Chapter One

Introduction

1.1 Biological Hazards of Electromagnetic Field

Exposure to electromagnetic fields has been a source of concern for resident's throughout the world who are living with the advancements of modern technology. The increased use of cellular and wireless technology, electronics, and household appliances in the past decade have meant that people are exposed to more Electromagnetic field (EMF) in day to day environments from a variety of sources[1].

Governments have begun to legislate and stipulate regulatory policies regarding the allowable limits of EMF, but the over whelming majority of such legislation is concerned only with EMF from higher frequency and radio-frequency sources such as telecommunica-tions and microwave ovens. [2, 3]

However, power transmission lines, and other sources which relate to the transmission and generation of electrical energy, emit extremely low frequencies between 0-300 Hz. The EMF Research and public information dissemination program (EMF RAPID) of the National Institute for Environmental Health Sciences in the US determined that exposure to extremely low frequency EMF is a "possible" cancer hazard; however, in 2001, the International Agency for Research on Cancer issued a monograph announcing that as a possible carcinogen, extremely low frequency magnetic field have statistically been linked to childhood leukemia. Although not conclusively linked at this time, higher incidents of cancer development have been documents not just among children, but also among adult residents who live or work near high voltage power lines [2, 4, 5] Electric devices and infrastructure and wireless communication are hallmarks of modern life [6]. The proliferation of these technologies in recent years has dramatically increased our exposure to electromagnetic radiation (EMR), or electromagnetic fields (EMF). While the science on the health impacts of this form of radiation is inconclusive, many people are concerned about how long-term exposure to excessive EMR may impact human health and nature [7, 8].

The World Health Organization maintains that "no adverse health effects are expected." However, the International Agency for Research on cancer (IARC) has classified extremely low frequency EMR (associated with power lines) and radiofrequency EMR from cell phone use as possible human carcinogens [9].

Compared to cell phones, radiofrequency EMR exposure from other wireless devices is lower because other devices are typically located farther away from the body — but in some cases continuous. Other wireless devices, such as smart meters, transmit only intermittently [10, 11]. PG&E claims that EMR exposure from a home electricity smart meter transmitting intermittently for 1000 years is equivalent to one month of typical cell phone use. IARC has not drawn any conclusions about an association between cancer and radiofrequency EMR from sources other than cell phones In 2007, an independent, international collaborative of 14 scientists and public health and policy experts reviewed more than 2000 studies of health effects from EMR (the Bioinitiative project). They concluded, "Chronic exposure to EMF is associated in some scientific studies with increased health risks that vary from impaired learning, headaches, mental confusion, skin rashes, tinnitus and disorientation to a variety of cancers, and neurological diseases like ALS and Alzheimer's." The Bioinitiatve Report is probably the most comprehensive literature review on the subject, but some critics claim it is one-sided A smaller number of studies hint at possible environmental impacts of EMR.

In one, scientists found that bees refuse to return to their hives when mobile phones are placed nearby, suggesting that EMR may play a role in colony collapse disorder. Another study linked Wi-Fi exposure to tree leaf damage. The results of these studies are considered preliminary and inconclusive [12, 13].

WHO also identifies and promotes research priorities for radiofrequency fields and health to fill gaps in knowledge through its research agendas. WHO develops public information materials and promotes dialogue among scientists, governments, industry and the public to raise the level of understanding about potential adverse health risks of mobile phones [4, 14]. Proximity of high-voltage towers to nearby buildings [15]:

Figure 1.1 High-voltage towers to nearby buildings

1.2 Hazards to Humans

Magnetic fields induce electric currents in electrical conductors including human, animal or plant bio-systems. E-smog creates an artificial stress situation in the bio-system which, in turn, affects the metabolism as well as hormone production. An individual's stress tolerance, which varies from person to person, determines the outbreak of an e-smog related disease. Adverse health effects manifest because the bio-system is exposed to technically- produce electromagnetic alternating fields which are many times stronger than the body's currents, and the frequency of which interferes and irritates the body's regulatory mechanism. When the body ages and lacks exercise and proper diet, the e-smog degenerates the weakness into sickness and disease [16, 17].

Biological effects are measurable reactions of the organisms or cells to a stimulus or to an environment change. However, the body might not own adequate compensation mechanisms to dampen all environmental changes or stresses. Health effects result from biological effects that cause deficiency in the health or well being of exposed individuals when the energy of the fields is absorbed and transformed into movement of molecules. Temperature is raised because of friction between rapidly moving molecules [18]. Compliance with exposure limits recommended in international guidelines helps to control the risks of exposure.

During the tests and according to locals, one strange medical condition happened with an inhabitant and exhibited in him perceiving things upside down accompanying any sudden movement he makes. A hospital practitioner attributed this and other similar cases in the area to suffering a previous head injury and living beside an EMF tower.[6,19] E-smog has an effect on cell physiology and consequently on the control mechanism of the body. EMFs produce reactions because cell communication happens at several thousandths, even millionths of a volt. For good health, the body must be able to communicate within itself, that is, to be in harmony with the natural rhythm. The random patterns from e-smog can create noise in the body and force it out of synchronization. The body is a complex communication system where cells, tissues, organs, and organisms all talk to each other; the communication includes finely tuned bio-electrical transmitters and receivers [20].

Two more well-known biological impacts of e-smog are the interruption of the brain wave patterns leading to behavioral complications, and the interfeA. B. Rifai, M. A. Hakami 10 rence with the body's communication system (cytoskeleton) leading to unusual neurological function, such as dementia, chronic fatigue syndrome and fibromyalgia. The cell membrane receptors recognize EMFs at very low levels of exposure by producing a stress response similar to that produced by exposure to heavy metals or toxic chemicals. This can cause the cell membrane to go from an active or permeable state where it allows nutrients in and toxins out, to an inactive state where the cell membrane is impermeable. During the day, the cells will alternate states thousands of times, but the membranes can be locked in the inactive state under constant environmental stress. This is often referred to as "oxidative stress" as nutrients are able to enter into the cell, while toxins are not allowed to leave. There is evidence that the inactive state can even have geno-toxic effects, which means that e-smog is toxic and is damaging to the DNA and inhibits the body from repairing it [14, 21].

The limited studies that have been conducted on adults showed no conclusive proof of a link between EMF exposure and adult cancers. Nevertheless, continuous education on practical ways of EMF exposure reduction is recommended

1.3 Research Problem:

The research problem is related to the fact that studies on the effect of electric transmission lines on human health is not sufficient to assure biological hazards.

1.4 Literature Review:

Many a hemps were made to study the biological effects of magnetic and electromagnetic fields. In the study of Raymond [9] three mulginant human cell lines were exposed to a 7 tesla uniform static magnetic field for 64 hours. The results shows that prolonged exposure to a very strong magnetic field to inhibit the growth of three human tumor cell lines in vitro. The mechanism of inhibition has not been identified. Another work done Allay to study the effect of extremely low frequency magnetic fields (50 Hz,0.5mT) on phosphate metabolism [12] in the isolated ganglions of the garden snail theix ponatia, after 7 and 16 days of snail exposure , it was observed that for the period of 7 days intercellurar PH shifted twards more a lkline conditions , beside increase in the activity of investigated enzymes. Raymond R.Raylman etal, Exposure of strong static magnetic field shows theGrowth of Human cancer cells vitro, Bioelectromagnetics .The exposure for the period of 16 days caused decrease of PCr and ATP levels anddecreased enzyme activity compared to the 7 days treatment.

1.5 Aim of the work:

The aim of this work is to find the magnetic field intensity and electromagnetic power generated by low frequency electric power transmition lines. One also needs to study the biological effect of magnetic field on lymphocyte transformation percentage.

1.6 Thesis layout:

The thesis consists of 4 chapters. Chapter 1 is the introduction, while Chapter 2 is devoted for the theoretical background. The literature review is in chapter 3. Materials and methods, results and discussion are in chapter 4.

Chapter Two

Electromagnetic Radiation and Biological Hazards

2.1 Introduction:

Electric and magnetic fields are well known to people. Oscillating charges produces electromagnetic waves (EMW) [22] . These EMW have been widely used in many applications. These wide applications made people continuously exposed to them. This may cause biological hazards. This chapter is concerned with all these topics [23, 24].

2.2 Electric Current and Electric Field:

When a current of strength flows through a conductor of resistance R. the potential difference between the terminals of the conductor is given by

$$V = Ri \qquad (2.2.1)$$

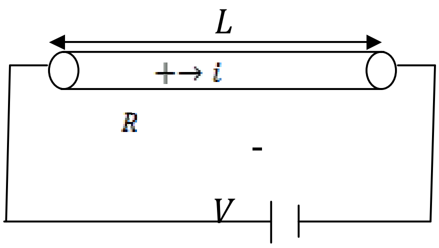

Fig (2.2.1) Electric current flow through a conductor

If the conductor length is L then the electric field intensity is related to the potential V through the relation [25].

$$V = EL \qquad (2.2.2)$$

For variable E the potential is given by

$$V = \int E \cdot dL \qquad (2.2.3)$$

2.3 Magnetic field:

The magnetic field can be generates by flowing charge. If a certain charge flow with current of strength i the produced magnetic flux density B depends on the geometry of the flowing wire. For long straight wire the mfd is given by [26].

$$B = \frac{\mu i}{2\pi r} \qquad (2.3.1)$$

while for circular wire

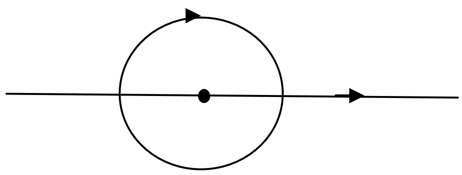

Fig (2.3.2): circular wire

The magnetic flux density is given by

$$B = \frac{\mu i}{r} \qquad (2.3.3)$$

The varying magnetic field can produce electric field and induce electromotive force of potential V given by

$$V = -\frac{\partial \emptyset}{\partial t} = -\frac{\partial}{\partial t}\int B\, dA \qquad (2.3.4)$$

$\emptyset =$ Magnetic flux penetrating area A

2.4 Electromagnetic Field Equation:

Time varying electric field can produce magnetic field. Also time varying magnetic field produce electric field [27].

The relations between electric field intensity E, magnetic flux density B and intensity H, beside current density J and electric flux density D are given by

$$\nabla \times E = -\frac{\partial B}{\partial t} = -\mu \frac{\partial H}{\partial t} \qquad (2.4.1)$$

where μ is the magnetic permeability

$$\nabla \times H = J + \frac{\partial D}{\partial t} \qquad (2.4.2)$$

The conductivity σ and the electric permitivily are $J = \sigma E$ defined as

$$D = \varepsilon E \quad , \quad B = \mu H \qquad (2.4.3)$$

taking the curl of (2.4.1) yields

$$\nabla \times \nabla \times E = -\mu \frac{\partial \nabla \times H}{\partial t} = -\mu\sigma \frac{\partial E}{\partial t} - \mu\varepsilon \frac{\partial^2 E}{\partial t^2} \qquad (2.4.4)$$

using the vector relation

$$\nabla \times \nabla \times E = -\nabla^2 \mathrm{E} + \nabla(\nabla \cdot \mathrm{E}) \qquad (2.4.5)$$

and the fact that in free space

$$\nabla \cdot D = \varepsilon \nabla \cdot E = \rho = 0 \qquad (2.4.6)$$

the electric equation is given by

$$-\nabla^2 \mathrm{E} + \mu\sigma \frac{\partial \mathrm{E}}{\partial \mathrm{t}} + \mu\varepsilon \frac{\partial^2 E}{\partial t^2} = 0 \qquad (2.4.7)$$

This equation represents electric field equation for non changed and non polarized medium [23, 28].

2.5 Propagation of Electromagnetic wave in:

Electromagnetic waves (EMW) can be produced by osculating charges like electrons in antennas. For free space the conductivity vanishes, i.e. [29]

$$\sigma = 0 \qquad (2.5.1)$$

And equation (2.4.7) reduce to

$$-\nabla^2 \text{E} + \mu\varepsilon \frac{\partial^2 E}{\partial t^2} = 0 \qquad (2.5.2)$$

The solution of this equation can be written in the form of a traveling wave

$$E = E_0 e^{i(kx-\omega t)} \qquad (2.5.3)$$

where E_0 stands for the amplitude, and k is the wave number and ω is the angular frequency given by

$$k = \frac{2\pi}{\lambda}, \quad \omega = 2\pi f \qquad (2.5.4)$$

λ, f Stands for wave length and frequency respectively.

2.6 Power and Energy of Electromagnetic waves:

When the electromagnetic wave enters a certain medium they deliver it with electric and magnetic energies. The electromagnetic energy density is given by

$$s = \frac{1}{2}(E \times B) \qquad (2.6.1)$$

The energy density of electric field is given by

$$\mu_E = \frac{1}{2}\varepsilon E^2 \qquad (2.6.2)$$

While that of a magnetic field is given by

$$\mu_B = \frac{1}{2}\mu H^2 \qquad (2.6.3)$$

But since

$$E = CB \qquad (2.6.4)$$

Where $C$the speed of light in vacuum therefore the total energy density is is given

$$s = (\mu_B + \mu_E)C = \left(\frac{1}{2}\varepsilon E^2 + \frac{1}{2}\mu H^2\right)C = \varepsilon E^2 C$$

$\lambda = \frac{c}{f} \rightarrow$ (3-28)

Here, C corresponds to the speed of light in (m/s). f to the frequency of the radiation in (Hz). And λ to the wave length in (m).

Example:

Measurements exposure-limit of Abd Allah El Tayeb Street pretends you measure 591.0 nT at 49.3 MHz with antenna gain 10.000 nT at 49.3 MHz? [31].

$$S = \frac{10^{\left[\frac{P-G}{10}\right]}}{1000} \times \frac{4 \times \pi}{\lambda^2}$$

$$\lambda^2 = \frac{c}{f} = \frac{3 \times 10^8 m}{49.3 MHz} = 6.08 m$$

$$\lambda^2 = 37.03 m$$

$$S = \frac{10 \times log 59.1}{1000} \times \frac{12.57}{37.03} = (0.0177)(0.34)$$

S= 6.018× 10^{-3}nT

Exposure-limit = S= 6.018× 10^{-3}nT

2.7 Electromagnetic Spectrum:

Electromagnetic radiation is the name given to a whole range of transverse radiation is having differing wave-lengths but five common properties [32]:

① It is propagated by varying electric and magnetic fields oscillating at right angles to each other.

② It travels with a constant velocity of 3×108 m/s in a vacuum.

③ It is untenanted by electric and magnetic field.

④ It travels in straight lines in a vacuum.

⑤ It may be polarized.

For convenience the electromagnetic spectrum is divided into the following regions [33]: Gamma-rays, x-rays, ultraviolet radiation, visible light, infrared radiation, microwaves, radio-waves. Radio and TV signals are electromagnetic waves. Which are generated by driving charges back and forth in antennas of various shapes and sizes? At higher frequencies the antennas needed to generate the waves efficiently are smaller and the wave length of the radiation produces is correspondingly smaller, it is found that the electromagnetic waves are generated most efficiently when the length of the transmitting antenna is of the same order of magnitude as the wavelength of the radiation produced. By using a wide variety of sources and sensors, electromagnetic radiation can be produced and detected a cross a continuous spectrum which range over at least thirty decades in frequency.

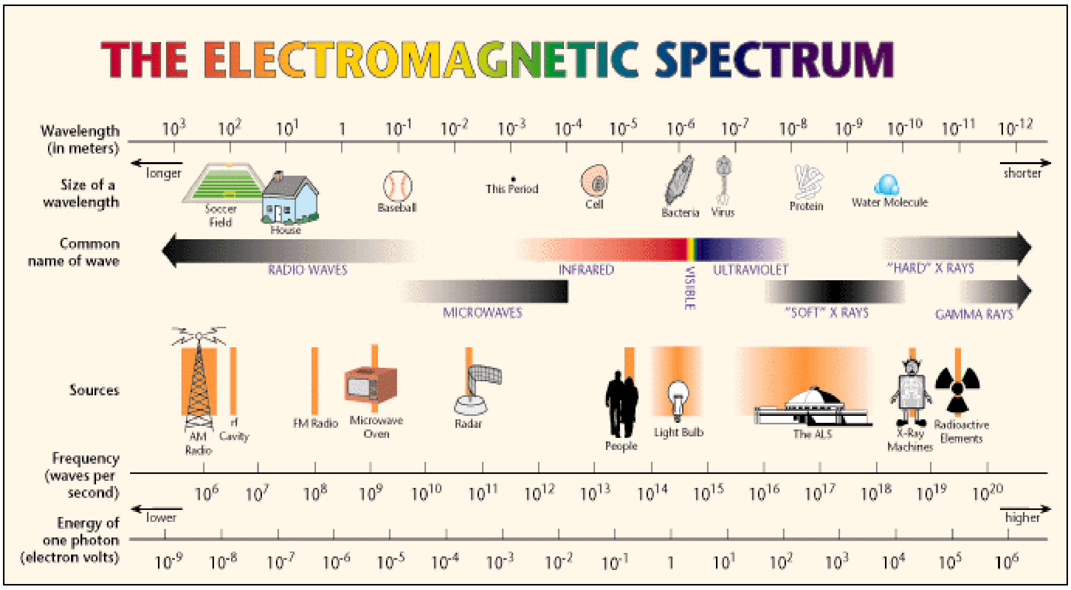

Fig (2.7.1) electromagnetic spece

2.8 Ionizing and non ionizing Radiation:

Electromagnetic radiation can be classified into ionizing radiation and non-ionizing radiation, based on if it is capable of ionizing atoms and breaking covalent bonds .

Ultra violet and higher frequencies, such as X-rays or gamma rays are ionizing. These pose their own special hazards. Non-ionizing radiation is associated with two major potential hazards [34, 35]:

electrical and biological. Additionally, induced electric current caused by radiation can generate sparks and create a fire or explosive hazard. The electromagnetic spectrum includes several different classes of radiation: low frequency, radio waves, microwaves, infrared, visible light, ultraviolet light, x-rays and gamma rays. Wave frequency is what differentiates one class of radiation from another. Fig.(2-1) shows the electromagnetic spectrum [36].

The electromagnetic spectrum divided into frequency and wavelength ranges on a logarithmic scale. Despite the continuous nature of the spectrum. It is convenient to Consider it as divided into the following frequency ranges, distinguished by the manner in which the radiation is produced and by the different effects observed when interacts with matter. The energy (E) associated with a photon depends on its frequency (f) due to Plank`s Law [37]:

$$E = hf \rightarrow \quad (2.8.1)$$

$h \equiv$ Plank Constant = 6.6×10^{-34} J.s

The higher the frequency of an electromagnetic wave, the greater will be the energy of a photon associated with it. Photon associated with X-rays and gamma rays have relatively large energy content. At the other end of the electromagnetic spectrum, photons associated with low-frequency wave have many times less energy. In between these extremes ultraviolet radiation, visible light, infrared radiation RF/MW (Radio Frequency of Electromagnetic Wave) energy exhibit intermediate photon energy content. For comparison, the photon energies associated with high-energy x-rays are billions of time more energetic than the energy of 1-GHZ microwaves photons. The photon energies of RF/MW electromagnetic waves are not great enough to cause the ionization of atoms and molecules and RF energy is therefore, characterized as non-ionizing radiation along with visible light, infrared radiation and other forms of electromagnetic radiation with relatively low frequencies. The electromagnetic radiations may be divided in two types: Ionizing Radiation, Non-Ionizing Radiation [38, 39].

Is the radiation that contains energy enough to extract atoms and molecule from livening cells. The gamma-rays and x-rays are ionizing radiation. “No doubt these radiations caus damages to living cells”. Ionizing radiation is energy in the form of waves or particles that has enough force to remove electrons from atoms. In this document, we will refer to it simply as radiation. One source of radiation is the nuclei of unstable atoms, as these radioactive atoms (also referred to as radio-nuclides or radioisotopes) seek to become more stable, their nuclei eject or emit particles and high-energy waves. This process is known as radioactive decay.

Some radio-nuclides, such as radium, uranium, and thorium have existed since the formation of the earth. The radioactive gas radon is one type of radioactive material produced as these naturally-occurring radioisotopes decay. Human activities, such as the splitting of atoms in a nuclear reactor, can also create radio-nuclides. Regardless of how they are created, all radio-nuclides release radiation. Ionizing Radiation is Classification into [40]:

Directly Ionizing Radiation. In Directly Ionizing Radiation.

2.8.1 Directly Ionizing Radiation:

The major types of radiation emitted during radioactive decay are alpha particles, beta particles and gamma rays. Radiation can come from natural sources or manmade radio-nuclides. Man made x-rays, another type of radiation, are produced outside of the nucleus. Most x-ray exposure that people receive is technologically produced [41, 42].

Alpha Particles:

Alpha particles are energetic, positively charge particles consisting of two protons and two neutrons. Alpha particles are commonly emitted in the radioactive decay of the heaviest radioactive elements such as uranium-238, radium-226, and polonium-210. Even though they are highly energetic, the high mass of alpha particles means they move slowly through the air [43].

The health effects of alpha particles depend heavily upon how exposure takes place. External exposure (external to the body) is of far less concern than internal exposure, because alpha particles lack the energy to penetrate the outer dead layer of skin. Internally alpha particle can be very harmful. If alpha emitters are inhaled, ingested (swallowed), or absorbed into the blood stream, sensitive living tissue can be exposed to alpha radiation [44].

An alpha particle is a highly energetic helium nucleus that is emitted from the nucleus of the radioactive isotope when the neutron to proton ratio is too low. It is a positive charged massive particle, consisting of an assembly of two protons and two neutrons [34, 45].

Beta Particles:

Beta particles are fast moving electrons emitted from the nucleus during radioactive decay. Humans are exposed to beta particles from manmade and natural radiation sources, such as tritium, carbon-14, and strontium-90. Beta particles are more penetrating than alpha particles but are less damaging over equally traveled distances. They travel considerable distances in air but can be reduced or stopped by a layer of clothing or by a few millimeters of a substance, such as aluminum. Some beta particles are capable of penetrating the skin and causing radiation damage, such as skin burns. However, as with alpha-emitters, beta-emitters are most hazardous when they are inhaled or ingested [46].

A beta particle is an ordinary electron that is ejected from the nucleus of a beta-unstable radioactive atom. The particle has a single negative electric charge (1.6×

10-19 C) and a very small mass (0.00055 atomic mass units). Since theoretical considerations preclude the independent existence of an intra-nuclear electron, it is postulated that the beta particle is formed at the instant of emission by the transformation of a neutron into a proton and an electron [47].

2.8.2 In directly Ionizing Radiation:

Gamma Rays:

Like visible light and x-rays, gamma rays are weightless packets of energy called photons. Gamma rays often accompany the emission of alpha or beta particles from a nucleus. They have neither a charge nor a mass and are very penetrating. Several feet of concrete or a few inches of lead may be required to stop gamma rays. One source of gamma rays in the environment is naturally occurring potassium- 40, manmade made source include cobalt-60 and cesium-137. Gamma rays are a radiation hazard for the entire body [48]. While gamma rays can easily pass completely through the human body, a fraction will always be absorbed by tissue.

X-rays:

X-rays are high energy photons produced by the interaction of charged particles with matter. X-rays and gamma rays have essentially the same properties but differ in origin. X-rays are either produced from a change in the electron structure of the atom or are machine produced. They are emitted from processes outside the nucleus, while gamma rays originate inside the nucleus. They also are generally lower in energy and therefore less penetrating than gamma rays. A few millimeters of lead can stop x-rays. Literally thousands for x-ray machines are used daily in medicine and industry for examinations, inspections, and process controls. Because of their many uses, x-rays are the single largest source of manmade radiation exposure. It is safe radiations and possesses harm to human being yet raises the temperature of the body that is exposed to it [49].

The hazards from non-ionizing radiation received little attention before the end of World War II. At that time, we already has a good deal of experience with damage to the eyes from observing solar eclipses, from exposure to ultraviolet light among welders, and from exposure to infrared energy among glass blowers and steel workers. We also had evidence of damage to the skin from exposure to ultraviolet and infrared [43, 45].

2.9 Natural and human made sources of electromagnetic fields:

Electromagnetic fields are present everywhere in our environment but are invisible to the human eye. Electric fields are produced by the local build-up of electric charges in the atmosphere associated with thunderstorms. The earth's magnetic field causes a compass needle to orient in a North-South direction and is used by birds and fish for navigation. Besides natural sources the electromagnetic spectrum also includes fields generated by human-made sources: X-rays are employed to diagnose a broken limb after a sport accident. The electricity that comes out of every power socket has associated low frequency electromagnetic fields. And various kinds of higher frequency radio waves are used to transmit information – whether via TV antennas, radio stations or mobile phone base stations. The basics of wavelength and frequency: What makes the various forms of electromagnetic fields so different. One of the main characteristics which define an electromagnetic field (EMF) is its frequency or its corresponding wavelength. Fields of different frequencies interact with the body in different ways. One can imagine electromagnetic waves as series of very regular waves that travel at an enormous speed, the speed of light. The frequency simply describes the number of oscillations or cycles per second, while the term wavelength describes the distance between one wave and the next. Hence wavelength and frequency are inseparably intertwined: the higher the frequency the shorter the wavelength [34, 50].

A simple analogy should help to illustrate the concept: Tie a long rope to a door handle and keep hold of the free end. Moving it up and then down slowly will generate a single big wave; more rapid motion will generate a whole series of small waves. The length of the rope remains constant, therefore, the more waves you generate (higher frequency) the smaller will be the distance between them (shorter wavelength) What is the difference between non-ionizing electromagnetic fields and ionizing radiation [51].

Wavelength and frequency determine another important characteristic of electromagnetic fields: Electromagnetic waves are carried by particles called quanta. Quanta of higher frequency (shorter wavelength) waves carry more energy than lower frequency (longer wavelength) fields. Some electromagnetic waves carry so much energy per quantum that they have the ability to break bonds between molecules. In the electromagnetic spectrum, gamma rays given off by radioactive materials, cosmic rays and X-rays carry this property and are called 'ionizing radiation'. Fields whose quanta are insufficient to break molecular bonds are called 'non-ionizing radiation'. Man-made sources of electromagnetic fields that form a major part of industrialized life - electricity, microwaves and radiofrequency fields – are found at the relatively long wavelength and low frequency end of the electromagnetic spectrum and their quanta are unable to break chemical bonds [52].

2.9.1 Electromagnetic fields at low frequencies

Electric fields exist whenever a positive or negative electrical charge is present.

They exert forces on other charges within the field. The strength of the electric field is measured in volts per meter (V/m). Any electrical wire that is charged will produce an associated electric field. This field exists even when there is no current flowing. The higher the voltage, the stronger the electric field at a given distance from the wire.

Electric fields are strongest close to a charge or charged conductor, and their strength rapidly diminishes with distance from it. Conductors such as metal shield them very effectively. Other materials, such as building materials and trees, provide some shielding capability. Therefore, the electric fields from power lines outside the house are reduced by walls, buildings, and trees. When power lines are buried in the ground, the electric fields at the surface are hardly detectable [53].

Magnetic fields arise from the motion of electric charges. The strength of the magnetic field is measured in amperes per meter (A/m); more commonly in electromagnetic field research, scientists specify a related quantity, the flux density (in micro tesla, µT) instead. In contrast to electric fields, a magnetic field is only produced once a device is switched on and current flows, the higher the current, the greater the strength of the magnetic field. Like electric fields, magnetic fields are strongest close to their origin and rapidly decrease at greater distances from the source. Magnetic fields are not blocked by common materials such as the walls of buildings. Plugging a wire into an outlet creates electric fields in the air surrounding the appliance. The higher the voltage the stronger the field produced. Since the voltage can exist even when no current is flowing, the appliance does not have to be turned on for an electric field to exist in the room surrounding it.

How do static fields differ from time-varying fields?

A static field does not vary over time. A direct current (DC) is an electric current flowing in one direction only. In any battery-powered appliance the current flows from the battery to the appliance and then back to the battery. It will create a static magnetic field. The earth's magnetic field is also a static field. So is the magnetic field around a bar magnet which can be visualized by observing the pattern that is formed when iron filings are sprinkled around it. Magnetic fields are created only when the electric current flows. Magnetic fields and electric fields then exist together in the room environment, the greater the stronger the magnetic field. High voltages are used for the transmission and distribution of electricity whereas relatively low voltages are used in the home[41].

The voltages used by power transmission equipment vary little from day to day; currents through a transmission line vary with power consumption. What are the main sources of low, intermediate and high frequency fields? The time-varying electromagnetic fields produced by electrical appliances are an example of extremely low frequency (ELF) fields. ELF fields generally have frequencies up to 300 Hz. Other technologies produce intermediate frequency (IF) fields with frequencies from 300 Hz to 10 MHz and radiofrequency (RF) fields with frequencies of 10 MHz to 300 GHz [50, 51].

2.10 Exposure:

Human exposure to EMF comes from many different sources and occurs in various situations in everyday life. Man-made static fields are mainly found in occupational settings, such as close to MRI scanners, although DC high-voltage overhead transmission lines are being constructed, which are expected to expose larger parts of the population to static electric and magnetic fields.[47]

EMF in the ELF range are ubiquitous. The main sources of these fields pertaining to the general public are in-house installations, household appliances and power lines. In recent years, attention has also been directed towards people living next to electric power transformers installed inside residential buildings. It appears that long-term exposure to ELF magnetic field of these people can extent to several tenths of μT. Today, for power regulation most modern electrical equipment uses electronics instead of transformers. Examples include the switched power supplies to laptops, drilling tools, chargers of mobile phones and similar devices. As a consequence, the frequency content of the daily magnetic field exposure has changed mainly by adding odd harmonics (150 Hz, 250 Hz, 750 Hz, etc.). In particular, the third harmonic (150 Hz) has become another dominating frequency in our environment.

In the household, more appliances have appeared in the intermediate frequencies (IF) range. It was found that at close range, some of them, including playthings, can exceed the reference levels set by exposure guidelines. An important source of exposure in this frequency range is induction hobs, which have become popular in recent years. These can expose their users (both members of the general public and professionals) to IF magnetic fields higher than the reference levels of exposure guidelines, mainly due to the fact that their safety standard requires conformity at a distance of 0.3 m only, and does not account for all the different modes and (worst case) use conditions [52].

By far the most applications which emit EMF are in the frequency range above 100 kHz up to some GHz. Multiple sources exist that contribute to an individual's exposure. However, transmitters in close vicinity to or on the body have become the main sources of exposure for the general population and professionals. Distance to the source is the main determinant of exposure, together with emitted power and duty factor.

In particular for brain tissues, the mobile phone used at the ear remains the main source of exposure. However, since the first generation of mobile telephony, the technology aimed at reducing the emitted power of mobile handsets. In particular, for GSM systems, already the introduction of dynamic power control reduced the average output power to about 50% of its rated value during calls, whereas the use of discontinuous transmission (DTX) during voice calls gave a further 30% reduction in average emitted power.

Adaptive power control became faster and more effective in the third-generation (3G) of mobile telephony systems leading to a further reduction (by about two orders of magnitude) in the specific absorption Specific energy Absorption Rate (SAR) compared to GSM phones. In addition, hands-free kits reduce the energy absorbed by the head drastically. DECT phones are another source of everyday exposure. Smart-phones, which operate within networks of different technologies, as well as other portable wireless devices, like tablets and laptop computers, have added complexity to the user’s exposure and changed the exposed body region. Due to the different sources used next to the body, it is important to take into account multiple exposures for risk assessment, which may also require organ-specific dosimetry. This issue is also important for occupational exposure, since there may be situations, such as working in[53]

Health effects of EMF – [2015 01 2014] an MRI suite, where professionals are exposed simultaneously to EMF of multiple frequencies ranges, different temporal variations and field strengths. The exposure from environmental sources is dominated by broadcasting antennas, antennas from private and governmental telecommunication services and mobile communications base stations. It has been shown that such systems have significantly increased the EMF levels in the urban environment compared to the levels measured during the 1980’s, when only analogue radio and television broadcasting were present.

However, historical data from spot measurement campaigns and continuous radiation monitoring systems indicate that the introduction of new mobile telecommunication technologies after the deployment of the GSM and UMTS systems did not substantially change the average levels of EMF in the environment.

At the same time, other technologies, like digital broadcasting, have in some regions contributed to the reduction of EMF exposure from far field sources. The number of sources has increased indoors. The installation of access points and short range base stations, such as 3G fem to cells, WiFi hotspots and DECT devices, has given rise to exposure at very close distances (within 1 m), whereas farther away the emitted EMF does not exceed the common background levels.

Consequently, the emitted EMF from these devices, even when combined, still results in a marginal exposure compared to reference levels of European and international guidelines. In general, it appears that, with respect to telecommunication applications, the technological trend is to use low power emitters, closer to or on the human body, and at higher frequencies [50].

Millimeter wave and THz applications are expected to be available soon in various industrial environments, such as for imaging systems used for non-destructive quality control, as well as for short-range broadband telecommunications. Currently, they do not significantly affect the average exposure of the general public. These applications will operate with low power and, due to the small penetration depth of the radiation, expose only superficial tissues. Interaction mechanisms Several interactions mechanisms are well established. They allow extrapolation of scientific results to the entire frequency range and wide-band health risk assessment. They have been used to formulate guidelines limiting exposures to EMF in the entire frequency range from static fields to 300GHz. A number of studies reported other candidate mechanisms. However, none that operates in humans at levels of exposure found in the everyday environment has been firmly identified and experimentally validated nor do they allow concluding on potential health risks at other exposure conditions both with regard to amplitude and/or frequency [53, 54].

Health effects from THz fields .The number of studies investigating potential biological, non-thermal effects of THz fields is small, but has been increasing over recent years, due to the availability of adequate sources and detectors. In vivo studies indicate mainly beneficial effects on disorders of intravascular components of microcirculation in rats under immobilization stress, but do not address acute and chronic toxicity or carcinogenesis. In vitro studies on mammalian cells differ greatly with respect to irradiation conditions and endpoints under investigation.

Studies suggesting effects of exposure have not been replicated in independent laboratories. Some theoretical mechanisms have been proposed, but no conclusive experimental support is available. Considering the expected increase in use of THz technologies, more research focusing on the effects on skin (long-term, low-level exposure) and cornea (high- intensity, short-term exposure) is recommended.[46]

Biological Hazard:

The effects of electromagnetic fields on the human body depend not only on their field level but on their frequency and energy. Our electricity power supply and all appliances using electricity are the main sources of ELF fields; computer screens, anti-theft devices and security systems are the main sources of IF fields; and radio, television, radar and cellular telephone antennas, and microwave ovens are the main sources of RF fields. These fields induce currents within the human body, which if sufficient can produce a range of effects such as heating and electrical shock, depending on their amplitude and frequency range. (However, to produce such effects, the fields outside the body would have to be very strong, far stronger than present in normal environment.

Heating is the main biological effect of the electromagnetic fields of radiofrequency fields. In microwave ovens this fact is employed to warm up food. The levels of radiofrequency fields to which people are normally exposed are very much lower than those needed to produce significant heating. The heating effect of radio waves forms the underlying basis for current guidelines. Scientists are also investigating the possibility that effects below the threshold level for body heating occur as a result of long-term exposure. To date, no adverse health effects from low level, long-term exposure to radiofrequency or power frequency fields have been confirmed, but scientists are actively continuing to research this area. Biological effects or health effects. What is a health hazard?[53, 54].

Biological effects are measurable responses to a stimulus or to a change in the environment. These changes are not necessarily harmful to your health. For example, listening to music, reading a book, eating an apple or playing tennis will produce a range of biological effects. Nevertheless, none of these activities is expected to cause health effects. The body has sophisticated mechanisms to adjust to the many and varied influences we encounter in our environment. Ongoing change forms a normal part of our lives. But, of course, the body does not possess adequate compensation mechanisms for all biological effects. Changes that are irreversible and stress the system for long periods of time may constitute a health hazard[54].

Typical exposure levels at home and in the environment. Exposure to EMFs electric currents exist naturally in the human body and play an important role in the normal physiological functions. Nerves transmit their signals by relaying electric impulses. The effects of exposure to EMFs on the body and cells depend on the EMF frequency and strength. At low frequency EMFs pass through the body, while at radio frequencies the fields are partially absorbed and penetrate only a short depth into the tissue.

Low-frequency electric fields influence the distribution of electric charges at the surface of conducting tissues and cause electric currents to flow in the body. Low-frequency magnetic fields induce circulating currents within the body; the strength of these induced currents depends on the amount of the external magnetic field and the size of the loop through which the current flows. When large enough, these currents can cause excitation of nerves and muscles

Electromagnetic fields at high frequencies:

Mobile telephones, television and radio transmitters and radar produce RF fields. These fields are used to transmit information over long distances and form the basis of telecommunications as well as radio and television broadcasting all overthe world. Microwaves are RF fields at high frequencies in the GHz range. In microwaves ovens, we use them to quickly heat food. At radio frequencies, electric and magnetic fields are closely interrelated and we typically measure their levels as power densities in watts per square meter (W/m2) What happens when you are exposed to electromagnetic fields?

Exposure to electromagnetic fields is not a new phenomenon. However, during the 20th century, environmental exposure to man-made electromagnetic fields has been steadily increasing as growing electricity demand, ever advancing technologies and changes in social behavior have created more and more artificial sources. Everyone is exposed to a complex mix of weak electric and magnetic fields, both at home and at work, from the generation and transmission of electricity, domestic appliances and industrial equipment, to telecommunications and broadcasting. Tiny electrical currents exist in the human body due to the chemical reactions that occur as part of the normal bodily functions, even in the absence of external electric fields. For example, nerves relay signals by transmitting electric impulses. Most biochemical reactions from digestion to brain activities go along with the rearrangement of charged particles. Even the heart is electrically active - an activity your doctor can trace with the help of an electrocardiogram [55].

Electric fields:

Low-frequency electric fields influence the human body just as they influence any other material made up of charged particles. When electric fields act on conductive materials, they influence the distribution of electric charges at their surface. They cause current to flow through the body to the ground. Low-frequency magnetic fields induce circulating currents within the human body. The strength of these currents depends on the intensity of the outside magnetic field. If sufficiently large, these currents could cause stimulation of nerves and muscles or affect other biological processes. Both electric and magnetic fields induce voltages and currents in the body but even directly beneath a high voltage transmission line, the induced currents are very small compared to thresholds for producing shock and other electrical effects, power lines. Electric appliances in the household.

The strongest power frequency electric fields that are ordinarily encountered in the environment exist beneath high voltage transmission lines. In contrast, the strongest magnetic fields at power frequency are normally found very close to motors and other electrical appliances, as well as in specialized equipment such as magnetic resonance scanners used for medical imaging. Typical electric field strengths measured near household appliances (at distance of 30 cm):

Many people are surprised when they become aware of the variety of magnetic field levels found near various appliances. The field strength does not depend on how large, complex, powerful or noisy the device is. Furthermore, even between apparently similar devices, the strength of the magnetic field may vary a lot. For example, while some hair dryers are surrounded by a very strong field, others hardly produce any magnetic field at all. These differences in magnetic field strength are related to product design. The following table shows typical values for a number of electrical devices commonly found in homes and workplaces. TV and radio broadcast towers from the “storage” of information transmission.

They are among the strongest radiation sources in existence. The highest transmitting powers are used by TV broadcast stations which may employ more than 1000 kw! (for comparison: a cell tower uses about 40 watts = 0.04 kw) shortwave radio stations employ transmitting powers of up tp approx. 600kw. FM radio broadcast employing approx. 100 kw are a beady “more conservative” in this respect. Recently these are being converted to digital standards. Seeing the enormous transmitting powers involved. It is not surprising that close to these stations (approx-100m) even the extremely high optical exposure limits are exceeded [46, 53].

An ever increasing numbers of employees now a day's use a PC at work. However, more than one out of two German households today owns a PC. PCs (not as much monitors) create large a mounts of electromagnetic fields (EMFs). Particularly the CPU and various expansion cards emit high dose of high frequency EMFs. Also various PC accessories like monitors printers, scanners etc, emit low-frequency EMFs through their mains cords. The Australian National Health and Medical Research Committee`s (NH&MRC) guideline for human exposure to power frequency EMF is similar to that as recommended by the World Health Organization (WHO). These guidelines recommend a set of limits of exposure to EMF based on the WHO environmental health criteria. Western power accepts and endorses these guidelines implicitly and designs, constructs and operates all its transmission lines, plants and facilities in compliance with these exposure guidelines.

The NH&MRC exposure guideline has also been adopted by health agencies of many other countries around the globe. All these bodies have considered many studies investigating the possibility that there may be an association between exposure to weak power frequency EMF and some types of cancer. They have concluded that, taken together, the evidence does not support such an association, and does not form a basis from which exposure guidelines can be formulated. In the United States, there are no national guidelines; however, some individual states have set their own limits. To date, there is still no conclusive evidence to prove that exposure to normally experienced power frequency EMF in the home or workplace can adversely affect human health. If there are adverse effects, it is not known what measure of 'dose', whether exposure level, cumulative exposure over time or rate of change of level- might be appropriate. Some studies of effects on cells suggest that higher field levels may not produce a larger effect than lower field levels, that is, it is not necessarily the case that 'more is worse'. Studies relating to concerns about possible cancer development therefore do not provide any basis for proposing limits for exposure to power frequency EMF.

Different limits have been set for persons exposed occupationally and for the general public. The main reason for this is that the occupationally exposed population consists of adults exposed under controlled conditions; these workers would have received training to inform them of potential risk, and also limited to the duration of the working day and over the working lifetime. The general public, on the other hand, includes individuals of all ages in all states of health. Who will not normally be aware of the exposure they are receiving. The typical EMF profile is such that the field levels drops off very rapidly as you move away from the electrical source. In the case of transmission lines the field level is at its maximum directly under the conductors of the line and drops off as one move away from it. Western power does impose restrictions on the usage of the land in close proximity to a transmission line that is based upon the electrical clearance requirements and the EMF profile of the line. For example, no building s or construction of any type are allowed within the restriction zone of a transmission line and the size of the restriction zone is dependent upon the voltage, configuration and construction of the line.

2.11 Potential Health Effects of Power Frequency EMF:

Power frequency EMF is not a form of radiation. Many newspapers and magazines articles on the subject talk about "radiation" from power lines or electrical equipment. The word 'radiation' is a board term, but generally refers to the propagation of energy away from some source. For example, light is a form of radiation, so are x-rays, radio waves and microwaves. EMF do not travel away from their source, but are fixed in placed around it. They do not propagate energy away from their source. They bear no relationship, in their physical nature or effects on the body, to true forms of radiation such as x-ray or microwaves [55].

From most people the greatest exposure to power frequency EMF arises from distribution lines in the street, household wiring arises from distribution lines in the street, household wiring and domestic appliances. Living near a transmission line may not substantially increase this exposure. If in the future a positive association between exposure to power frequency EMF and cancer were to be demonstrated beyond any doubt, the indications are that EMF would have to be a very weak carcinogen (cancer causing or promoting agent) in view of the very large-scale use of electricity [57].

Although most research has investigated possible associations between EMF and cancer, other studies have looked at other outcomes, such as birth defects and functioning of the nervous system. To date, no reliable conclusions can be drawn from this work. Any risks associated with electricity use, which include risks of fatal shock, are likely to be more than balanced by the benefits that electricity provides. If there is any risk from EMF it is unlikely to be much larger, and is likely to be small compared to other risks to life.

Several studies aimed at finding out if power frequency EMF are a potential cause of cancer have looked at whether, in a group of cancer sufferers, the proportion living near power lines (both high and low voltage lines) is greater than in a similar group of healthy ‘control’ subjects. Such studies have to be designed carefully to eliminate the effects of factors such as age, income smoking or exposure to chemicals, which might distort the results [58, 59].

Studies on adults generally show no association between risk of cancer and residence near power lines, but not enough work has been done to draw firm conclusions. Power lines are only one source of exposure to power frequency EMF. Even people living quite close to power lines may be exposed to higher (but more intermittent) fields produced by wiring and appliances in the home. Studies of relationship between adult and childhood cancer and the use of electrical appliances have been problematic and inconclusive. In studies of adult cancers there have been indications of a slightly increased risk to workers in electrical industries. However, many of the workers may also have been exposed to potential cancer causing agents such as solvent fumes and solder fluxes. Very few measurements of the actual field levels to which electrical workers are exposed have been made. Welders, who are exposed to very high level of power frequency EMF, do not appear to be at any particular risk [63, 62].

Research in laboratories suggests that power frequency EMF cannot directly initiate cancer. If they do play some role, it may be in promoting its subsequent development; however, experiments on cell cultures and animals do not provide good support for this hypothesis. There are also considerable theoretical doubts that there could be any effect of EMF at levels found around power lines and electrical appliances. Recent attempts to replicate some of the effects reported in cell cultures have been unsuccessful, hence, casting doubt on the original findings. It is to note that the carcinogenic risks of both asbestos and smoking did show up very prominently in the very early, initial studies which investigated them, and were confirmed by subsequent studies. However, similar studies on EMF have still shown no clear, unambiguous evidence of a carcinogenic risk. A prominent researcher who carried out studies establishing the carcinogenic potential of both asbestos and smoking has concluded that there is only very weak evidence to suggest the possibility that EMF may be associated with cancer. Different attitudes to risk can lead to different actions. Some people conclude that the current scientific ambiguity about possible health risks from EMF is so large, and the possible risks so small, that no action is necessary. They feel that there are plenty of known risks in life, and they would do better to direct their energies towards reducing these. Others find even the slight possibility of a risk sufficiently disturbing that they would like to take precautions any way, just in case [64].

The concept of prudent avoidance has been suggested as a means to control exposures to EMF if there is any doubt that they are harmless. Historically, it has been difficult to scope because, by its very nature, it cannot be defined in precise terms. Nevertheless, it is possible to adopt certain measures that are consistent with the notion of doing what can be done at modest cost and without undue[67] inconvenience to reduce people`s exposure to the EMF; that is, limiting exposures that can be avoided with small investments of money and effort, but not doing anything drastic or expensive. Western power is committed to the concept of prudent avoidance; it designs, constructs and operates all its plants and facilities prudently within the guidelines recommended by the Australian Radiation Protection & Nuclear Safety Agency [68, 69].

Western power sees ‘prudence’ as embracing a range of actions which is sensible to the current state of scientific uncertainty as to whether power frequency EMF cause adverse human health effects, the ongoing research on the subject, and the current community concerns [70].

Chapter Three

Literature Review

3.1 Introduction:

The use of magnetic resonance imaging (MRI) encourages researchers to study the side effect that can be caused by a magnetic field. This chapter is concerned with some of them.

3.2 Effect of alternating the magnetic field on phosphate metabolism

Decades scientific interest in the effect of static and alternating magnetic fields on the biological systems has increased. Various strengths of magnetic fields are investigated for their biological effects, but mostly at the strength of the Earth's magnetic field (35-70μT) and, much higher, man-made magnetic fields that are normally present in our environment. This interest arises from the fact that all living organisms are constantly exposed to the Earth's and man-made magnetic fields.

The ability of biological systems to detect the Earth's magnetic field is found in diverse invertebrates and vertebrates and is important for compass orientation of animals (Katz and Yilks, 1979; Mather and Baker, 1981; Zoeger et al., 1981; Blakemore, 1982; Mathis and Moore, 1984; Lohman and Willows, 1991; Wang et al., 2002). Furthermore, numerous studies have explored the interaction of man-made static and alternating magnetic fields with biological systems. Previous research showed that these magnetic fields can induce changes in behavior (Rudolph et al., 1985; Prato et al., 1996; Janac et al., 2005), enzyme activity (Nossol et al,1993; Blank and Soo, 1996; Liboff et al., 2003; Chen et al., 2009), the synthesis and release of neurohormons (Peric-Mataruga et al., 2008), biophysical properties of neurons (McLean et al., 1995; Calvo and Azanza, 1999; Ye et al., 2004; Todorovic et al., 2007), synaptic transmission (Rosen, 1992) and ion channel currents (Shen et al., 2007). Furthermore, magnetic field influence on nucleic acids and protein synthesis has been found (Cridland et al., 1999; Ciombor et al., 2002; Hirai et al., 2002; Schmitz et al., 2004). However, little is known about magnetic field effect on the phosphate metabolism of the nervous system. In order to test the effect of magnetic fields on nervous system metabolism, one chose the nervous system of pomatia, which is a well- described model system for neurophysiological studies (Rozsa 1984, Altrup 2004). It is known that, neuronal membrane properties of Helix pomatia are influenced by static magnetic fields (Nikolic et al., 2008). Other studies have documented that magnetic fields induce changes in the bioelectric properties of snail neurons.

(Balaban et al., 1990; Moghadam et al., 2008; Ayrapetyan et al., 2004). As is known, the firing properties of neurons and electrical signaling between cells imply specific energy demands (Magistretti, 2003).

Furthermore maintenance of the electrochemical gradient, particularly for Na+ and K+ ions by Na+/K+-ATPase, is the main energy consuming process in neuronal cells. Moreover, the energy status of the cell influences bioelectrical properties of the membrane (Lara et al., 1999).

Magnetic fields of extremely low frequency (50 Hz) and of a magnetic flux density of 0.5 mT (ELF-MF) would have effects on the nervous system metabolism. In order to explore whether exposure to ELF- MF can cause changes in the level of phosphate compounds in the nervous system of the snail, one used the 31P NMR spectroscopy, which provides direct information about tissue energy metabolism and indirect data from intermediary metabolism. To investigate ELF-MF influence in more detail, some of the enzymes involved in phosphate (P) turnover were also explored. So far, several reports about magnetic field influence on the activity of enzymes involved in P turnover have been reported (Blank and Soo, 1996; Chen et al., 2009).One needs chosen to explore the total ATPases, Na+/K+-ATPase and acid phosphatase enzymes in the snail nervous system.

3.2.1 Methods:

The 31P NMR and enzyme activity analysis were performed on the isolated ganglion complex of the garden snail Helix pomatia (Pulmonata: Helicidae). Snails used for all experiments were collected at spring, placed in polycarbonate boxes and kept in the cold chamber at 7˚C. The experiments were conducted in the winter period, because snail activity and variations in snail physiology, as seen by variations in the texture and rigidity of connective sheets, are minimal in the winter months. In this way the effects of seasonal changes in snail physiology are greatly minimized. Four weeks prior to the experiments, snails were acclimated at 22˚C, kept in an active state, and fed regularly.

An experimental group composed of randomly selected snails of similar age (with a shell diameter of approximately 4 cm) was placed in a polycarbonate box (26 cm wide x 43 cm long x 15 cm high) in a temperature controlled room (22±1˚C) and exposed to the ELF-MF as shown in Figure 1. For the purpose of 31P NMR analysis, the single group of snails (n = 20) was exposed to the ELF- MF. After 7 days of exposure, 10 randomly selected snails were used for recording NMR spectrum, another 10 snails were further exposed to the ELF-MF up to 16 days, and another NMR spectrum was recorded. Immediately afterwards, a control group was formed by placing 8 snails at the same position as the exposed group, but the source of ELF-MF was turned off and unplugged from its power supply (sham exposure) for 7 days, after which the control NMR spectrum was recorded.

A similar procedure was used for biochemical analysis. The only difference was the number of snails: 3 animals out of group of 7 snails were used for enzyme activity analysis after 7 days of ELF- MF exposure, and the remaining 4 snails were used for enzyme activity analysis after 16 days. The control group (n = 5), placed at the same position as the ELF-MF treated group, was sham exposed for a period of 7 days, immediately after the 16-day treatment.

Ganglion complexes were isolated as previously described in Nikolic et al (2008). Briefly, after the snail foot was separated, it was pinned onto a cork plate in the extended position. Incision at the dorsal anterior surface of the snail's foot enabled

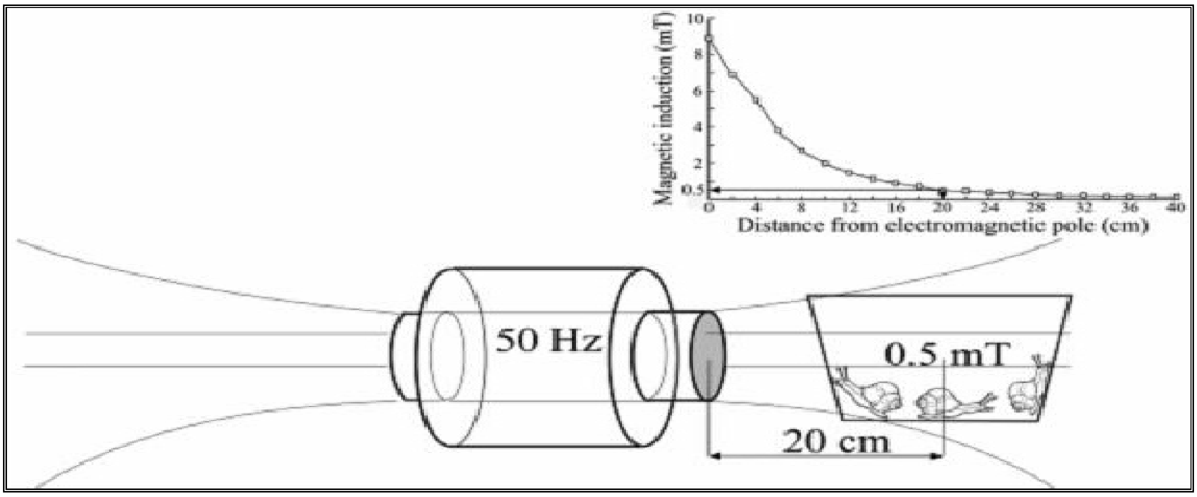

Figure 3.2.1 ELF-MF exposure system ,electromagnet and box with snails

With marked magnetic force lines. Inset: change of the magnetic induction within the box with snails access to the ganglion complex. In order to prevent tissue degradation, the isolated ganglions were kept in snail physiological solution on ice prior to measurements.

The source of ELF-MF was placed approximately 20 cm from the center of the box with snails (Fig.1). Alternating magnetic fields were generated by a solenoid-type electromagnet with a regular laminated transformer core and pole dimensions of 9.5 cm × 9.5 cm. A 50 Hz sinusoidal current (40V, 4.5A) was passed through the magnet. The alternating magnetic field was not uniform in the exposure space (Fig.1), but an average magnetic induction was 0.5 mT at the middle of the polycarbonate box, a value in the magnitude found in the vicinity of home appliances (Table1) (measured by a Hirst GM05 Gaussmeter, using a PT2837 probe). The temperature difference between ELF-MF treated and sham exposed groups, in the exposure space, was less than 0.3˚C measured in the air, and no difference was found measured in the liquid.

Magnetic force lines were parallel to the horizontal component of the local geomagnetic field. Earth magnetic field strength, measured by a GSM 10 proton magnetometer (Geomagnetic Institute - Grocka, Belgrade), was within the normal range throughout experiments in the area of study (44°38' N, 20°46' E). The background magnetic field did not exceed the value of 10-5 mT.

Exposure time was chosen based on the previous experiments, showing that a 0.5 mT alternating magnetic field can induce behavioral effects, as well as biochemical changes in the brains of rats exposed for as little as 7 days (Janać et al., 2005; Jelenković et al., 2006). Analysis of enzyme activity was performed on isolated, individual snail ganglions. Each ganglion with a weight of approximately 61 mg was analyzed in triplicate. Ganglion tissue was homogenized in 0.7 mL Tris-HCl buffer at pH of 7.4 with 0.01% Triton X-100. The homogenate was centrifuged in refrigerated in an Eppendorf microcentrifuge, model 5415R, at 10000 rpm. The supernatant was used for enzyme activity measurements. Protein content was determined by the method of Bradford using BSA as standard proteins (Bradford, The activity of investigated enzymes was measured usi Shimadzu UV-2501 PC spectrophotometer (Shimadzu Scientific Instruments, Japan). ATPase activity was determined by measuring ATP decomposition to inorganic phosphate and ADP. Three reaction mixtures were set, one experimental and two controls. The reaction was started by adding 70 µg of total proteins from isolated ganglions into the final volume of the reaction mixture. The experimental reaction mixture contained: 40 mM KCl, 10 mM ATPMg, 10 mM MgCl2, 240 mM NaCl, and 25 mM Tris-Cl buffered at pH 7.4. First the control experiment was performed with the addition of 2 mM ouabain and without KCl, and the control experiment was performed without ATPMg. The reaction mixture was incubated at 22˚C for one hour and the reaction was stopped by adding SDS to a final concentration of 1%.

Inorganic phosphate was quantified by the method of Ohnishi et al. (1975) modified for microplate reader. The activity of ATPases was obtained as follows: the total ATPases were calculated by subtracting the probe absorbance from the total ATPases absorbance; by subtraction of the ouabain insensitive absorbance values from the total ATPases we obtained ouabain sensitive ATPases (Na+/K+-ATPase). Acid phosphatase activity was measured by the rate of p-nitrophenyl phosphate hydrolysis for 5 minutes by following absorbance at 405 nm. The reaction was started by adding 200 mg of total protein from isolated ganglions in the final volume of reaction mixture. The reaction mixture contained 10 mM acetate buffer (pH 5.5), 1 mM MgCl2, and 5 mM p-nitrophenyl phosphate. The p-nitrophenol concentrations were estimated by using extinction coefficient 18.5 cm2/µmol. All chemicals used for enzyme essays were supplied from Merck.

3.2.2 Discussion:

In the present work, performed on Helix pomatia isolated ganglions, exposure of snails to the ELF-MF for a period of 7 days increased intracellular pH value and caused changes in the activity of the total ATPases, Na+/K+-ATPase and acid phosphatase, enzymes involved in phosphate turnover. Another important finding is the difference between the effect of 7 and 16 days of ELF-MF exposure on snail phosphate metabolism. The level of phosphate compounds, PCr and ATP, as well as the activity of investigated enzymes, decreased in the16-day treatment group of snails, compared to the 7-day treatment group. Two alternative explanations can be proposed for the obtained 31P NMR spectrum of ganglia from the 7-day treatment group of snails. The first is that the tested ELF-

MF did not cause changes in the metabolism of identified phosphate compounds in the snail nervous system. As can be seen from Figure 3, we did not find prominent changes in the intensities of PME, Pi, PCr and ATP signals. The second explanation of the apparent lack of change in the 31P NMR spectrum of snail ganglia after exposure to ELF-MF for 7 days is that an increase in both synthesis and the degradation of phosphate compounds occurred. We find the second explanation more plausible, since the increase in the activity of total ATPases and Na+/K+- ATPase, as found in the 7-day treatment group, should result in a decrease of ATP signal intensity, and we did not detect this by 31P NMR. We interpret this finding as an indicator that metabolic pathways involved in the synthesis of ATP increased in the ganglia from the 7-day treatment group. Furthermore, the detected increase of acid phosphatase activity, involved in the processes of catabolism (Hollander, 1971), in the 7-day ELF-MF treatment group of snails indicates that the processes of catabolism of phosphate compounds in the snail nervous system increased.

A longer period of magnetic field exposure, according to our 31P NMR data, decreased the level of energy source compounds ATP and PCr. Depressed ATP levels were also reported in experiments where rat brains were subjected to low frequency microwaves (Sanders et al., 1980; Sanders and Joines, 1984) and in the experiments with 60 Hz sinusoidal magnetic field on Physarum amoeba (Marron et al., 1986). Overall, our data suggest that magnetic fields probably cause a transient increase in the activity of enzymes involved in the synthesis of ATP, followed by the decrease in their activity with prolonged exposure. The increase of the Na+/K+-ATPase activity, which we found after exposure to ELF-MF in vivo, is in agreement with the results of the ELF-MF effect on the Na+/K+- ATPase activity obtained on the isolated enzyme preparations. The in vitro effect of 60 Hz magnetic field was reported for the Na+/ K+-ATPase containing vesicles prepared from frozen rabbit kidneys (Blank and Soo, 1996). The increase in the activity of Na+/K+-ATPase, found in both, in vivo and in vitro research indicates that ELF-MF interactions with biological systems as reflected in this enzyme activity might be at the protein level. Recent research showed that the 0.5 mT 60 Hz magnetic field can increase the activity of F0F1- ATPase in chromatophores prepared from the cells of bacteria Rhodospirillum rubrum (Chen et al., 2009). The F0F1-ATPase is also present in the inner membrane of eukaryotic mitochondria. To what extent this mitochondrial level of the ELF-MF- biological system interaction has a determining role in the complex phenomena whose net results we measured, needs to be further explored.

The prominent decrease after 16 days exposure at the level of PCr, which serves as the source of ATP (Mellergard and Siesjo, 1998) suggests that long exposure most probably affected an energy demanding cellular processes, such as gene transcription and protein synthesis. Therefore, the possibility of magnetic field-biological system interaction on the gene level should not be excluded. We found that with longer exposure to ELF-MF in comparison to 7 days ELF-MF treatment there was a significant decrease in the activity of total ATPases and acid phosphatase. Even though it seems that some compensatory mechanism is in place, it is hard to say what levels and mechanisms of the regulation of enzyme activity are involved. Although it is quite possible that long term effects of ELF-MF exposure involve some gene transcription and translation changes that was not the object of our present study. Finally, on the basis of the results obtained, one proposes that exposure to the ELF-MF for the period of 7 days increased the overall phosphate turnover in the snail nervous system, while after prolonged ELF-MF exposure phosphate metabolism adjusted to the tested ELF-MF by reaching a balance at the new level.

Most probably, more than one level of magnetic field-biological system interaction is involved in the detected perturbations of the phosphate metabolism. Several aspects of nervous system energy status after exposure to ELF-MF in vivo were measured in this study. The results presented here, to our knowledge, are the first description of the ELF- MF influence on the phosphate metabolism in the nervous system of Helix pomatia. We have found that the magnetic field induced an increase in the consumption of phosphate compounds and altered the activity of some enzymes involved in phosphate turnover. Together with in vitro conducted research, it could contribute to further understanding of the magnetic field - biological systems interactions.

3.3Magnetic Resonance Imaging: Health Effects and Safety:

Magnetic Resonance Imaging (MRI) is one of the most rapidly advancing diagnostic imaging tools today. Hazards intrinsic to the MR environment must be understood, acknowledged and respected. MRI is safe, but if something goes wrong, it can go very wrong. MRI-related accidents do happen, however they were not reported in most countries, including Malaysia. There are several safety issues to be considered by the radiologists, clinicians, radiographers, nurses and medical physicists involving with MRI examinations. These include those related to the magnetic field, gradient magnetic fields, and radiofrequency (RF) magnetic fields. This paper reviews the health effects and current safety issues related to MRI environment for both the patients as well as the staff members. Injuries from MRI accidents are occurring more frequently now and there is an urgent need for MRI facilities to implement safety guidelines. We propose several safety recommendations for implementation by the MRI facilities and the health authority.

Magnetic resonance imaging (MRI) is one the most rapidly advancing imaging techniques available today. It is normally used to produce detailed sectional images of the body in any imaging plane. Compared to the x-ray based medical diagnostic techniques e.g. general radiography, positron emission tomography (PET) and computed tomography (CT), MRI does not employ ionising radiation but uses radiofrequency (RF) fields. Therefore, the modality is considered to have less health effects than the ionising radiation-based imaging modalities.

As a start, lets review your knowledge of MRI health effects and safety. How would you answer the following questions?

1. What advice would you give to a medical doctor about scanning a pregnant woman?

2. Can a pregnant staff member enter the MRI scanning room?

3. What procedures would you advise if a patient suffers from cardiac arrest in the

MRI scanning room?

If you are uncertain in answering these questions then you are advised to review your understanding of MRI health effects and safety. There are many excellent books and review papers on MRI health effects and safety.

3.3.1HEALTH EFFECTS:

The potential benefits of MRI are numerous. However, there are hazards intrinsic to the MR environment which must be understood, acknowledged and respected. In general, during MR diagnostic imaging and spectroscopy, patient being scanned and those individuals in the immediate vicinity of the equipment can be exposed to three types of magnetic fields simultaneously:

• The static (main) magnetic fields

• Time-varying magnetic field gradients

• Radiofrequency (RF) magnetic fields

The hazards caused by these fields can affect patients, staff and other persons within the magnetic field environment. Several incidents involving MR have been reported in ECRI Health Device Alerts (HDA), U.S. Food and Drug Administration (FDA) Medical Device Reporting (MDR). Below are some examples from the database:

• “ A 6-year-old boy died after undergoing an MRI exam at a New York-area hospital when the machine's powerful magnetic field jerked a metal oxygen tank across the room, crushing the child's head (2001)”

• “A patient with an implanted cardiac pacemaker died during or shortly after an MR exam. The coroner determined that the death was due to the interruption of the pacemaker by the MR system (1989)”

• “A patient with an implanted intracranial aneurysm clip died as a result of an attempt to scan her. The clip reportedly shifted when exposed to the magnetic field. The staff apparently had obtained information indicating that the material in this clip could be scanned safely (1992)”

• “A patient complained of double vision after an MR exam. The MR exam as well as an x-ray revealed the presence of metal near the patient's eye. The patient was sedated at the time of the exam and was not able to inform anyone of this condition

• “A patient received blistered burns on the finger where a pulse oximeter was attached during MR scanning. A skin graft was required to treat the affected area (1995)” MRI is safe, but if something goes wrong, it can go very wrong. MRI-related accidents do happen, however they were not reported in most countries, including Malaysia. Lack of uniform safety rules and negligence in screening of the patients and staff contribute towards this unfortunate situation. Anecdotal accounts abound, only the fatal accidents make it to the mass media and the professional journals.

Effects of Static Magnetic Field ($\boldsymbol{B0}$)

The static or main magnetic field is used to align the nuclei in patients body. This powerful static magnetic field is always present even when the MR scanner is not imaging. The strengths of the static magnetic fields used in clinical and research MR systems for imaging and/or spectroscopy range from 0.012 T to more than 10 T compared to the 50 mT of the earth magnetic field. Safely above this level, evidence of safety must be provided by the sponsor or device manufacturer prior to routine clinical use [1]

There are two major safety issues regarding the static magnetic fields used in MR: attraction of ferromagnetic material towards the magnet and biological changes. Devices made from ferromagnetic material such as surgical tools (e.g. aneurism clips scissors and haemostats) and certain components of implantable medical devices (e.g. prostheses, pacemakers and neuro-stimulators) will be attracted to the core of the main magnet and this effect is known as projectiles. Anyone or anything in the direct path of the object may be struck as the object moves toward the magnet. Individuals in or near the MR system could be seriously injured by the effect. In addition, the object, the MR system, or other equipment in the room could be damaged. For some sensitive devices such as physiological monitoring instruments and pacemaker, permanent damage may occur when exposed to certain level of magnetic fields. Furthermore, the implantable device such as pacemaker may experience a torque, which is sufficient to cause displacement in the body. Even devices such as sandbag that might appear safe have become projectile in the MR environment. This is because some sandbag contains ferromagnetic pallet to add weight to the bag without increasing its size. The biological effects of static magnetic fields is one of the most controversial topics in the field of MR safety. It have been reported in several literature that several structures within humans are affected by the static magnetic fields such as the retina, pineal gland, and some cells in the paranasal sinuses. However, the effects are not the same as harmful, or teratogenic/ carcinogenic. [2, 10]

Effects of Time-varying Magnetic Field (dB⁄dt)

Time-varying magnetic field gradients in MR system functions to provide position dependent variation in magnetic field strength. The gradients are pulsed during and between RF excitation pulses. The faster the sequence of imaging or spectroscopy, the greater the gradient fields change rate.

The main safety concerns with the time-varying magnetic field gradients are biological effects and acoustic noise. Subjecting the human body to time-varying magnetic fields leads to induced electric fields and circulating currents in conductive tissues. At any particular location, the currents induced will be determined by the rate of change of the magnetic field and the local distribution of the body impedance, which is primarily resistive at frequencies below about 1 MHz.

3.4 Biological Effects of Long-Duration, High-Field (4 T) MRI on Growth

Magnetic Field Exposure System

The MRI exposure was performed using a 4.0T, 31 cm diameter, clear bore imaging spectrometer [Surrey Medical Imaging Systems (SMIS), Guildford, Surrey, UK] and a superconducting magnet (Magnex Scientific, Abingdon, UK). MRI-exposed animals were placed in cylindrical plastic exposure chambers, which were 11 cm in diameter and 15 cm in length. The chambers were perforated to allow air exchange. A layer of animal bed- ding (ground corncobs) approximately 2 cm deep was placed in the chamber, and apple wedges were provided as a source of water and food. The exposure chamber was placed inside the SMIS volume coil (8-element bird- cage, 14 cm diameter, 25 cm length). The coil and exposure chamber were positioned at the center of the 4T superconducting magnet. The imaging parameters were set similarly to those used in our previous study (8), with the exception of the RF resonance frequency, which was 170 MHz instead of 200 MHz. A standard spin-echo imaging sequence (TR/TE 2000/30 msec, one slice) was applied for 9 hours (10 PM to 7 AM) on the chosen day of gestation. RF exposure at 170 MHz consisted of two five-lobe, sincmodulated RF pulses, each 4 msec long with peak powers of 76 and 19 W (p and $\pi/2$ flip angles).

The SAR was estimated from the total power (p) delivered to the RF coil when loaded with five mice weighing approximately 30 g each (M = 0.15 kg), from measurements of loaded and unloaded coil Q, and considering the duty factor for the 180° pulse(durati t =4 msec) and the TR time of 2000 msec, according the following formula (26): SAM=(1/M)(τ/TR)P[1-(Q(loaded))/(Q(loaded))] $W/k\tau$.

The average SAR in mice for these exposure conditions was estimated to be 0.2 W/kg. These SAR conditions were chosen in order to maintain typical MR conditions and to avoid introducing a thermal burden on the animal; current Food and Drug. Administration guidelines specify a maximum whole-body average SAR of 0.4 W/kg, with a peak SAR of 8 W/kg in any 1 g of tissue (10). Gradient exposure consisted of the readout gradient along the x- (transverse) axis and the slice-selection gradient along the z- (axial) direction of the magnet. The phase-encode gradient was turned off. The readout gradient strength was 5 G/cm with a ramp time of 500μsec, resulting in dB/dt ranging from 0 to 5T/sec at the center and walls of the cage, respectively, with 10 ramps applied every 2 seconds (slice, rephase, π, readout, and refocusing gradient lobes).

Thus, the read gradient (Gx) was the major contributor to the dB/dt (the slice gradient Gz was small, with one slice, and the phase-encoding Gy was off). The exposure chamber was positioned at the center of the magnet in the x- and z-directions and was approximately 4 cm below the center in the y-direction. The ambient temperature in the magnet bore was measured using an alcohol, liquid-in-glass thermometer; the mean temperature was 18°C. The mean ambient tem-premature of the room was 20°C. Sham MRI animals were placed in identical chambers outside the magnet at the 5 G line and remained there for the duration of the exposure. The acoustic sound level was measured (A scale weighting, peak response) at the position of the sham animals and at the bore opening of the magnet using a digital sound meter (model 01617-00, Cole- Parmer Instrument Company, Vernon Hills, IL) (27).

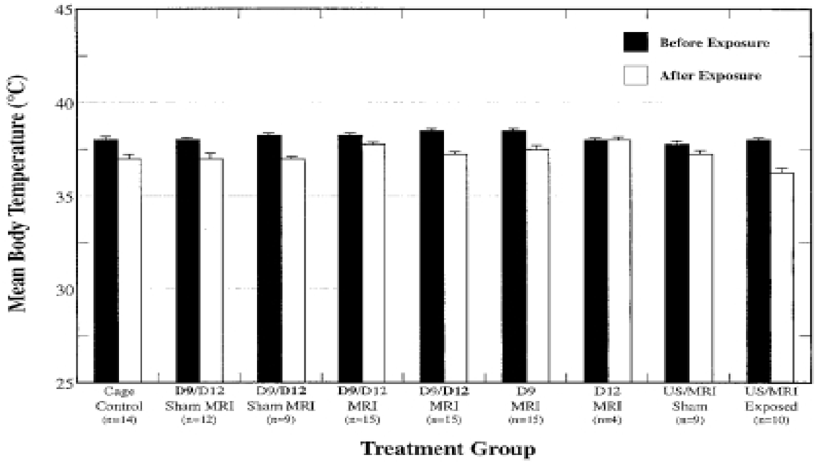

Figure 3.1 Mean body temperature in Celsius of exposed animals measured

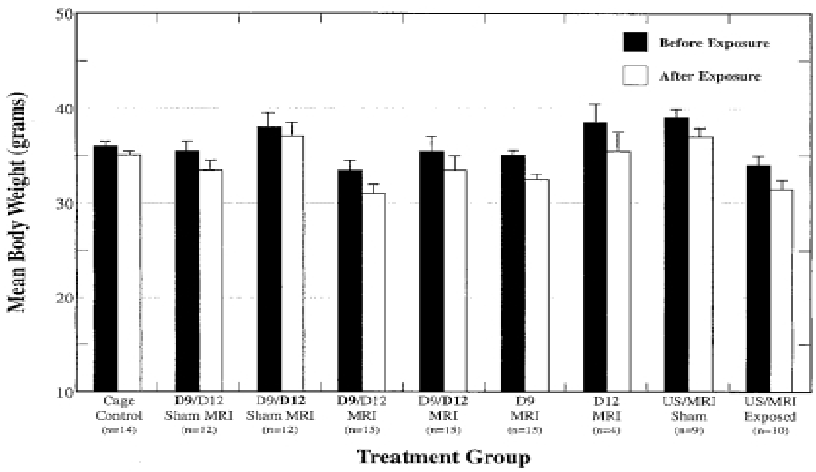

Figure 3. 2 Mean body weight in grams of exposed animals measured before and after each MRI exposure.

Bold type indicates ex- posure day for the 2-day MRI. Closed bars are pre exposure weights; open bars are post-exposure weights. Error bars are SEM. n is the total number of animals in each group exposure values for each group. The ANOVA analysis showed no differences between the changes in rectal temperatures between any of the experimental groups at the $P \leq 0.10$ level. With regard to mean body weight, however, the observed weight losses were significantly different at the $P \leq 0.10$ level for the MRI-treated groups compared with the cage control group and for the US/MRI-exposed group compared with its sham. The pairwise t-test indicated that the post-exposure temperatures and mean body weights differed from the pre-exposure temperatures for each of the groups at least at the $P \leq 0.05$ level. In the case of the cage control, the mean body weight and temperature for the group prior to exposure were 36.2 g and 38.0°C, respectively. Overnight, this group lost an average of 0.9 g, and the body temperature fell an average of 0.9°C. For the sham group, which was placed outside the magnet at the 5 G line, the initial mean body weight and rectal temperature were 37.4 g and 38.1°C. At the end of the experiment, the following morning, these animals had lost an average of 1.7 g of body weight, and their body temperature had fallen an average of 1.0°C. The four MRI exposure groups used in this study all exhibited similar small decreases in body weight and rectal temperature during the exposure to MRI conditions. As an example, the day 9/day 12 MRI group, which consisted of 15 animals, showed an average drop in body weight of 2.0 g on the day 9 exposure and 2.1 g on the day 12 exposure, while the corresponding decreases in rectal temperature were 0.4°C and 0.8°C on days 9 and 12, respectively. Both sham and MRI-exposed animals had free access to food and water in the form of apple slices placed in the exposure chamber. However, the sham animals usually consumed the apple slices while the MR-exposed animals did not.

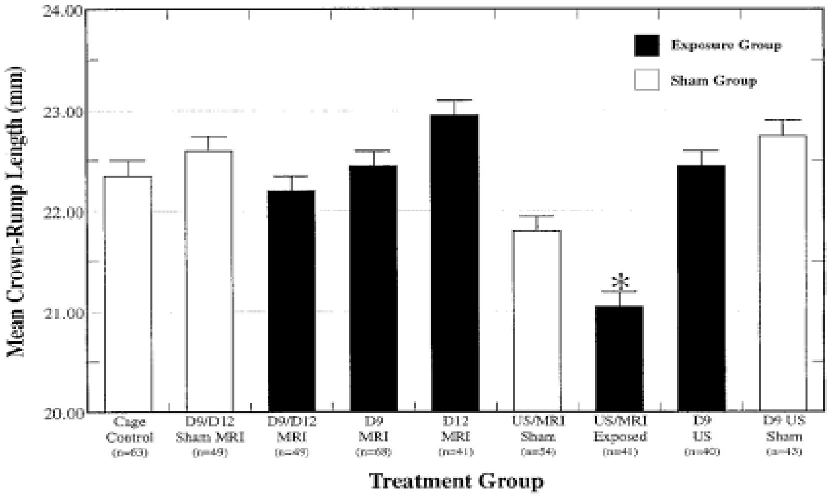

Figure 3.3 Mean crown-ump length in mm measured on day 18 post coitus. Closed bars are exposure groups; open bars are sham groups. Asterisk indicates group that is significantly lower (P ≤ 0.05) than its sham group. Error bars are SEM. n is the total number of fetuses in each group.

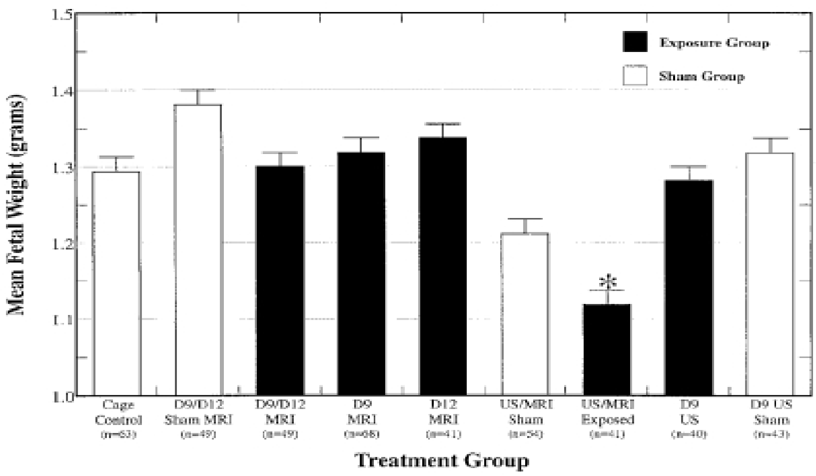

Figure 3.4 Mean fetal weight in grams mea- sured on day 18 post coitus.

Fetal Study

The crown-rump length (CRL) and fetal weight were measured on day 18 pc; these data are shown in Figs. 3 and 4. No significant differences were observed between the cage control group (or sham-exposed groups) and the experimental treatment groups exposed to ultra- sound or MRI alone. Statistically significant ($P \leq 0.05$) reductions in fetal weight and CRL were observed for the experimental group exposed to both ultrasound and MRI when compared with the sham-exposed animals. Litters from four dams were analyzed for each treatment group, resulting in an average of 50 fetuses per group. The sham MRI/ultrasound group also showed weight and CRL reductions when compared with the cage control group, suggesting the influence of animal handling procedures on this combined exposure group. No significant differences between treatment groups were observed for litter size or the number of fetal deaths (Table 1). However, the number of resumptions and stillbirths was increased for the day 12 MRI-exposed group (statistically significant at the $P \leq 0.05$ level) and the day 9/day 12 MRI-exposed group (difference not statistically significant when compared with the sham group). The ratio of males to females per litter was also not significantly different between treatment groups (data not shown).

Adult Study

The mean weights for each treatment group at birth, weaning, and euthanasia on day 50 are shown in Table 2. Significant reductions in weight at birth, weaning, and sacrifice were observed for the group exposed to ultrasound on day 9 and MRI on day 12 of gestation compared with its sham group. No statistically significant changes in weight were observed for the other treatment groups when compared with the shams or the cage controls.

The incidence of post-partum deaths was significantly higher for the day 12 MRI-exposed group than for any of the other treated groups (Fig. 5). This group also had a significantly higher incidence of resorptions and stillbirths in the fetal portion of the study (Table 1). There were no significant differences in spleen weights between treatment groups for either males or females (Table 3). There were also no significant differences in testis weight or seminal vesicle weight (Table 3) between the exposure groups and the sham or cage control groups

The effects of long-duration, high-field magnetic resonance imaging (MRI) on fetal growth and postnatal development in mice were studied. Seven experimental groups of pregnant ICR mice were exposed for 9 hours on day 9 and/or day 12 post coitus (pc) to magnetic fields (4 T static, 5 T/sec switched gradient, and 0.2 W/kg radiofrequency at 170 MHz) associated with MRI conditions. Two experimental groups (sham and exposure groups) were ex- posed to a combination of ultrasound (day 9 pc, 3.25 MHz, focused) and MRI-associated fields (day 12 pc). No statistically significant changes in fetal growth were observed in the animals exposed to only MRI or ultrasound fields. How- ever, in the combined ultrasound and MRI-exposed group, the fetal weight and crown-rump length were reduced compared with the sham and cage controls. These results suggest that MRI and ultrasound exposure well in excess of current clinical conditions can exert biological effects if applied at sensitive stages of fetal development.

3.5 INTRODUCTION:

Ultrasound is currently the standard approach for the initial evaluation of fetal anatomy. It is an imaging modality that is widely available, is cost-effective, and allows real-time examination of the fetus.1 US has the advantage of providing better spatial resolution than many other imaging techniques including MRI.

However, for a variety of reasons, US may not allow adequate assessment of a complex case or provide critical information for antenatal clinical management. MRI can provide additional information resulting in better counselling, management, and perinatal outcomes.2 This guideline has been developed to discuss safety, pre-procedure counselling, procedural considerations, and indications in the use of obstetrical MRI.

SAFETY OF MRI IN THE OBSTETRICAl PATIENT:

Maternal Risks

Maternal risks associated with the use of MRI are the same as for non-pregnant patients.3,4 One safety consideration for the obstetrical patient is prolonged supine positioning. A gravid uterus of significant size can lead to hypotension due to compression of the inferior vena cava. This can be avoided by placing the patient in a lateral oblique or lateral decubitus position. Fetal/Neonatal Risks theoretical fetal concerns include teratogenic and biological effects. It is known that MRI may cause effects at the cellular level from the induction of local electric fields, currents from static and time-varying magnetic fields, and tissue and cellular heating from RF fields. Most of the biological effects associated with exposure to RF fields are related to thermogenesis. The term "specific absorption rate" refers to the dosimetric absorption of RF power. During an MRI procedure, the SAR is influenced by many complex factors and variables including the strength of the static magnetic field, the type of RF pulse used, the repetition time, the type of transmitting RF coil used and volume of tissue contained within, and the anatomical region exposed, among other factors.5 Other physiological, physical, and environmental factors include exposure length, the of energy deposition, physiological thermoregulatory response, concomitant illness, and local environmental conditions.5 Limits are determined for SAR for each pulse sequence to ensurethat the increase in body temperature is less than 0.5°C. Maternal and fetal temperatures remain within the specified limits even when sequences with higher SAR values are used, including when SAR increases significantly when using higher magnetic fields.

First trimester

Static field exposure has been the subject of animal research. Some animal studies have documented effects on the early fetus in terms of growth, miscarriages, and eye malformations.6–8 The applicability of these animal models to humans has been questioned.9 The National Radiological Protection Board in the United Kingdom stipulates in its principles for the protection of patients and volunteers during MRI that it “might be prudent to exclude pregnant woman during the first three months of pregnancy,”10 whereas the latest American College of Radiology guideline for safe MRI practices does not differentiate among the pregnancy trimesters, and states that all pregnant patients could undergo MRI as long as the benefits outweigh the risks.11 From a practical standpoint, MRI done during first trimester is usually performed for maternal indications and not for prenatal diagnosis. There are limited case reports of unplanned exposure to MRI in the first trimester of pregnancy. To date there is insufficient evidence to understand the true risks of first trimester exposure to the developing fetus.8,12 Until these theoretical concerns can be appropriately addressed, we advocate a cautious approach to using obstetrical MRI in the first trimester.

Second and third trimesters

The high level of acoustic noise generated in an MRI system may be of concern for both mother and fetus. The attenuation of sound within the abdomen of a pregnant mother, and its effect on the fetus, is currently under investigation.9 There are no reports of significant acoustic impairment resulting from exposure to prenatal MRI. Fetal MRI is typically performed at 1.5 T. The higher field strength of 3T is also considered to be safe.3 Artifacts may be more pronounced in the second and third trimesters due to the large amount of amniotic fluid and increased abdominal girth.13 There are no published studies of the long-term effects in human children who have had prenatal exposure at magnetic field strengths of 3T or more.14

Summary Statement

1. Fetal magnetic resonance imaging is safe at 3.0 tesla or less during the second and third trimesters. (II-2)

Recommendation

1. Use of magnetic resonance imaging during the first trimester of pregnancy should be restricted to maternal indications for which the information is considered clinically imperative. Inadvertent exposure to magnetic resonance imaging during the first trimester has not been associated with any long-term sequelae and should not raise clinical concern. (III-C) Use of contrast agents in obstetrical MRI Gadolinium is classified as a category C drug by the United States Food and Drug Administration. Intravenous gadolinium is teratogenic in animals at high and repeated doses.14 Gadolinium crosses the placenta and is excreted by the fetal kidneys into the amniotic fluid, where it remains, exposing the developing fetus, particularly the lungs and gastrointestinal tract, for an extended period of time.15 The 2010 American College of Radiology guideline for safe MRI practices recommends that intravenous gadolinium be avoided during pregnancy and used only if it is judged absolutely essential. One example of appropriate use could be in an examination for placenta percreta when planned delivery is imminent and fetal

exposure to gadolinium is thus limited.16 The risks and benefits of gadolinium use must be discussed with the pregnant patient and referring clinician.11 Despite animal data and concerns about the use of gadolinium in pregnancy, there have been no reported adverse human fetal effects.17 However, many authors remain cautious about the use of gadolinium at any time in pregnancy.13,18,19.

2. Gadolinium contrast may be used in pregnant women when the benefits outweigh the potential risks. (III-C) Risks of oral contrast media administration during lactation. In the postnatal period, it may be necessary to perform an MRI for maternal indications and contrast may be used in the lactating mother. A minimal amount of gadolinium is excreted in the breast milk: 99.2% of orally administrated Magnevist (a Gandolinium contrast) is fecally excreted; only 0.1% of the maternal intravenous dose is found in the breast milk, and only 1% of this is subsequently absorbed by the infant.14 In fact, the 2012 edition of the American College of Radiology manual on contrast media states that “the available data suggest that it is safe for the mother and infant to continue breast- feeding after receiving such an agent.”14 A similar conclusion was reached by the Contrast Media Safety Committee of the European Society of Urogenital Radiology in 2005.20

Summary Statement

2. It is safe to continue breastfeeding after receiving a gadolinium contrast agent. (III) PROCEDURAl CONSIDERATIONS Obstetrical MRI can be technically challenging to perform and interpret given the movement of the fetus and its variable lie and presentation.

Technical Requirements

The imaging team should consist of:

1. a technologist who fulfills the competency profile of the Canadian Association of Medical Radiation Technologists and has experience in fetal MRI, with specific training in MRI principles, sequences, and safety, and ideally.

2. a radiologist who is either trained or highly experienced in fetal MRI. Standards for credentialing MRI physicians vary from province to province. In British Columbia, subspecialty MRI accreditation (such as fetal MRI), requires 3 months of full-time training. Selection of optimal sequences and interpretation of resulting images requires knowledge of fetal anatomy, pathology, development, and maturation, as well as experience in discriminating between artifacts and true pathology. Fetal MRI is operator-dependent and requires appropriate sequences tailored to the organ system and suspected pathology. The imaging protocol must be altered when the fetus moves or if new anomalies are detected in the course of the scan. In addition to investigating the anomaly in question, the operator should examine the entire fetus and intrauterine structures whenever possible.

Ideally, three orthogonal planes should be obtained through the fetal head and body in each sequence. The MRI protocol primarily includes T2-weighted sequences. T1- weighted, diffusion-weighted, and additional sequences may be added if indicated, and ideally should provide documentation of the entire fetus as well as the placenta, uterus, and surrounding maternal structures. Repeated sequences may be required if the fetus moves. The field of view should be as small as possible without causing fold over artifacts. Slice thickness between 2.5 and 5 mm is used in examining most fetal structures. Thinner slices are possible but have adverse effects on signal- to-noise ratio. At present, the minimum voxel size that may be obtained with fetal MRI is 0.8 × 0.8 × 2.5 mm, with slice thickness and fetal maternal movement the major limiting factors. These factors decrease resolution and may obscure structures smaller than 1 mm and create difficulties in accurately measuring small or thin structures. Pre-procedure Counselling

Pre-procedure counselling and education is important prior to obstetrical MRI as it may help alleviate maternal anxiety.21 Counselling should include discussions of the working diagnosis and the indications for the MRI as well as procedural details, such as the duration of the scanand the noise involved. A communication plan should be formulated to relay information to the patient from the interpreting physician via the primary caregiver as soon as reasonably possible. However, both patient and referring physician should understand that in view of the number of images acquired and the complexity of anatomical data, formulation of an opinion can take many hours and therefore the expectation of a prompt verbal report is in most cases unrealistic.

Maternal and/or Fetal Sedation

Patients may find the claustrophobic environment distressing, particularly if the exam is prolonged by fetal movement and repetitive sequences. In the past, maternal and or fetal sedation was frequently used in obstetrical MRI. With the development of ultrafast sequences, maternal and fetal sedation is no longer required except in extraordinary circumstances.

Technical Considerations

There are limitations in performing fetal MRI in obese patients. With increased body wall thickness, the signal- receiving elements of the coil are not close to the intrauterine regions of interest, and a larger field of view is required; therefore, signal and image resolution are not optimal. A large mother may not fit inside the MRI unit, particularly when placed in decubitus position. Maximum values for body size and weight vary among manufacturers; however, a body circumference of more than 140 cm and/or a weight of more than 140 kg may be problematic.

MRI resolution can also be suboptimal if there are excessive fetal movements. Polyhydramnios can allow increased fetal movement, so should a decompression amniocentesis be performed for other clinical indications, a clinically indicated fetal MRI should be done as soon as reasonably possible following the decompression.

Central Nervous System

The fetal brain is well-observed on T2-weighted sequences because of the contrast between cerebrospinal fluid and brain tissue. After 17 weeks, the advantages of\ MRI in diagnoses of both developmental and acquired intracranial abnormalities have been well established 23–25; however, diagnosis of some abnormalities may not be possible until after 24 weeks. Additional sequences such as T1-weighted and diffusion-weighted imaging provide information about brain development, cell density, myelination, hemorrhage, and ischemic lesions. It should be noted that calcifications are not demonstrated on routine MRI sequences, and consultation with the radiologist is recommended if confirmation of sonographically suspected calcifications is required. Fetal Oropharynx and Face MRI can be used to assess oropharyngeal anatomy in conditions where airway patency may be compromised by masses or mandibular or other facial malformations. MRI is useful to confirm or diagnose an isolated cleft of the posterior palate. MRI may also be helpful in clarifying anatomy in other anomalies, such as atypical facial clefts, retrognathia, micrognathia, craniosynostosis, cephaloceles, vascular anomalies, tumours, microphthalmia, and other ocular and orbital abnormalies.

The position of neck masses relative to the fetal airway can be assessed using MRI, which can assist in managing delivery when an EXIT (ex-utero intrapartum treatment) procedure is being considered. Fetal goiter and thyroid position relative to neck masses can also be imaged on T1- and T2-weighted views. Thoracic Anomalies Sonography is the primary screening method for the detection of thoracic anomalies, mediastinal shift, and the presence of fluid in the pleural space. For malformations such as bronchopulmonary sequestration orcongenital pulmonary adenomatoid malformation, MRI should be performed if fetal US cannot provide the information necessary for counselling or management.27 In congenital diaphragmatic hernia, MRI can be used to evaluate lung volume and the presence of liver and intra-abdominal organs in the thorax.28–30 Pulmonary hypoplasia can be a significant contributor to neonatal mortality and morbidity, and so the antenatal assessment of lung growth and development maybe useful in predicting survival and may aid in perinatal management.

Evaluation of the Fetal Heart

Although sequences are being developed to evaluate cardiac structures and function, fetal echocardiography remains the method of choice for screening and prenatal diagnosis of cardiovascular anomalies. Intra-abdominal Anomalies MRI should be reserved for circumstances when fetal US cannot provide the information necessary for counselling or management. After 20 weeks, high signal from meconium on T1-weighted sequences forms the basis for an MRI colonography. This technique can confirm the presence of bowel within the thorax in congenital diaphragmatic hernia, and it can confirm suspected bowel obstruction and anorectal malformations. Calcifications in meconium peritonitis may be depicted sonographically but not on MRI.31, 32

Urogenital Tract

Urogenital tract structures are readily visualized on USunlesssevere oligohydramnios or anhydramnios, fetal position, or other condition precludes adequate visualization of anatomy. MRI may be helpful in providing anatomical information in these situations.

Extremities and Bone

US is the primary method of evaluating skeletal biometry and observing findings involving distal appendages. However, sequences have been developed to image musculoskeletal structures with MRI.

Spine

US is the imaging modality of choice to screen for open neural tube defects. MRI can be used to confirm suspected anomalies of the spinal cord.35

Maternal Conditions

MRI provides images of maternal anatomy in 3 orthogonal planes without interference from bowel gas. Upper abdominal organs, bowel, kidneys, bladder, ovarian and adnexal masses, uterine anatomy, placental position, and cervical anatomy are visible, and additional targeted sequences can be obtained if necessary. MRI may be particularly useful when appendicitis is suspected clinically and US examination is negative.36

Placental Adhesion Disorders

The diagnosis of placental percreta can be made with either US or MRI. However, MRI is the imaging method of choice when there is a risk of posterior placenta increta or percreta.37

SUMMARY

Fetal MRI is an expensive and limited resource in Canada. Questions arise over its utility, indications, and safety in the obstetrical patient. Ultrasound remains the primary diagnostic tool for fetal imaging. Although MRI may provide additional relevant clinical information, fetal movement can create artifacts leading to non-diagnostic images. MRI in the obstetric patient should only be done if the ultrasound assessment is inadequate for antenatal clinical management and the desired information is required in the fetal period; on occasion it may replace neonatal MRI requiring general anaesthesia. MRI should only be performed and interpreted in centres with sufficient expertise following a careful review of all imaging and clinical information. During the first trimester of pregnancy, MRI should be used only as a clinically necessary precaution in the case of theoretical risks. Gadolinium contrast can be used during pregnancy when it can provide critical information for the health of the mother and fetus. Although no documented adverse effects to the human fetus have been documented, gadolinium crosses the placenta and has teratogenic effects in animals. It is safe to breastfeed after receiving a gadolinium contrast agent.

While screening for fetal anomalies and prenatal diagnostic imaging relies primarily on US, fetal MRI tailored to gestational age and suspected pathology has a complementary role in prenatal and perinatal management.

3.6 Subjective acceptance of 7 Tesla MRI for human imaging

Exposure to 7 T whole-body MRI of head, extremities, or breast was assessed in 102 subjects. They judged sources of discomfort (examination duration, room temperature) and physiological sensations (vertigo, light flashes) on a 10-point scale, differentiating between examination phases: table stationary or moving. For comparison, the same questionnaire was completed by 43 of these subjects after undergoing a 1.5 T examination. Vertigo was the most pronounced sensation at 7 T with 5% rating it as very unpleasant (none at 1.5 T). This should be compared with the fact that the lengthy exam duration was regarded as even more uncomfortable. Compared to 1.5 T, average study duration at 7 T was roughly doubled, and 7 T elicited a wider range of complaints. Although the number of side effects is increased at 7 T compared to 1.5 T, 7 T was well tolerated by the majority of subjects. Further data collection is necessary for better understanding of these effects.

The study was performed in 102 subjects at a clinically oriented research site in cooperation with a university hospital. The subjects (healthy volunteers n = 24; patients with malignancies n= 18; patients with other diseases n=60) were informed about possible side effects, and contraindications were carefully examined. The volunteers were also informed about the fact that the 7T exam would not yield any individual diagnostic information. Scans were performed on a whole-body 7T scanner (Magnetom 7T, Siemens Medical Solutions, Erlangen, Germany) equipped with a gradient system capable of 45 mT/m maximum amplitude and a slew rate of 220 mT/m/ms. The region of interest was predominantly the head (n=73). An overview of volunteer characteristics and body parts imaged is shown in Table 1. After each examination (7 and 1.5 T, when performed), an extensive questionnaire was filled out by the subjects with the help of a physician, covering a wide range of possible sensations or side effects (referred to as “sensations” in Fig. 2), sources of discomfort (referred to as “causes for discomfort” in Fig. 3), as well as locations of potential muscle twitching (Fig. 4). The definition of “twitching” as was given to the subjects included unusual and or involuntary muscle contractions. This definition was meant to cover feelings associated with the rapidly switching gradients through the phenomenon o peripheral nerve stimulation (PNS). Due to lack of experience with PNS in most of the examined subjects, direct propagation of scanner vibration to the body, paresthesia, e.g., of extremities, or other sensations unrelated to PNS, could theoretically be misinterpreted as PNS, although a dedicated instruction was given to all subjects. To separate effects due to purely low frequency (LF) time-varying magnetic fields (i.e., due to moving through the static magnetic field), the participants were asked similar questions repeatedly for the different phases of an MR examination: slow table movement into and out of the scanner and while exiting the scanner room (LF magnetic field); stationary location in the isocenter (control situation: interme- diate-frequency gradients and high-frequency RF pulses). An additional potential sensation while entering or exiting the scanner room was termed “circulatory disturbance”. This could include feeling dizzy or shaky, things turning black, or vertigo. Objective sources for the general sensation of “circulatory disturbance”, such as low blood pressure, abnormal heart beat, brain activity disturbance, were not evaluated. All potential sensations and muscle twitching were rated on a 10-point scale regarding intensity level (scale A: 0/2=no/very weak sensation, 4 = weak sensation, 6 = medium sensation, 8/10 = strong/very strong sensation) or level of discomfort (scale B:0= not unpleasant at all, 5 = tolerable, and 10 = very unpleasant). Additional comments could be added if so desired. Comparisons between the different examined regions of interest, different positioning of the subjects (head-first, feet- first), or between the genders were performed with help of the Mann–Whitney U -test. Sensations, causes for discom- fort, and twitching were compared between 1.5 and 7 T where possible (subjects who received both 7 T and 1.5 T examinations) with help of the Wilcoxon rank test. This test was also used for comparisons of sensations at different table move- ment states (moving or stationary table). A p value <0.05 was considered significant. The number of examinations performed to date on 7T systems is limited, and publications of subjective acceptance by patients and volunteers of ultra-high-field imaging are rare.

The presented data represent a contribution to a more detailed insight into the impact of various external (room temperature, exaination duration) and internal (sensory perceptions) factors influencing 7T exams.

The following observations of the study support the idea that 7T would be tolerable for a clinical diagnostic examination: (a) only 5% of all subjects felt uncomfortable vertigo during table movement, (b) in comparison to other sources of discomfort associated with the examination, sensations presumably due to the static magnetic field or changing LF magnetic fields (vertigo, metallic taste, nausea, light flashes) were considered relatively less disturbing at 7T, and (c) 78 of the 102 subjects were patients from a university hospital with various diseases, thus representing at least in part a potential clinical 7T population of the future.

To partially account for potential subjective influence, comparisons of the 7T experience with 1.5T exams were made: 43 subjects underwent both 7 and 1.5T exams with identical questionnaires, and, in contrast to other studies such as [19], paired comparisons could be performed. These comparisons indicate an evident dependence of side effects on the larger $B0$ and $dB0/$.

General acceptance

Based on our first results, it is apparent that each individual has a personal sensitivity threshold for experiencing side effects associated with high magnetic fields. For example, the two volunteers not starting the examination due to strong side effects (one with pressure around the head with magne to phosphene effects and one with nausea) reported similar symptoms during exposure to 1.5T, albeit of lower intensity, in agreement with Cavin [22] and Glover [12], who indicated that besides the field- dependence of side effects like vertigo and metallic taste, individual constitution plays an important role.

The individuals examined in this study were either healthy individuals or patients who could not expect a personal benefit from the 7T exam. The “willingness” to accept disturbing factors will almost certainly increase if patients are exam- ined for whom a 7T exam might have an important impact in the diagnosis of disease. Furthermore, the prolonged examination time of 7 T compared to clinical average is likely to be reduced significantly; today it is related to the still experimental nature of 7T imaging, requiring extensive optimization of image contrasts. In addition, 7T images were generally acquired with much higher spatial resolution than similar 1.5 T images, extending the scan time. It is expected that with additional experience, scan times will fall to the more conventional level of less than 30 min per exam.

It is difficult to determine each individual’s subjective perception of what is “uncomfortable” or “intolerable”. For instance, none of the five patients (5%) reporting very uncomfortable muscle stimulation requested termination of the examination, although all were equipped with an emergency squeeze-ball. Even at 7 T, where a significantly higher proportion of subjects experienced effects (also with higher intensity), the large majority would still be willing to undergo a 7T MRI examination again, as would four out of the five volunteers who terminated the examination due to side effects. Certainly “intolerable” is a relative descriptor.

The worse rating of room temperature at 7T compared to 1.5T was not related to SAR concerns; the room temperature at 7T was repeatedly criticized in the beginning of our study as being too cold, so that for later participants all effort was undertaken to minimize complaints in this regard. The air-conditioning in the scanner room is well- regulated to 21.5 ± 0.5˚C to guarantee magnetic field stability; blankets were provided if desired.

The poorer rating of opportunities for contact with scanner personnel at 1.5T could have been due to the busy schedules of the clinical 1.5T scanners. At the 7T scanner, the person- nel had more time to develop a rapport with each volunteer.

Extension of the results drawn from this study to occupational workers, who are the focus of the recent debate about the European Union Directive 2004/40/EC [20], is tempting, but due to different motion profiles within the magnetic field the results are only in part applicable. All data were acquired in subjects exposed to a magnetic field range from 0 to 7T, whereas workers are typically exposed to a maximum of 1–2T when moving around the scanner, since the 2T line is located approximately at the bore opening. On the other hand, workers would typically move faster through the stray field of the magnet than patients.

Main magnetic field and movement

Sensations that have been typically associated with high field strength (vertigo, light flashes) were reported as significantly more disturbing at 7T than at 1.5T, reflecting higher sensitivity to motion in a higher main magnetic field. On the other hand, they were often rated less disturbing and much less important than external factors which are not field-specific. For example, vertigo during table movement at 7T (five subjects with 8–10), which was by far the most disturbing field-related sensation, was rated less disturbing than some external factors such as acoustic noise and exam duration.

Introduction into the bore “head-first” produced more frequent and more intense experiences of physiological sensations compared to “feet-first”; in the “feet-first” orientation, the head is only moved to about the 2–3T area of the static field. A difference in this context was even found between knee exams and ankle exams (in the latter case, the head is moved to a location more distant from the 7T area). The prone position (hand) was associated with more frequent feelings of vertigo, which, following the ideas of Glover [12], might be related to increased head movements inside the bore due to missing fixation. 7T mainly led to more cases of vertigo-like sensations during movement into the scanner as well as while leaving the scanner room than 1.5 T. Forty-seven subjects experienced problems after getting up from the 7T table and while exiting the 7T scanner room. This effect may have been exasperated due to circulatory disturbance after an extended time in the supine position, but an effect by LF magnetic field exposure while walking through the decreasing magnetic field cannot be ruled out with this study. No statistically significant difference in sensations between the two field strengths was found for the non-time-varying main field in the isocenter during imaging.

Gradients, twitching

It was not our purpose to test the acceptance of gradient switching, since this factor is well known from 1.5T scanners [21]. Rather, these questions were added to the questionnaire to potentially serve as a control for effects more likely to be high field dependent. Unexpectedly, the frequency of “twitching” was statistically significantly higher at 7T com- pared to 1.5T (5/100 or 4/43 at 7 T vs. 0/43 at 1.5 T with grades 8– 10); this was unanticipated, as the gradient strength is similar to clinical 1.5T scanners, and both gradient systems follow the IEC safety guidelines [4]. Twitching, however, most frequently occurred in arms and legs, possibly asso- ciated with paresthesia due to the extensive length of time lying in the scanner, or by misinterpretation of mechanical vibration as muscle twitching due to contact with the scanner wall. In single cases the subjects indeed stated that the effects were more like “cramps”. Thus, we believe this effect is not equivalent to gradient-induced PNS, but rather paresthesia through prolonged nerve compression.

Noise

For a safe operation, the noise inside the scanner has to be less than 99 dBA [2] with hearing protection. The worse rating of acoustic noise at 1.5T might be explained by the of additional passive noise dampening material in the bore of the 7T. However, objective measurements of the noise inside the scanner reveal that the 7T scanner is louder (max. 109 dBA) than the 1.5T systems (max. 99 dBA) used in this study for equivalent sequences. The most probable explanation is that at 7T frequently stronger dampening earplugs (32–41 dBA) were offered to the subjects for noise reduction, whereas at 1.5T system headphones providing only 14 dBA were used as the standard.

The better noise reduction through ear plugs might more than compensate the loudness inside the 7T scanner.

Limitations

The individual stages of preparation and examination procedure cannot be perfectly separated from one another. On the other hand, future 7T exams will consist of a combination of patient preparation on the table, moving into the scanner, as well as scanning with gradient and RF fields similar to the ones used in this study, so that a general evaluation could be more meaningful for judging overall acceptance. Although all questionnaires were filled out together with a physician, it is difficult to know whether some sensations were interpreted incorrectly, rendering erroneously high or low numbers. For example, muscle twitching due to gradient stimulation is difficult to distinguish from other muscle effects. And finally, all of the ratings remain qualitative on the subjective scale of each individual subject. Another limitation is the effect of clarification of the study process itself. All of the volunteers were informed extensively about possible side effects before proceeding with the 7T examination. It is likely that this intensive exchange sen- sitized the volunteers to certain effects that would otherwise go unnoticed and unreported.

The 1.5T examinations were performed on two different scanners with different dimensions. An individual assessment of these scanners would, however, not change the general conclusions of this study.

Chapter Four

Methods and Results

4.1 Introduction:

In this chapter a brief description of the instrument used in this project is given. One start by giving general information about the SPECTAN NF which is used to measuring the magnetic flux density.

The experimental works are discussed, and the calculations are illustrated briefly. The aim of the chapter is to find the magnetic flux density generated by some in Khartoum state, besides finding the electromagnetic power generated by these towers. The study also accounts for the effect of magnetic field on lymphocytes transformation percentage.

4.2 Apparatus and Instruments:

In the first experiment many devices were used in the measurement of magnetic flux density (mfd) and the height beside the distances from the towers. The location and coordinates of the towers and transmition line are also determined.

The following apparatus were used in this work

4.2.1 Towers Experiments:

In this experiment magnetic field of tower was measured at different distances by using the following devises:

4.2.1.1 Spectrum NF (5020) Device:

This device is used to measure mfd down to non scales. Fig(4.2.1) shows the device itself, while Fig(4.2.2) shows its blocked diagram with specifications written below

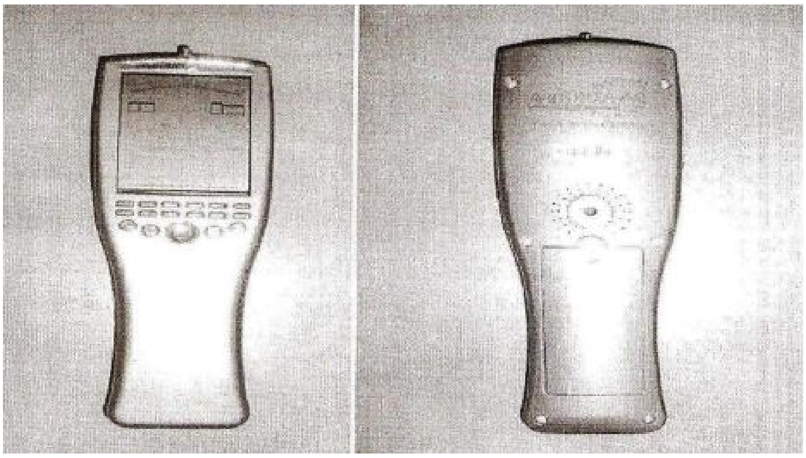

Fig (4.2.1): the view of spectrum NF (5020) device

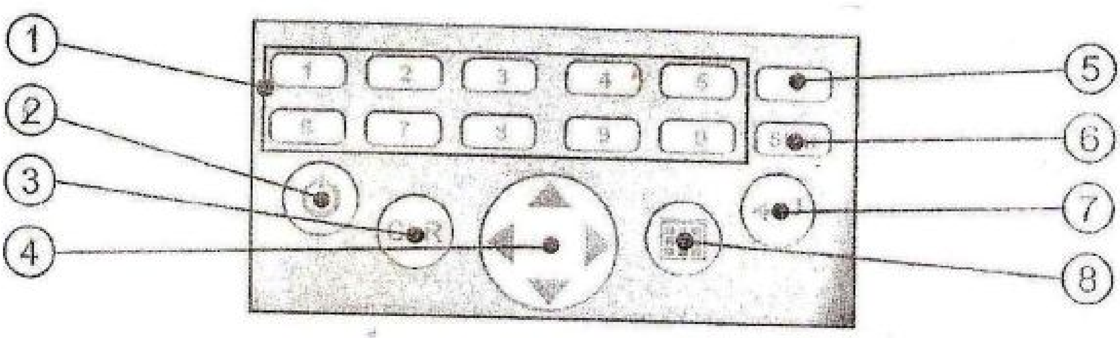

Fig (4.2.2): Block Diagram of NF (5020) device

(1) Numeric Block (Hotkeys).

scan 0-1 GHz, scan1-2 GHz, scan2-3 GHz, scan3-4 GHz, scan4-3 GHz, scanWLan(2.4GHz), scanGSM900 (D1&D2 Cell towers, no cell phones), scan GHz GSMI800 (E-Plus Cell towers, no cell phones)., scanUMTS (UMTS celltowers, no cell phones), DECT-Analyzer (Measure DECT phones).

(2) On/Off button:

Turn the unit on/off.

(3) Clear/Reset Key:

1. ESCAPE Key: Reset all hotkeys to default settings.

2. With main menu active: Delete input.

(4)Arrow Keys:

1. With main menu active: Selection of menu entries.

2. In Spectrum analysis mode:

- Right/Left Keys: Move frequency range by one SPAN.

- Up/Down Keys: Move reference-level by 10 dB.

3. In exposure limit calculation mode: Right/Left Keys: Select exposure limits or W/m-Display.

4. In Audio Mode:

- Right/Left Key: Increase/decrease Center frequency by one RBVV.

- Up/Down Key: Increase/decrease RBW (band width).

(5)Dot-Key:

1. In spectrum & exposure limit calculation modes (HOLD, on/off).

2. In audio mode: Switch between AM/FM.

(6)Shift-Key:

In spectrum & exposure limit calculation modes (PULSE, on/off).

(7)Enter-Key:

1. Switches between the operation modes spectrum analysis, audio, exposure limit calculation and broadband detector (power-meter).

2. With main menu active: confirms clirrent input (ENTER-Key).

(8) Menu-Key:

Call/Dismiss: main menu for changing various setting.

4.2.1.2 GPS Device:

The abbreviation GPS stands for the Global positioning system this system reties on set of-satellites. The GPS function is to identity the position of these satellites as well as calculating the distances between them and the earth in order to deduce the site of the receiver hence identifying their subordinates on the surface of the earth. Results Analysis And Discussion: All power lines give off radiation called electric domain and magnetic domain. Both domains have maximum limit to which workers exposed at different standards.

In this chapter, we present the results obtained during the study of the high- voltage towers. Exposure limit and frequency are measured for each high-voltage towers for different distance. For each high-voltage towers the measured distances could reduce real exposure limit and frequency at the time of measurement.

4.2.2 Blood magnetic Exposure Experiment:

In this work blood samples were exposed to magnetic field having different strengths at different expose times.

2.2.2.1 magnetic field generates:

The magnetic field generate consist of two coils wounded around to magnetic bars. The coils are delivered by dc current dc generator.

4.2.2.2 Blood sample:

The experiment was done on blood sample for three healthy fit person. 5ml is collected for each person. The blood samples were treated by heparinised sterile tubes after one hour from samples are 90 blood samples.

4.3 Methods :

Two types of experiments were done in this work. In the first type the mfd produced by electric pwer transmition lines in Khartoum state at different distances from the lines. The second type is concerned with the biological effects of magnetic field on lymphocytes transformation percentages.

4.3.1 Electric transmition lines Experiments:

In this experiment the mfd produced by 21different locations at ifferent distances from tansmition lines were measured by ung NF(5020)device. The following steps were done:

The height of the tower was measured. The horizontal distance at which mfd reading were taken was measured, where the number of readings ranges from 5 to 10. The mfd was measured b using NF(5020) .The corresponding frequency is also determined by NF(5020). The location of towers were determined by GPS device

4.3.2 Blood Exposure to static Magnetic field Experiment:

In this experiment blood is exposed to static field having different strengths. The Lymphocyte transformation percentage is tested.

4.3.2.1 Magnetic exposure:

The samples are exposed to static magnetic field by using dc current the samples were located between. Two magnetic piles which can move apart freely with maximum distance of 12cm. the magnetic field was changed by changing the current value , the blood samples were put in water path of 37i when exposed to magnetic field. The control samples are exposed is different magnetic fields of intensities 0.1, 0.2, 0.3, 0.4 and 0.5 tesla respectively for each magnet strength the exposure time is changed to be 60, 90,120,150 and 180 minute.

4.3.2.2 The lymphocyte test:

The lymphocyte test and analysis blood samples were for 72 hours at 37°C then the blood cells were inoculated and developed by coma day the percentage of transformation cells of lymphocyte cells were determined as shown in the tables below The percentage of transformation cells to lymphocyte cells for control and exposed samples and their relation to magnetic field intensity and exposure time were displayed graphically. 3. The following tables and graphs shows effect of magnetic field and exposure time on lymphocyte transformation.

4.4 Results and Results of towers Experiments:

The following table shows the maximum permissible mfd limits

Country “reference	Distance (m)	Exposure-limit (nτ)
Germany	35	10.000
Russia	50	1.000
Italy	40	500.00

4.5 Discussion

In view of figure (4-1-2) it is clear that electric devices like fans contribute to the radiation exposure limit.

This radiation intensive varies with the radiation angle with respect to the device antenna. It attains maximum valve at angle 90. The same hold for fig (4-1-3) for from key.

This confirms with the fact that radiation in intensity depends on the of incidence. The non uniformly of the curves is due to the presence of many electric devices inside the room, where readings were taken figures (4.1.4, 5.6.7) shows variation of radiation exposure (flux density to magnetic (d) with distance the fan and fan key at different angles. The figures show intensity drop with distance in crease, which a grees with inverse square law.

However the maximum intensity 3931.29 nT which can sometimes be greater than that of high tension towers (see tables (4-1-7)) and (4-1-13). This means that the electric devices inside house may also cause considerable higher radiation intensity which may became danger for long exposure.

In view of figures (4-1-8, 9, 10…, 27) and tables (4-1-8,9,10,…m 27) which shows magnetic energy density change with horizontal and vertical distances from the tower, one can observe the following. For high tension tower the readings are much higher compared to ordinary towers (see table (4-1-11) and (4-1-15).

However in general the readings of vertical horizontal and vertical distances does no vary considerably.

It is very interesting to note that the magnetic flux distance empirical relations for all figures in general resembles the theoretical one shown in fig (4-1-30). The empirical relations of electromagnetic energy density I versus distance for all figures in general agrees with the theoretical one in fig (4-1-31).

The biological effect of magnetic field produced by electric trans mitian lines, is shown by many authors to be useful same times, while it became dangerous some times. This requires studying the effect of magnetic field n blood since it circulates to deliver organs and cells with oxygen energy and materials that are important for life.

Unfortunately there are no enough devices to study the same magnetic oscillating field produced by electric transition lines.

This forces the researcher to study the effect of static magnetic field on lymphocytes transformation.

Three samples from 3 persons were exposed to magnetic fields of density 0.1, 2,0.3, 0.4 and 0.5T.

They are exposed by this fields for times 30,60,90,120,150,180 minutes respectively the lymphocyte transformation percent for the three samples 51,52,53 (taken form 3different persons) are 36,28 and 33 respectively (see tables 4.4.2.1,6,11).

The increase of magnetic density increases the lymphocyte transformation percent as shown by figures (2, 3, …6). The increase is large for 0.1 and 0.2T, while it because small above 0.2T. the increase with magnetic flux density is large and it can exceed 100 % same times. The effect of increase of time exposure is shown in figures (4.2.1 ,2…,15). The time exposure also increases the transformation percent appreciably and can also exceeds 100% compared to control. This indicates. That long exposure may cause biological hazards.

4.6 Conclusion

With the measure this study is concerned dose and effect of the high and ordinary tension electric towers on human body. The study shows that the magnetic and electromagnetic doses are be y and the permissible limit. However the study of the effect of static magnetic field on human blood shows that the exposure time plays an important trans formation. This means that time exposure is an important factor in biological effect.

4.7 Future work and Recommendation

1. The effect of a.c current having the same frequency an human blood need to be studied.
2. More study is receded to see the effect of magnetic and electromagnetic field an uital crgans like heart and brain.
3. The effect of long time exposure extending for hous, days, mothes and years needs. Intensive investigation.

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