained. This is then used to calculate the increase in concentration near wire, to calculate the increase in the time taken for this increase in concentration to build up, and to compare the force on the particle to its weights.

The polarization force F on a spherical particle of radius r and relative permittivity $\epsilon \gg 1$ is given by Bleancy [10].

$$F = 4\pi r^3 \epsilon_0 (E. \nabla) E \tag{2.1}$$

where ϵ_0 is the permittivity of free space. In one dimension, equation (2.1) simplifies to

$$F_x = 4\pi r^3 \epsilon_0 E \frac{dE}{dx} \tag{2.2}$$

Consider the case of a single long straight wire of radius x_0 and surface electric field E_0. The electric field at a distance x from its center is

$$E = \frac{x_0 E}{x} \tag{2.3}$$

and hence, combing equations (2.2) and (2.3)

$$F = -4\pi \epsilon_0 r^3 \frac{x_0^2 E_0^2}{x^2} \tag{2.4}$$

The polarization force causes the particles to drift towards the source of the field and hence causes concentration to increase closer to the source. This is countered by diffusion operating in the reverse direction. When an equilibrium has been established, the two are equal and opposite:

$$-D = \mu F n \tag{2.5}$$

where D is the diffusion coefficient, n the particle concentration, and for this equation only, μ is the general mobility rather than the electrical mobility. Equation (2.5) can be solved for various forms of F. However, a more elegant approach is to calculate the work done against the polarization force in bring a particle to a distance x from infinity:

$$W = \int_x^\infty F dx = -2\pi c_0 r^3 E_0^2 \frac{x_0^2}{x^2} \tag{2.6}$$

for the case of the single wire. The concentration of particles is then obtained by inserting this energy into the Boltzmann distribution. Walton [11].

$$\frac{n}{n_\infty} = e^{-WKT} \tag{2.7}$$

Both methods, i.e. equations (2.6) and (2.7), lead to the same result:

$$\frac{n}{n_\infty} = \left(\frac{\exp 2\pi c_0 r^3 E_0^2 x_0^2}{kTx^2} \right) \tag{2.8}$$

On the surface of a wire, at $x = x_0$, this expression becomes independent of x_0. On the surface of a 400*kV* conductor, $E_0 = 1.5 \times 10^6\ Vm^{-1}$, and on the surface of a thin wire at mains potential, $E_0 = 6 \times 10^4 Vm^{-1}$. In both cases, the increase in concentration for ultra fine particles (radius < $10^{-8}m$) is a few millimeters of the surface. Large increases in concentration on the surface are predicted for attached radon daughters and bacteria. These increases are unlikely to occur in practice. They will occur only if the system is free of perturbations for a sufficiently long time for the increase in concentrations to build up. The time *t* required for a particle to reach the surface of the conductor, starting at a distance of *k* conductor radii, is

$$t = \frac{3\eta x_0^2}{8\varepsilon_0 r^2 E^2}\left(k^4 - 1\right) \tag{2.9}$$

where η is the viscosity of the medium (1.8×10^{-5} Pa for air). The time taken to move just the final centimeter on to the surface of a high-volume conductor is of the order of $10^3 s$ for an attached radon daughter and 5*s* for a bacterium. The maximum speeds produced close to the surface of the conductor are of the order $10^{-4}ms^{-1}$ for the, $10^{-3}ms^{-1}$ for the attached and $10^{-1}ms^{-1}$ for bacteria. These speeds fall as the cube of the distance from the conductor, so is a factor of 10^3 smaller just 0.01 m from the power line conductor. Air speeds are typically 0.2-10m^{-1} outdoors and up to 0.3ms^{-1} close to the human body, rather greater than the speeds obtained by radon daughters. In practice, therefore, the motion of the particles under polarization forces is swamped by air current and any increase in concentrations is vastly less than predicted above.

The weight of a particle is $mg = 4\pi r^3 \rho g/3$, where *m* is the particle mass, *g* is the acceleration due to gravity and ρ is the particle density, assumed to be that of water, $10^3 kgm^{-3}$. Because both the polarization force and the weight are proportional to the particle's volume, the ratio of the two is independent of the particle size. The polarization force exceeds the weight for $(E - \nabla)E > \rho g/3\epsilon_0 \approx 4 \times 10^{15} V^2 m^{-3}$, which in practice never occurs. For a single wire as already considered in equation (2.3)

$$\frac{F}{mg} = \frac{3\varepsilon_0 r^3 E_0^2 x_0^2}{pgx^3} \tag{2.10}$$

for a high-voltage power line conductor, $F/mg = 0.6$ on the surface and drops to 0.01 at around 0.04 m. Therefore, except very close to the conductor surface, polarization forces are negligible compared with the gravitational forces which all particles experience (Swanson, et. al. [8].

3.0 Materials and Methods

Measurements of radiation dose were made of using digilert 50 nuclear radiations Geiger Muller counter. The measurement was carried out at Power Holding Company subtraction in Edo State, Nigeria.

Four different high tension power lines 330*kV*, 132*kV*, 33*kV*, and 11*kV* environment were monitored. Also, the free area where there were no transmission line cables was monitored.

The measurements were carried out by positioning the radiation meter directly under high-tension transmission line cable at about one meter above the ground to avoid the interference of other radioactive elements.

4.0 Results and discussion

The results obtained are shown below

Table 4.1

Transmission line	**Mean radiation dose Gy/*hr***
330*kV*	18.14×10^{-8}
132*kV*	17.30×10^{-8}
33*kV*	17.01×10^{-8}
11*kV*	13.85×10^{-8}
Free Zone	13.58×10^{-8}

From the results, clear differences were seen between the mean radiation dose under the transmission lines cable and the free zone. In order to have a clear comparison, a graphical representation of the result obtained is shown in Figures 4.1 and 4.2.

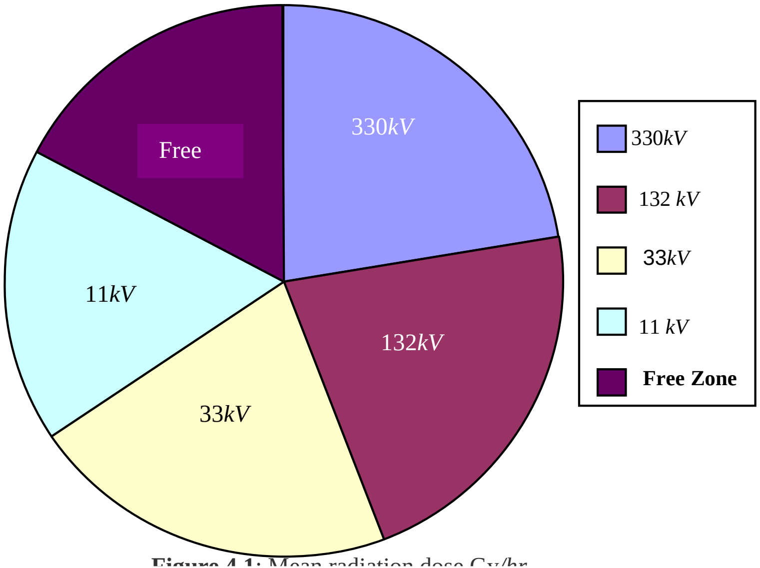

Figure 4.1: Mean radiation dose Gy/*hr*

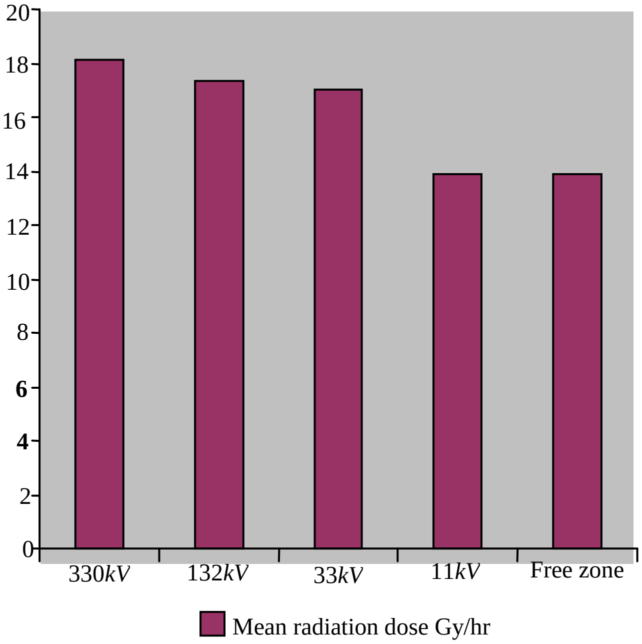

Figure 4.2: Mean radiation dose Gy/*hr*

Henshaw et al [9] measured plate out of radon daughter products by observing the tracks left by alpha particles, after etching in TARSTRAK plastic detectors. Increased plateout was observed in several situations.

Few and Henshaw [11] deployed similar TARSTRAK detectors outdoors near a 400kv transmission line. Results are reported as deposition velocities, which is less direct than plate-out rates but which normalizes for any local variations of radon concentration.

Clear differences are seen under the line compared with far distance from the line (though not in proportion to the electric field).However, McLaughlin and Gath [12] used similar detectors with different support arrangement but failed to find any significant change in measurements at various distances from 400kv lines in Ireland.

5.0 Conclusion

From the study, it was discovered that significant increases in deposition are plausible in electric fields at the high end of the range found in the environment for particles with higher mobilities i.e. air-borne particles, in certain air conditions. Overall, this experiment shows that an increase in concentration of airborne particle is possible, but the increase is not high enough to be harmful to health, since the highest value obtained is less than 20.0×10^{-8} Gy/hr which is the minimum standard of ionizing background radiation to cause health hazard in conformity with the International Atomic Energy Agency (IAEA) Standard.

References

[1] WHO (1997): Electromagnetic fields (Local, authorities, health and environment briefing pamphlet series; 32. Regional Office for Europe).

[2] Nacy Wertheimer and Eleeper E. (1979): Electrical wiring configurations and childhood cancer Amercian J. Epidem 109: 273-284.

[3] Swanson J. Renew D and Wilkinson N (1996): Power lines and health Phys. World November 29-33.

[4] Nair I. Morgan M.G. and Florig H.K., U.S. Congress, Office of Technological Assessment for the office of Technological Assessment (1989). Biological effects of power frequency electric and Magnetic fields – Background paper, report No. OTA BP – E- 53 (U.S GPO, Washington D.C)

[5] Davis S., Mirrick DK et al (2002): Residential magnetic fields and the risk of breast cancer. American Journal of epidemiology 155: 446-454.

[6] Doll R. (1994) : Electromagnetic fields and the risk of cancer: supplementary report by the advisory Group on Non-ionizing report. Documentary NRPB 5 (2) 77-81

[7] Portier C.J. and Wolfe M.S (1998): Assessment of health effects from exposure to power-line frequency electric and magnetic fields: NIEHS working group Report (Research Triangle Pak, N.C; US National Institutes of Health).

[8] Savitz F.A. etal (1998): Lung cancer in relation to employment in the electrical utility industry and exposure to magnetic fields. Occup. Enviorn. Med. 54, 396-402

[9] Henshaw D.L., Ross A.N. Fews A.P. and Peece A.W. (1996): Enhanced deposition of radon daughter nuclei in the vicinity of power frequency electromagnetic fields inc. J. Radiant Biol. 69, 25-38

[10] Bleancy B.I. and Bleaney B (1976): Electricity and Magnetic (Oxford: Oxford University press)

[11] Fews A.P. and Henshaw D. L. (1998): Aerosol behaviour near high voltage powerliness implications for human exposure. Bioldectronagnetics society: 20th Annual meeting (Frederick, M.D. Bioelectromanetics society).

[12] Mclaughlin and Gath (1999): Radon progeny activities in the vicinity of high-voltage power lines. Radiant Prot. Dosim 82, 257-62

[13] Walton A.J. (1983): Three phases of matter (Oxford: Clarendon)