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Explore our latest gallery of Editors' Picks.Browse Editors' Favorites 1 Effects of Electromagnetic WavesLight is made up of electromagnetic waves When you feel the warmth of the sun you are feeling energy through electromagnetic waves Electromagnetic waves are a disturbance that transfers energy through a field. That field is an area where they could be a push or pull on a object 2 How EM waves form EM waves occur when electrically charged particles move. Electromagnetic Waves have properties of wavelength and frequency 3 Sources of EM Waves The Sun's high temperature allows it to give off countless electromagnetic waves Stars also give off EM Waves, but they are so far away we don't feel them. There are a large number of EM waves from technology that we have such as Microwaves, radio waves, radar, cell phones. 4 Electromagnetic Waves can travel in a vaccum.Energy that moves in the form of electromagnetic waves is called radiation. An EM wave can travel without a material medium, and does not lose energy, and can travel forever 5 Converting Energy from one form to anotherElectromagnetic energy can be converted into many different forms. How EM waves interact with a medium depends on the type of wave and the type of the material 6 Converting Energy from one form to anotherFor example a microwave oven uses a type of EM wave called microwaves. Microwaves pass through the air with very little interaction. However they reflect off the oven's fans and sides. When microwaves encounter water, they convert that energy to thermal energy. 7 The Electromagnetic SpectrumThe range of all EM frequencies is known as the electromagnetic spectrum. The spectrum is set up on the left are the frequencies with the longest wavelength and the lowest frequencies such as radio waves and microwaves. On the right are the shorter wavelengths and highest frequencies such as x rays and gamma rays 8 Light comes from the Sun and other natural sourcesMost of the visible light waves in the environment come from the sun. The Sun's high temperature produces light of every wavelength. Other sources produce visible light such as stars, lightning, and fire. 9 Important terms to know for Electromagnetic WavesRadiation Electromagnetic Spectrum Radio Waves Visible Light Infrared Light Ultraviolet Light X Rays Gamma Rays Absorption Scattering Transmission Electromagnetic radiation (EMR) is a kind of radiation in which electromagnetic (EM) field waves carry radiant energy through space. Electromagnetic radiation includes radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays. The electromagnetic spectrum consists of all these frequencies. Electromagnetic waves are produced when electric particles are accelerated, interacting with and exerting force on other particles. Energy, momentum and angular momentum can all be transferred from a source particle to the substance it interacts with. Electromagnetic radiation definitionElectromagnetic radiation has traditionally been understood as comprising electromagnetic waves, synchronised oscillations of electric and magnetic fields. When an electric or magnetic field changes regularly, electromagnetic radiation, also known as electromagnetic waves, is produced. Different wavelengths of the electromagnetic spectrum are produced depending on how this periodic change occurs and the generated power. Electromagnetic waves travel at the speed of light in vacuum, commonly represented by the letter "c". Therefore, the oscillations of the two fields are perpendicular to each other and perpendicular to the direction of energy. Wave propagation is homogeneous, isotropic media, forming a transverse wave.According to quantum mechanics, EMR comprises photons, which are uncharged elementary particles with zero rest mass and are the quanta of the electromagnetic field, responsible for all electromagnetic interactions. Quantum electrodynamics is a theory that describes how electromagnetic radiation interacts with matter at the atomic level. EMR can also be caused by quantum effects such as electron transitions to lower energy levels in an atom and black-body radiation. A single photon's energy is quantized and increases with frequency. Planck's equation E = hf expresses this relationship, where E is the energy per photon, f is the photon's frequency, and h is Planck's constant. A single gamma-ray photon, for example, may have 100,000 times the energy of a single visible light photon.James Maxwell derived the waveform of the electric and magnetic equations, revealing the wave-like nature and symmetry of electric and magnetic fields. Maxwell concluded that light is an EM wave because the speed of EM waves predicted by the wave equation coincided with the measured speed of light. Heinrich Hertz's experiments with radio waves confirmed Maxwell's equations. Maxwell reasoned that because much of physics is symmetrical and mathematically artistic in some ways, there must be a symmetry between electricity and magnetism. Light, he realised, is a combination of electricity and magnetism, and the two are inextricably linked. According to Maxwell's equations, a changing magnetic field is always associated with a spatially varying electric field.Properties of Electromagnetic radiationElectrodynamics studies electromagnetic radiation, whereas electromagnetism is a physical phenomenon related to electrodynamics theory. Both electric and magnetic fields obey superposition properties. As a result, a field caused by a specific particle or a time-varying electric or magnetic field contributes to other areas in the same space. Furthermore, because magnetic and electric field vectors are vector fields, they add up similarly. In optics, for example, two or more coherent light waves may interact and produce a resultant irradiance that differs from the sum of the component irradiances of the individual light waves due to constructive or destructive interference.Light's electromagnetic fields are unaffected by travelling through static electric or magnetic fields in a linear medium, such as vacuum. However, in nonlinear media, such as some crystals, interactions between light and static electric and magnetic fields can occur; these interactions include Faraday and Kerr.When a wave refracts from one medium to another medium of different density, its speed and direction change as it enters the new medium. Snell's law expresses the degree of refraction as the ratio of the media's refractive indices. When the light of composite wavelengths (natural sunlight) passes through a prism, it disperses into a visible spectrum due to the prism material's wavelength-dependent refractive index (dispersion); that is, each component wave within the composite light is bent differently.At the same time, EM radiation has both wave and particle properties (see wave-particle duality). Therefore, many experiments have been carried out to confirm the existence of wave and particle properties. Wave characteristics are more visible when measuring EM radiation over relatively large timescales and distances, whereas particle characteristics are more visible when measuring over small timescales and distances. When electromagnetic radiation is absorbed by matter, for example, when the average number of photons in the cube of the relevant wavelength is significantly less than one, particle-like properties emerge. When light is absorbed experimentally, it is not difficult to observe non-uniform deposition of energy; however, this alone is not evidence of "particulate" behaviour. Instead, it reflects the quantum nature of matter.When wave and particle theories are combined, the emission and absorption spectra of electromagnetic radiation are fully explained. The nature of the absorption and emission spectrum is determined by the matter composition of the medium through which the light travels. These bands correspond to the atoms' permitted energy levels. Dark bands in the absorption spectrum are caused by particles in the medium between the source and the observer. The atoms absorb specific light frequencies, emitting them in all directions between the emitter and the detector/eye. As a result of the scattered radiation from the beam, a dark band appears on the detector. Dark bands in the light emitted by a distant star, for example, are caused by atoms in the star's atmosphere. When a gas emits light due to atom excitation caused by any mechanism, including heat, it is referred to as emission.ConclusionThe electromagnetic field can be viewed as a smooth, continuous field that propagates in a wave-like manner from a classical perspective in the history of electromagnetism. This field is quantized, which means that the effects of the free quantum field (i.e. non-interacting field) can be expressed in energy-momentum space as the Fourier sum of creation and destruction operators. In contrast, the effects of the interacting quantum field cannot be. On the other hand, Ionising radiation refers to high-frequency ultraviolet, X-ray, and gamma-ray photons that have enough energy to ionise molecules or break chemical bonds. These radiations, which pose a health risk, can cause chemical reactions and damage living cells in ways that simple heating cannot. 100%(1)100% found this document useful (1 vote)805 viewsThe document discusses electromagnetic (EM) radiations and their effects on living things and the environment. It aims to teach students to identify ionizing and non-ionizing radiations, the...AI-enhanced title and descriptionSaveSave The-Effects-of-EM-Radiations-on-Living-Things-and-... For Later100%100% found this document useful, undefined Standard Grade Physics Health Physics The Effects of Radiation on Living ThingsFrom this lesson and for the exam, you should be able to: • State that ionisation can kill living cells or change the nature of living cells. • State that radiation energy may be absorbed in the medium through which it passes. • State that for living materials, the biological effect of radiation depends on the absorbing tissue and the nature of the radiation. Understand that the dose equivalent measured in sieverts takes account of the type and energy of radiation.Radiation What types of radiation are harmful? Why is ionising radiation harmful?Radiation can kill living cells or change the nature of living cells. • All living things contain living cells. We have many different types of cells which perform different functions including: • Skin cells. • Red blood cells (they transport oxygen around the body) • White blood cells (they fight infection). • Nerve cells. • Muscle cells. • Brain cells.The Effects of Ionising Radiation • Ionising radiation can kill or change the nature of living cells. • The effects of the damage inflicted by the ionising radiation may: • be severe and cause immediate effects, or • not become apparent for a long time. • The biological effect of radiation depends on: • The type of radiation. • The type of body tissue or body organ that absorbs the radiation. • The total amount of energy absorbed.Short-Term Effects of Radiation Short-term effects usually occur when there's a large amount of exposure to radiation.WW2 – Hiroshima and Nagasaki During the Second World War, two atomic bombs were dropped on Hiroshima and Nagasaki in Japan. Those people who survived the blast were exposed to a large dose of radiation. Such doses caused severe damage to every part of the body, especially in the skin, blood, bone tissue and gut. Those people who were exposed to a smaller dose recovered from such immediate effects.Chernobyl Nuclear Power Station There was also a huge nuclear accident at the Chernobyl Nuclear Power station in the former USSR in 1986. Workers there were carrying out experiments on the reactor rods which caused fires to start. A number of firemen were exposed to very large amounts of radiation and 30 people died as a result. The damage to the power station was extensive but the radiation effects over a wide area were considerable. Chernobyl Nuclear Power Station • 135 000 people were removed from an area within a radius of 30 km. • The smoke and radioactive debris reached a height of 1200 m and travelled across Russia, Poland and Scandinavia. • A cloud of material from the accident reached the UK and, with heavy rain, there was material deposited on parts of North Wales, Cumbria and Scotland. This caused certain farm animals (e.g. lambs) to be banned from sale as they had absorbed radiation from the grass.Long-Term Effects of Radiation These effects take longer to become apparent and can be caused by much lower levels of radiation. One of the most important long-term effects of radiation is that of cancer in various parts of the body. Uranium miners tended to get lung cancer due to breathing in gases which emitted alpha particles. People who painted the dials of clocks with luminous paint developed one cancer from using their lips to make points on the brushes.Exposure to ionising radiation does not necessarily cause cancer The mechanisms for cancer occurring are poorly understood at the moment. One theory is that the ionising radiation affects the DNA material within us – our genetic make-up. Our DNA contains genetic instructions which control the operation and reproduction of the cells. If ionisations caused by ionising radiations alter these instructions in the DNA, then there is a chance that cancer will develop. Genetic damage can be caused to cells by radiation, including cells which are involved in reproduction.Quality Factor Different types of radiation have different effects on living cells. Even though the same type of tissue may receive the same dose, the biological effects of different radiations will be different. To take this into account, a quality factor is assigned to all types of radiation. The quality factor, Q, allows the effects that different radiations have on living cells to be compared.Quality Factor The quality factor for each type of radiation is shown below: From this it can be seen that alpha radiation is the most ionising radiation out of the three types.Dose Equivalent • REMEMBER, the biological effect of radiation depends on: • The type of radiation. • The type of body tissue or body organ that absorbs the radiation. • The total amount of energy absorbed. The DOSE EQUIVALENT is a measure of the biological effect of radiation and it takes account of the type and energy of the radiation as well as how the radiation is distributed. The DOSE EQUIVALENT is measured in sieverts (Sv). Because 1 Sv is a very large dose of radiation which could only happen as a result of a very serious nuclear accident or explosion, doses are given in millisieverts (mSv) or microsieverts (Sv).Suppose that 100 people all receive a dose equivalent of 1 Sv spread over the whole body. It is estimated that, of the 100 people on average 4 of them would eventually die as a result of the radiation. But precisely who would die, or when they would die, or what illness they would die of, cannot be predicted.Background Radiation Background radiation is radiation that is naturally occurring.Natural Sources of RadiationMan-Made Sources of RadiationDeath Risk - Cause FactMyth.com is a fact-checking website that presents a collection of facts and myths. It is an educational resource for full of explainer videos, citations, history, logic, and quotes. FactMyth.com intro video. We fact-check the conclusions of common internet talking points, peer-reviewed journals, the classics, Netflix documentaries, historians' accounts of history, smart TV shows, select claims by officials and official reports, YouTube videos, economic theories, scientific theories, popular science, folklore, commonly held beliefs, and other academically minded "factoids" (unverified claims AKA unverified propositions) passed around the culture and media of any era. After researching a "factoid," curating the best citations and videos we can find in the process (the best evidence of any sort), we rate the overarching statement (proposition) as "fact" or "myth" (thus assigning a certain truth-value to the proposition based on research). We then explain our position in as simple and clear terms as possible to build a case for our conclusion, using citations and offering insight into counterpoints (we back up our assigned truth-value by presenting an informal argument, generally written in essay form). It isn't that we are always correct, in fact we are only human (as Montaigne said, "what do I know?", as Plato's Socrates had previously answered "I know that I know nothing", although as Lichtenberg said, "I am not a Know-Nothing"). In fact, that is an important part of the site, we are always digging deeper and seeking alternative viewpoints! To reprimand the above, digging for the truth is complex, we don't have all the answers, and that is why we need your help! Users can help us stay relevant and accurate by commenting on our facts and myths to offer rebuttals and insight. We "follow the truth where it may lead" as they say, so feel free to offer citations and challenge our findings! Simply put, we aren't experts, we are researchers, and the hunt for truth is a collective process of "being skeptical" and "questioning everything" (feel free to join in on the fun by commenting and questioning us!) With that all said, one should note that FactMyth.com isn't a place to debate emotionally charged opinions and rhetoric (we cover relevant political science and policy, but try to avoid the political talking points of the day, for example). The focus is instead on high-level academic information (including facts and myths on history, geography, people, the arts, sciences, maths, and philosophies) and practical information (including facts and myths related to self-help, health, skill-sets, technology, finance, and culture). In this way the site serves as a free online university for general knowledge (or at least an encyclopedia or reference guide of interesting and useful truths; i.e. it is an encyclopedia of knowledge of all types, presented as a fact-checking site). We ask a lot of the reader intellectually, but we try to keep it simple and "explain it like you are five (a really smart 5)." Help us level up the collective intelligence of the internet by commenting and sharing. There is cake! TIP: If you're not feeling epistemological, you're no paying attention! Learn more about "How FactMyth.com works." As a library, NLM provides access to scientific literature. Inclusion in an NLM database does not imply endorsement of, or agreement with, the contents by NLM or the National Institutes of Health. Learn more: PMC Disclaimer | PMC Copyright Notice . 2015 Feb 25;2015:234098. doi: 10.1155/2015/234098 Current technologies have become a source of omnipresent electromagnetic pollution from generated electromagnetic fields and resulting electromagnetic radiation. In many cases this pollution is much stronger than any natural sources of electromagnetic fields or radiation. The harm caused by this pollution is still open to question since there is no clear and definitive evidence of its negative influence on humans. This is despite the fact that extremely low frequency electromagnetic fields were classified as potentially carcinogenic. For these reasons, in recent decades a significant growth can be observed in scientific research in order to understand the influence of electromagnetic radiation on living organisms. However, for this type of research the appropriate selection of relevant model organisms is of great importance. It should be noted that the great majority of scientific research papers published in this field concerned various tests performed on mammals, practically neglecting lower organisms. In that context the objective of this paper is to systematise our knowledge in this area, in which the influence of electromagnetic radiation on lower organisms was investigated, including bacteria, E. coli and B. subtilis, nematode, Caenorhabditis elegans, land snail, Helix pomatia, common fruit fly, Drosophila melanogaster, and clawed frog, Xenopus laevis. Current technologies have become a source of omnipresent electromagnetic pollution from generated electromagnetic fields and resulting electromagnetic radiation. In many cases this pollution is much stronger than any natural sources of electromagnetic fields or radiation. Wireless and radio communication, power transmission, or devices in daily use such as smartphones, tablets, and portable computers every day expose people to electromagnetic pollution. The harm caused by this pollution is still open to question since there is no clear and definitive evidence of its negative influence on human beings. This is despite the fact that extremely low frequency electromagnetic fields were classified as potentially carcinogenic. For these reasons, in recent decades a significant growth can be observed in the scientific research on the influence of electromagnetic fields and/or electromagnetic radiation on living organisms. Electromagnetic fields and/or electromagnetic radiation, as electromagnetic pollution, affect various elements of the environment. Among the elements of that environment all living organisms should be placed at the first position. Therefore it seems to be very important to appropriately determine the nature and related side effects of electromagnetic pollution and its impact on living organisms. Every day living organisms are exposed to different types of electromagnetic pollution. However, all of them can be well characterised by their physical parameters such as type (electric, magnetic, electromagnetic), frequency, and intensity/power. Electronic devices such as smartphones, tablets, microwave ovens, radio, and television sets emit low intensity electromagnetic radiation at frequencies from 300 MHz to 300 GHz that can be associated with microwaves. On the other hand power transmission lines and electric devices are strong sources of electromagnetic fields (primarily electric for power transmission lines, primarily magnetic for transformers, electromagnetic for antennas) and radiation of much lower frequencies but much higher intensities. According to the European Commission the sources of nonionizing electromagnetic radiation can be classified as [1]: radio frequency fields (RF fields), intermediate frequency fields (IF fields), extremely low frequency fields (ELF fields) and static fields. In order to illustrate quantitatively the authors' considerations presented above, the most typical sources of electromagnetic fields and/or electromagnetic radiation that influence living organisms are listed and described in Table 1. Sources of electromagnetic fields and radiation influencing living organisms [1]. Type Frequency Source Static* — Natural, video screens, magnetic resonance imaging, and other diagnostic/scientific equipment, electrolysis, and welding devices ELF Below 300 Hz Power transmission lines, home wiring, car electric engines, electric trains and trams, and welding devices IM 300 Hz ÷ 100 kHz Video screens, antitheft devices used in cars, homes, and shops, card readers, metal detectors, magnetic resonance imaging, and welding devices RF 100 kHz ÷ 300 GHz Radio, television, smartphones, tablets, microwave ovens, radar and radio transmitters, and magnetic resonance imaging It should be realised that different types of electromagnetic fields and/or electromagnetic radiation are responsible for different types of phenomena that can be observed as a result of radiation exposure. For example, high energy microwave radiation at frequencies from 300 MHz to 300 GHz can be carcinogenic and cause thermal effects, increasing the temperature of exposed organisms. On the other hand the same type of microwave radiation at lower frequencies from 100 kHz to 300 MHz has no such effect. It is very important to note that the sources of electromagnetic radiation characterised by field frequencies below 300 GHz are the source of the nonionizing type of radiation [2]. On the other hand low frequency electromagnetic fields are the source of another type of electromagnetic radiation as in the case of power transmission lines or transformers (by the action of the processes and devices present in the Power System [3]). Such electromagnetic fields that are characterised by field frequencies of 50 Hz or 60 Hz are quasi-stationary and their two field components (electric and magnetic) can be considered as separate [2]. The opinions of researchers about the influence of electromagnetic pollution on living organisms are divided. This is due to the fact that earlier studies very ambiguously indicated either negative or positive, or sometimes neutral, influence of electromagnetic fields and/or electromagnetic radiation. The scale of this problem can be illustrated by the fact that from 1980 to 2002 more than 200 epidemiological studies were published about the effects of electromagnetic fields generated by power transmission lines on human beings. About 60% of them indicated no negative effects of these fields, whereas the remaining 40% reported some smaller or greater negative effects [2, 4]. For these reasons in recent decades a significant growth can be observed in scientific research effort to understand the influence of electromagnetic fields and/or electromagnetic radiation on living organisms. Alarming reports of potentially harmful effects of electromagnetic pollution drew the attention of the World Health Organization (WHO), which in 2007 presented a summary report of an international research program titled Electromagnetic Fields [5]. In that program more than 1,100 various scientific publications and research reports were examined. In the report section dedicated to the effects of low frequency magnetic fields of 50 Hz and smaller or greater than 60 Hz it was stated that there are no firm grounds to tighten up the current limits for long-term exposure to these fields; however, caution is advised [5]. In May 2011, in Lyon, France, the International Agency for Research on Cancer (IARC) and WHO qualified the electromagnetic fields of radio frequencies as possibly increasing the risk of developing a malignant brain cancer, glioma, which is mainly associated with the use of mobile phones [6]. The problems described above still remain unanswered today and result in a great increase of interest in all aspects of electromagnetic pollution and especially its influence on living organisms. This statement can be also backed up by Figure 1, which presents the annual number of research papers published after 1995 and entirely dedicated to this problem, based on the Science Direct research publication database. The following list of keywords was used for the search of relevant publications: influence, electromagnetic radiation, magnetic field, electric field, and living. The search results include both epidemiological and experimental studies. The annual number of research papers published on the influence of electromagnetic fields and/or electromagnetic radiation on living organisms, based on ScienceDirect database. In general, research on the influence of electromagnetic fields and/or electromagnetic radiation on living organisms reported in the available literature can be either epidemiological (described in detail in Section 3.1) or experimental (described in detail in Section 3.2). Epidemiological research concerned the observation of human individuals who had been exposed to increased electromagnetic radiation for longer periods of time, such as railway workers or people living in the neighbourhood of power transmission lines. On the other hand experimental research concerned specific selected model organisms and as such were conducted considerably more often than epidemiological studies. In contrast to the epidemiological research, in the experimental research the appropriate selection of model organisms is of the greatest importance and must be completed prior to any experimental phase and is also based on the nature of the research and expected results. In this paper, research results reported in the available literature, focused on specific and current investigations concerning model organisms, are presented and discussed. Therefore the content of this paper may be considered as offering certain guidelines for those who want to start research in the area of electromagnetic fields and/or electromagnetic radiation and their influence on living organisms. The review carried out by the authors in this paper was based on important research papers and reports available in IEEE Xplore Digital Library, ScienceDirect, PubMed, and Google Scholar databases. Two criteria were used in order to differentiate the results taken into consideration: epidemiological and experimental. At the same time three main thematic groups can be easily distinguished based on the careful analysis of the selected papers (please see Figure 2). A group of research papers and reports on the influence of electromagnetic fields on mammals was also including human beings: this is also the largest group and it comprises research results of epidemiological and experimental nature as well as review papers. However, review papers are not the subject of the current authors' analysis. A group of research papers and reports concerned the influence of electromagnetic fields on lower organisms such as bacteria, nematodes, molluscs, arthropods, and amphibians: within this group numerous papers and reports are focused on several specific model organisms, which are the species of bacteria Escherichia coli and Bacillus subtilis, nematode Caenorhabditis elegans, land snail Helix pomatia, common fruit fly Drosophila melanogaster, and clawed frog Xenopus laevis. The extensive results of research related to the influence of electromagnetic fields on the model organisms just mentioned until today have not been a subject of a unified and thorough review analysis. This is the main objective of the current author's analysis. A group of research papers and reports on the influence of electromagnetic fields on rhythm abnormalities and functioning of various systems (mostly immune) in the case of different animal species, especially rodents, birds, or mammals: the effects of electromagnetic radiation on the functioning of the pineal gland were investigated both epidemiologically [7–11] and experimentally [12–35]. Within this thematic group most papers and reports concerned the influence of electromagnetic fields on birds and were carried out on chicken Gallus gallus subsp. domesticus and Japanese quails Coturnix coturnix subsp. japonica [34–39]. It is worth noting that both the chicken species have practically the same number of genes as humans, which is from 20,000 to 23,000 for the chickens and from 20,000 to 25,000 for humans. Moreover, the firm position of the chickens in scientific research has economic grounds, since the global consumption and production of chicken meat and eggs constantly increase [40]. Also the influence of electromagnetic fields on immune systems of rats and humans was investigated and reported in [37, 41–43]. As before, these types of problems are not the subject of the current authors' analysis, since it was extensively and systematically analysed by the authors in their other review paper published in 2014 [44]. Three main thematic groups distinguished based on the analysis of research papers and reports available in the subject literature. Historically, the 19th century was the golden age for electricity and magnetism and the time of their rapid development as scientific branches. What is more, at those times the opinion about a positive influence of electricity and magnetism on the human body, to be found in many medical textbooks, was very common [2]. However, in the 50s and 60s of the 20th century this positive opinion started to gradually evolve and change as a response to new discoveries that followed the development of relevant areas of contemporary science. Many scientists who tried to describe the mechanisms of the phenomena observed were more often inclined to the opinion of a neutral effect of electricity and magnetism on living organisms [2]. One of the first reports of their potentially harmful effects on living organisms was an epidemiological research report published in 1979 by Wertheimer and Leeper [45]. They examined the health of children from Denver (Colorado, USA), who lived in homes exposed to magnetic fields of high intensities. The intensities of the magnetic fields under consideration were estimated based on the total number of power transmission lines nearby the homes exposed and located in the investigated area [45]. It was stated by the authors that the children exposed to higher intensity magnetic fields had slightly higher risks of developing leukaemia than unexposed children. The authors also developed in a visual way their own methodology to estimate the exposure level based on the total number of all transmission lines in the area of residence. The published results raised a lot of controversy mainly because of the methodology that was used by the authors, which omitted and neglected many other important effects. Nevertheless, they resulted in an increased interest of scientists in this area of investigation. It should be also said that later tests confirmed the validity of the charges against the report of Wertheimer and Leeper. The health examination of the children of Rhode Island [46] excluded connections between the influence of magnetic fields and an increased level of morbidity to cancer. However, at the same time different results were obtained and published by the researchers from Sweden [47], which showed an increased risk of developing cancer as the incidence of brain tumours, which may increase, in the case of human individuals exposed to higher intensity magnetic fields [47]. The National Institute of Environmental Health Sciences of United States of America [48] proposed a new methodology to be used in this kind of examination. While Wertheimer and Leeper [45] used in their report information from children's death certificates, the new methodology was based on information from children's health cards. Despite this, negative effects of higher intensity magnetic fields on the incidence of leukaemia may decrease contrary to the research published by the same researchers from Sweden [49], who studied all children under the age of 16, who lived within the span of 25 years from 1960 to 1985 no closer than 300 meters from 220 kV or 400 kV power transmission lines [49]. The authors noticed the incidence of diagnosed leukaemia in this group of children which was 2.4 times greater than among their peers. Quite different results were obtained by researchers from Denmark [50] and Finland [51], who could not formulate any similar conclusions under similar test conditions, and who found no direct magnetic field influence on the children's health. A significant contribution to the clarification of the influence of electromagnetic fields and/or electromagnetic radiation on living organisms was made independently by two research groups: Ahlbom et al. [52] from Stockholm and Narvia et al. [53] from Los Angeles. The use of meta-analysis in their research allowed them to analyse data from previous research papers and reports which allowed the two groups to obtain sufficiently large and representative research material. As a result of their independent and parallel research very similar conclusions were obtained, which allowed them to estimate the safe level of the magnetic field intensity as equal to 0.33 A·m−1. Ahlbom et al. [52] and Narvia et al. [53] suggested that magnetic fields of higher intensities than the safe level of 0.33 A·m−1 raise the risk of developing leukaemia by a factor of two. However, their research results [52, 53] could not confirm any increased risk of developing other cancer diseases including glioblastoma. It should be emphasized that this safe limit is an estimated value and as such has not been confirmed by any rigorous calculations. Another very thorough and comprehensive analysis of the influence of magnetic fields generated by high-voltage power transmission lines on the risk of developing cancer in children was conducted by Draper et al. [54]. The authors themselves were very surprised by the results obtained, though they were later confirmed by other researchers from Iran [55], Tasmania [53], and Norway [56]. Draper et al. [54] examined children from England and Wales, who lived within 200 m of high-voltage power transmission lines at birth, having therefore higher risks of developing lung cancer. They also took into consideration children who developed leukaemia, who lived within the distance from 200 meters to 600 meters from the field sources, where typical intensities of magnetic fields were lower than 0.08 A·m−1 [54]. It should be realised that such intensities of magnetic fields are significantly lower than the field intensities generated by electrical devices in daily use, such as refrigerators, washing machines, radio, and television sets, which questions the main research hypothesis. Similar inconsistencies could be found in the first epidemiological research reported by Wertheimer and Leeper [45] as well as in the reports published [54–57]. However, based on the results presented in [52–54] a new safe level of the magnetic field intensity for children was established as equal to 0.15 A·m−1. Yet again this value is only an estimated boundary, which is not sufficiently supported by any rigorous calculations. The main problem that can be formulated in this kind of research is the determination of the direct field source, to which the subjects under investigation are exposed. The authors of the above-mentioned papers and reports silently assumed that the main sources of electromagnetic fields were always high-voltage power transmission lines, while the contribution from low-voltage parts of the electrical system was neglected. The low-voltage contribution may be generated by power sources in buildings themselves or in their neighbourhood, as, for example, they can be generated by working household appliances such as washing machines, refrigerators, radio, or television sets. All these factors make precise and unique determination of any intensity limit for electromagnetic fields practically impossible, despite the fact that such a limit is strongly required in almost all epidemiological literatures. It should be also said that regardless of their certain drawbacks all the papers and reports already mentioned form the basis of a modern view on the influence of electromagnetic fields and/or electromagnetic radiation on human beings. A different and very important area of investigation concerned all groups of professional workers exposed to long-term and/or high intensity magnetic fields. However, the results of research obtained in this case also turned out to be inconclusive. Because of that, in Denmark over 2.8 million adult citizens were examined in order to identify the groups exposed to magnetic fields of intensities stronger than 0.24 A·m−1 [50]. In total 154,000 people were classified as temporarily exposed to such intensive magnetic fields and 18,000 as constantly exposed [50]. During the examination 39 cases of leukaemia were confirmed, which suggested the risk of circulatory system cancer 1.6 times greater in comparison to 24 cases noted in a control group. However, the incidence of malignant tumours were observed [50]. Meanwhile, totally different results were obtained in Norway, where railway workers were examined, who were exposed at the second half of the 20th century. A comparison of health of steam and electric train service workers and operators suggested no negative influence of magnetic fields, and at the same time the number of diagnosed cancer cases turned out to be smaller [2]. On the other hand in Sweden a comprehensive examination of 134,000 workers was performed, who were employed in the power generation sector. The results obtained from the examination confirmed 4,833 cases of cancer [58]. van Wijngaarden et al. examinated a cohort of 138,905 male electric utility workers from five US companies [59]. They found that a mortality rate from cardiovascular diseases and cancer was higher among the workers who worked close to electric fields in comparison to the administration personnel in the same companies [59]. Other examination results reported and published in the literature were carried out among Swiss railway workers exposed to magnetic fields. The same effects were observed after a 5-day exposure to magnetic fields, where the field frequency was 16.7 Hz [7]. A decreased excretion of melatonin related compounds in the urine was also observed in the case of those workers, who were exposed to magnetic fields of 60 Hz [8]. These changes were observed already on the second day of their working week. In order to clarify all the above considerations, a synthetic summary is presented in Table 2. A synthetic summary of a historical review of epidemiological investigations. Field source Examined group Location, years Observation and result Literature 1 MF from power transmission lines Children Denver, USA, 1979 Increased risks of leukaemia, objection of lacking precision [45] 2 MF Children Rhode Island No incidents of cancer [46] 3 MF Various Sweden Decreased incidents of leukaemiaIncreased incidents of brain tumour [47] 4 MF from 220 kV and 400 kV power transmission lines distant 200 m and 200 ÷ 600 m Children England, Wales, Iran, Norway, Tasmania Safe level of intensity for children equal to 0.15 A·m−1 – objection of Lacking precision [52–57] 9 MF from power transmission lines Railway workers Norway Decreased incidents of cancer [2] 10 MF from power transmission lines and devices Power sector workers USA Morbidity of cancer increased 1.2 times3.6% confirmed cancer [58, 59] 11 MF of 16.7 Hz and 60 Hz Railway workers Swiss, USA Blood generation system disorders [7, 8] It can be noted from the research results of epidemiological investigation on the influence of electromagnetic fields and/or electromagnetic radiation on living organisms requires more thorough research. This type of research the appropriate selection of relevant model organisms is of very great importance. A major contribution to the research of the influence of magnetic fields on animals was made by Japanese scientists, who conducted a series of tests in four independent research centres in Japan within the period of 6 years from 1993 to 1999 [2]. In the tests animals were firstly exposed to a constant magnetic field of intensity from 400 A·m−1 to 4000 A·m−1 and then examined for cancer incidences. The negative results obtained were later confirmed by scientists from the U. S. and Germany and clearly proved that strong magnetic fields of low frequencies cause no permanent physiological problems as well as no changes to genetic structures [2]. In January 2013 a very extensive report by the Institute of Environmental Sciences and the National Institute for Public Health in the Netherlands was published [36]. The authors of this report made a very thorough review of all published studies related to the environmental effects of electromagnetic fields from RF to EMF withed the frequency range 10 MHz to 3.6 GHz. In total, 113 original research papers were reviewed, mostly focused on birds (embryos and eggs), mycelium, and plants. The authors concluded that, in 65% of all cases (50% for animals and 75% for plants), certain influences of electromagnetic radiation were observed in the cases of large and small doses of radiation. The authors [36] divided the selected research papers into sections by making a careful assessment of the contribution of each section, which involved birds, other vertebrates, insects, plants, and other organisms. The latter group included, among others, bacteria Escherichia coli, nematode Caenorhabditis elegans, and land snail Helix pomatia. The authors also emphasized that the electromagnetic radiation had a significant influence on these organisms; however, they concluded that the results obtained cannot be directly transferred and related to human individuals, not only because of a lack of standardisation procedures, but primarily because of the limited number of observation specimens [36]. Moreover, after a thorough analysis of the most recent results available in the literature they underlined the need to extend this kind of investigation to a larger number and a wider range of specimens [36]. Basic information on the model organisms found in the related literature and discussed in the following parts of this paper (bacteria E. coli and B. subtilis, nematode Caenorhabditis elegans, land snail Helix pomatia, common fruit fly Drosophila melanogaster, and clawed frog Xenopus laevis) is collected and presented in Table 3. As can be clearly seen, the information included in the table strongly supports the need for further scientific investigations that aim to determine the influence of electromagnetic fields and/or electromagnetic radiation on the living organisms mentioned above. Basic information on selected model organisms. Organism Description Literature Bacillus subtilis (i) Gram-positive bacterium, cell division every 10 minutes(ii) Rod-shaped, around 0.8 μm in diameter and 3 μm in length(iii) Endospores resistant to high temperature (10% alive after 1-hour bath is boiling hot water, 1% after 2-hour bath), high pressure (2 GPa for 45 minutes), space vacuum (for 24 hours)(iv) Responsible for bread ropiness(v) Produces peptide antibiotics (polymyxin, subtilisin, etc.) and enzymes (amylase, protease, etc.)(vi) Few literature sources documenting the influence of EMF [120] Escherichia coli (i) Gram-negative bacterium, cell division every 20 minutes(ii) Rod-shaped, around 0.8 μm in diameter and 3 μm in length(iii) Element of human and warm-blooded animals colon gut bacterial flora, where it participates in digestive processes and production of B and K group vitamins(iv) Pathogenic leading to human diseases of the digestive or urogenital systems(v) Dies out in temperature of 60°C after 20 minutes, in propitious conditions (for example in faeces) can survive for 1 year(vi) Used for production of a human hormone, insulin(vii) Few literature sources documenting the influence of EMF [120, 121] Caenorhabditis elegans (i) Transparent body hermaphroditic nematode (male individuals represent around 0.2% of the entire population), around 1 mm in length(ii) Lifespan of 2 or 3 weeks at room temperature, lifecycle around 56 hours(iii) Body consisting of 959 somatic cells including 302 neurons, internal organs consisting of a constant number of cells(iv) No negative effects of cryopreservation(v) Sole organism of a fully mapped connectome and genome (in 1998)(vi) Numerous body processes similar to human, shares 40% of genes with humans (vii) Few literature sources documenting the influence of EMF [121, 122] Helixpomatia (i) Common species of a land pulmonary snail(ii) Lives in the Southeast and Central Europe(iii) Shell 5 cm in diameter(iv) Body cells contain 54 chromosomes(v) Hatching of young snails after 3 or 5 weeks(vi) Considered as a model organism due to simplicity of its nervous system response investigations(vii) Few literature sources documenting the influence of EMF [89, 123] Drosophila melanogaster (i) Standard model organism, considered as the essential one due to several aspects(ii) Requires no special laboratory conditions(iii) High fecundity: females laying up to 100 eggs per day and around 20 in their lifespan(iv) Short lifespan around 10 days at room temperature(v) Body cells contain 4 chromosome pairs(vi) Exhibits sexual dimorphism: females about 2.5 mm, males 2 mm(vii) About 75% of known genes of human diseases can be matched with the genome of fruit flies(viii) About 50% of protein sequences have mammalian homologs(ix) Moderate number of literature sources documenting the influence of EMF [121, 124] Xenopus laevis (i) Model organism for more than 50 years(ii) Easy to breed in captivity, requires no special laboratory conditions(iii) Invasive species capable of surviving droughts hidden in sludge at the bottom of water reservoirs(iv) Males around 8 cm in size, females around 13 cm in size(v) Lifespan ranges from 5 to 15 years(vi) Females sensitive to human chorionic gonadotropin and in the past widely used as a natural pregnancy test(vii) Females lay large eggs with large embryos that are easy to manipulate and test(viii) Transparent tadpoles allow observation of subsequent stages of their development(ix) Moderate number of literature sources documenting the influence of EMF [110] The number of literature sources documenting the influence of electromagnetic fields and/or electromagnetic radiation on bacteria Escherichia coli and Bacillus subtilis has been relatively small. Information about both bacteria can be found in [60]. These two types of bacteria are recognised as both gram-negative and gram-positive model organisms and due to their well identified and documented metabolism, structure, and heredity. The growth of E. coli and B. subtilis is relatively simple and related costs are low, while at the same time cell division stays around tens of minutes and with identification process of resulting mutations being straightforward [61]. Out of the two bacteria the endospores of B. subtilis are not only very easily identified but are also substantially more resistant to adverse environmental conditions [62]. Between the years 1944 and 2013 a great number of research papers were published summarizing results of investigations on the influence of electromagnetic fields on E. coli and B. subtilis in the area of health care, food protection, and husbandry. In one of the first papers Fleming [63] subjected bacteria E. coli to electromagnetic radiation of variable frequencies within the range from 11 MHz to 350 MHz. The results obtained indicated a possibility to inactivate bacteria cells by electromagnetic radiation with no local temperature increase. However, later these results could not be reproduced by Brown and Morrison [64]. Furthermore, a local temperature increase due to electromagnetic radiation was reported by Bernikova et al. [65]. On the other hand no effects of electromagnetic radiation within the frequency range from 10 MHz to 20 MHz on cell inactivation could be repeated at the frequency of 60 MHz [67]. Furthermore, a significant success in the inactivation of bacteria B. subtilis was achieved in the case of electrostatic fields of intensity of 15 kV·cm−1 by Bu et al. [68]. It should be added that the inability to successfully inactivate bacteria E. coli by electromagnetic radiation was recently confirmed by Hamoud-Agha et al. [69]. In 1967 Goldblith and Wang [70] reported that electromagnetic radiation of high frequencies of 2.45 GHz could interact with both types of bacteria. In their opinion the process of bacteria deactivation was feasible and similar to commonly used temperature treatments [70, 71], while in [72] the resemblance between the dynamics of heat and microwave treatments was described in more detail. In 1968 another research paper on the influence of high frequency electromagnetic radiation on bacteria was published by Webb and Dodds [73], where E. coli metabolism was investigated under electromagnetic radiation of frequency of 136 GHz. During their investigation a slowdown in cell division and suspension of some metabolic processes were observed. A year later it was found that the absorption of electromagnetic radiation of particular frequencies by various cells' walls can result in alterations in important metabolic processes [71]. More recent results published in the literature indicate that observable disorders of E. coli growth can result from electromagnetic radiation of frequencies within the range from 70.6 GHz to 73 GHz [74]. An increased secretion of beta-galactosidase as a result of electromagnetic radiation was described in [71, 75], which was associated by the authors with small variations in temperature at the cellular level. Moreover, in [76] the energy of ELF electromagnetic radiation was characterised as a factor intensifying changes in E. coli metabolism induced by a temperature increase. Simultaneously, the bacteria were described as being highly resistant to electromagnetic radiation due to the autoregulation mechanisms of numerous biological processes. In [77] these relationships were also proven; however this was in the case of electromagnetic fields only. Furthermore, the metabolism acceleration of bacteria E. coli was observed and described by German researchers in 1995 [78]. They suggest that the observed increase resulted from the application of high intensity electromagnetic fields above 1.6 kV·m−1, while at the same time no difference between various field frequencies was noted. In conclusion it was stated that slight temperature changes at the cellular level are responsible for the bacterium metabolism acceleration. Synthetic information from investigation results on bacteria E. coli and B. subtilis is collected and presented in Table 4. Information from investigation results on bacteria E. coli and B. subtilis. Type Parameters Results Literature EMF 11 MHz ÷ 350 MHz (i) Possibility of inactivation(ii) No local increase in temperature (unconfirmed) [63, 64] EMF 10 MHz ÷ 20 MHz, 60 MHz (i) Local increase in temperature(ii) No effects on the vitality(iii) No inactivation [64–67] EF 15 kV·cm−1 (i) Significant inactivation in the case of Bacillus subtilis [68] RF Microwaves of various frequencies (i) Possibility of inactivation(ii) Resemblance between the dynamics of heat and microwave treatments(iii) Absorption of the radiation of particular frequencies may affect metabolic processes(iv) Disorders of E. coli growth resulted from EMF of 70.6 GHz and 73 GHz(v) Increased secretion of beta-galactosidase(vi) Highly resistant to EMF & MF due to autoregulation of numerous biological processes(vii) Metabolism acceleration due to slight temperature changes at the cellular level) [69–71, 73–78] More than thirty years ago Sydney Brenner precisely described Caenorhabditis elegans which allowed scientists and researchers to use it as a model organism. More information about Caenorhabditis elegans can be found in [79]. Since that time more than 7,000 publications and reports have been published covering all possible aspects of its body functioning starting from social behaviour and ending at neurotransmission [80], while in 1998 the entire genome of Caenorhabditis elegans was sequenced [81]. It was also found that about 40% of Caenorhabditis elegans genes are in common with human genes, as well as many cellular processes [82]. A great scientific effort was made in order to understand regulation, interaction, and expression of the whole set of genes in the genome of Caenorhabditis elegans [83]. As a result new genetic and molecular tools became available for investigation of all relevant subjects. Additionally it should be said that Caenorhabditis elegans as a model organism is characterised by a simple, multicellular structure consisting of exactly 959 cells, comprising a variety of tissues such as muscles and nerves. At room temperature the nematode has a relatively short lifespan of about 3.5 days, during which it is able to deposit from 300 to 1000 eggs [80]. A great advantage of Caenorhabditis elegans is its sexual dimorphism, which allows for easy observation of both mutations in the processes of self-fertilization as well as hybridization in the case of mating with a male partner [80]. It is worth noting that Caenorhabditis elegans is transparent at every stage of its life, which allows for easy investigation and observation of the entire lineage of every cell in Caenorhabditis elegans during its embryonic development and postembryo was also described in detail by Sulston [75, 84]. This fact allows the continuation of investigations and observations of the mutated nematode phenotype at the single cell level [80]. Possible cryopreservation and long-term storage of the nematode for further future examination are also a matter of great significance. All the factors mentioned above resulted in a high scientific interest in Caenorhabditis elegans as a subject of research that aimed to explain various biological issues [80] including primarily the influence of electromagnetic fields and/or electromagnetic radiation on living organisms. The earliest papers published in the literature regarding Caenorhabditis elegans reported on the influence of long-term weak electromagnetic radiation at microwave frequencies within the range from 750 MHz to 1 GHz and power of 0.5 W. Their authors claimed that at an ambient temperature of 25°C this kind of electromagnetic radiation can lead to thermal shock effects [85] in transgenic nematodes. However, in order to achieve a similar thermal reaction with no influence of electromagnetic radiation a higher temperature of 28°C was required. This fact led de Pomerai et al. [85] state that the direct result of microwave radiation on nematodes is a thermal shock. This kind of investigation was continued by scientists from Nottingham [86], who studied the effect of microwave radiation of the same parameters on larvae of Caenorhabditis elegans. In order to properly describe the observed changes they defined a number of additional factors such as the growth rate (GR), the size of deposited eggs, and maturing proportion (MP) [86]. As a result of radiation they observed 8% to 11% increase in the growth rate (GR) as well as 28% to 40% increase in the maturing proportion (MP). However, they also found 10% decrease in the growth rate (GR) in the case of the reference population that was subjected only to temperature modulations; nematodes were heated up to 28°C, as indicated in [85], while the maturing proportion (MP) was unaffected. The observed changes indicate that microwave electromagnetic radiation has a direct influence on Caenorhabditis elegans as well as an indirect influence resulting from elevated temperature from active microwaves [66]. Similar investigations concerned electromagnetic radiation of lower frequencies within the range from 300 MHz to 750 MHz. It was observed that microwave radiation of such characteristics, particularly of 750 MHz, increases the stress hormone level [87]. Very similar results were obtained by German researchers [88], who observed the same effects as resulting from the exposure to microwave electromagnetic radiation of frequency of 50 MHz [88]. Synthetic information from investigation results on nematode Caenorhabditis elegans is collected and presented in Table 5. Information from investigation results on nematode Caenorhabditis elegans. Type Parameters Results Literature RF 750 MHz ÷ 1 GHz0.5 W25°C Long-term exposure (i) Thermal shock(ii) Increase in growth rate by between 8% and 11%(iii) Increase in maturing proportion between 28% and 40% [66, 85, 86] RF 50 MHz, 300 MHz, 750 MHzLong-term exposure (i) Increase of the stress hormone level [87, 88] The relative simplicity of the investigation of nervous system responses of land snails as well as their low breeding costs [89] results in the fact that land snailsare commonly considered as model organisms. In the past many different snail species were examined in order to determine their resistance to electromagnetic fields and/or electromagnetic radiation [89–93]. In the case of Helix pomatia, a particularly important effect of electromagnetic fields and/or electromagnetic radiation was found in the case of a low-power magnetic field of intensity 98.5 A·m−1 as well as low-power electromagnetic fields of intensities within the range of 55.6 A·m−1 to 2.701 A·m−1 and low frequencies within the range of 8.3 Hz to 217 Hz. Only those effects that remain unrelated to local changes in temperature were considered. It was found that hyperpolarization of nerve cells results in changes in resting potential; however, this effect was only observed in the case of electromagnetic fields. This fact led to the conclusion that calcium release from the cell cytoplasm was observed only in the presence of the electrical components of electromagnetic fields [91]. In the case of other land snail species, papers by Regoli et al. [92] and Ossenkopp et al. [93] provide much very valuable information. Regoli et al. [92] investigated the influence of electromagnetic fields of frequency of 50 Hz, which can be associated with power transmission lines, as proxidant in the case of land snail Helix aspersa. The research programme spanned a two-month field exposure of the snail under investigation and during that time two different values of the field intensity were tested, that is, 0.596 A·m−1 and 2.288 A·m−1. As a result significant disorders of oxidation at cellular level, lysosomes membrane damage, and loss of DNA integrity were revealed. Ossenkopp et al. [93] investigated snail Cepaea nemoralis under different exposure times within the range of 0.5 hrs to 120 hrs and the magnetic field intensity of 79.43 A·m−1. A linear increase in snail mortality was found as a function of the exposure time. Additionally, slight differences between daytime and nighttime exposures were also found. Synthetic information from investigation results on land snail Helixpomatia. Type Parameters Results Literature MF, ELM 98.5 A·m−1 55.6 A·m−1 ÷ 2.701 A·m−1 8.3 Hz ÷ 217 Hz Nerve cells hyperpolarization under electromagnetic fields [91, 92] ELM 50 Hz0.596 A·m−1 2.288 A·m−1 2-month exposure Significant disorders of oxidation at cellular levelLysosomes membranes damageDNA integrity loss [93] EF, ELM 79.43 A·m−1 0.5hrs ÷ 120 hrs exposure Linear increase in the mortalitySlight differences between daytime and nighttime exposures [93] Common fruit fly Drosophila melanogaster has become one of the most widely used model organisms. The reason for its high position among other model organisms comes from certain of its attributes as a species [94]. The essential principles of its inheritance traits are known nowadays thanks to the pioneering research conducted by Thomas Morgan [94], while various characteristics of Drosophila melanogaster as a model organism were described in [95–97]. Thanks to Drosophila melanogaster attributes, intensive research on the influence of electromagnetic fields and/or electromagnetic radiation on living organisms could be carried out. However, the published results were very often leading to somewhat ambiguous conclusions. In 1985 the team lead by Hamnerius observed neither effects of high frequency electromagnetic fields on changes in the eye pigmentation nor genetic changes influencing Drosophila melanogaster mortality [98]. On the other hand in 1988 Shima and Tomura observed certain gene changes that affected the wing shape [99], while in 1992 the team led by Ho et al. reported that weak static fields influence Drosophila melanogaster during embryogenesis causing changes in its circulatory system [100]. In 1995 Koana et al. described the effect of magnetic fields on the growth of the mitotic recombination frequencies [101]. However, research conducted in 1993 by Kikuchi et al. reported no changes resulting from exposure to electromagnetic fields of extremely low frequencies [102], while Nguyen's team in 1995 found no teratological changes in Drosophila melanogaster embryonic cells [103]. However, in the same study they reported that exposure of Drosophila melanogaster embryos to the same fields results in the abnormal development of the embryos. In 2002 Mirabolghasemi and Azarnia investigated the influence of the exposure of eggs and subsequent larval stages of Drosophila melanogaster to magnetic fields of intensity of 8.738 kA·m−1 and frequency of 50 Hz, with exposure times from 2 hrs to 8 hrs, on the physical form of the adult flies [98]. The examination of morphological characteristics of the adults, such as the head or abdomen, allowed the researchers to state that pathological morphology changes concerned only the adult flies exposed to magnetic fields in the larval stage, whereas field exposure in the egg stage led to no pathological changes. The changes concerned size differences of certain body elements, wing deformation, or even their complete underdevelopment. It is worth noting that the observed pathological changes were also present in the case of control groups but at a lower rate. Additionally, it was noted that the number of pathological cases was directly proportional to the exposure time; however, no significant differences were observed in Drosophila melanogaster mortality or gender distribution. In 2001 the Stamenković-Radak's group conducted a similar investigation under static magnetic fields [104]. In their research the second and the sixth generation of Drosophila melanogaster were exposed to a static magnetic field of intensity of 27.8 kA·m−1. By measuring some morphological parameters of the adult flies the researchers observed that in later generations the wing size varied for both sexes, though no increased rate of wing asymmetry was noted in comparison with reference groups. They also pointed out that the genes responsible for the size of different body parts of Drosophila melanogaster or the development of the wings can have possibly different sensitivities to magnetic fields. In the era of modern technology human beings are constantly exposed to electromagnetic fields and/or electromagnetic radiation, for example, associated with GSM transmission. Therefore it is not surprising that potential threats posed by this type of electromagnetic radiation on living organisms are of very high interest. In 2003, a group of scientists led by Weisbrot investigated the effects of electromagnetic radiation associated with GSM transmission on Drosophila melanogaster at 900 MHz and 1900 MHz mobile phone transmission frequencies [105]. Separate groups of insects were exposed to electromagnetic radiation daily for 2 hrs over a span of 10 days. This included all stages of Drosophila melanogaster development from the egg through subsequent larval stages to the adult fly. As a result a significant increase in the levels of hsp70 protein, SRE bindings, and ELK-1 phosphorylation were observed in the case of exposed larvae. An increased number of mature individuals, up to 50%, were observed. The researchers pointed out that the cause of this effect can be found at the chromosome level as the salivary gland chromosomes of Drosophila melanogaster indicated an increased transcriptional activity of 73 out of the 200 transcriptionally active regions. Similar research was carried out by Panagopoulos et al. [106] involving a group of Drosophila melanogaster exposed to alternating magnetic fields generated by a GSM mobile phone transmitting at 900 MHz mode. During the experiment the phone was used in standby and active modes (unmodulated exposure) as well as when receiving and sending text messages (modulated exposure). Measured values of the magnetic field intensity were within the range of 7.943 ± 4.766 mA·m−1, for the modulated exposure, and 2.383 ± 0.238 mA·m−1, for the unmodulated exposure, and both were considered as safe values. As a result a decline by 50% to 60% in reproduction was revealed for the adult flies exposed to the modulated field and 15% to 20% for the adult flies exposed to the unmodulated fields in comparison to a control group. The authors concluded that exposure lowered the rate of cellular processes occurring during the formation and development of gonads. It seems that this is a result of changes in the cell proliferation rate as well as the rate of DNA, RNA, or protein synthesis. In 2000 the team led by Kohany carried out research on the influence of electromagnetic fields on 10 000 Drosophila melanogaster larvae and more than 7 000 adult flies [12]. Selected groups were exposed to electromagnetic fields of 5, 7.3, and 9.38 MHz frequencies and power of about 1 μW. The exposure time varied from 4 hrs to the full fly lifespan. In contrast to previously described tests a Faraday cage was used, screening both investigated and control groups from any interfering fields as well as those used in the experiment. As a result, the reduction of the time of the larval stage by 10% compared to the control group was noted. Another observation was an increase of the adenosine-5′-triphosphate (ATP) to adenosine-5′-diphosphate (ADP) ratio. In the case of the control group the ratio of ATP/ADP was 30% lower than in the case of the test group. No morphological lesions or changes in the lifespan of the adult flies were observed. In 1995 Koana et al. investigated the influence of magnetic fields on DNA [101]. They examined groups of Drosophila melanogaster larvae exposed for 24 hours to a static magnetic field of intensity of 476.6 kA·m−1. One group genotype was intentionally mutated. It was observed that the number of adult flies with altered genotype was 8% smaller in the exposed group, but the genotype itself remained unchanged. Based on the results obtained they stated that the larvae DNA code was damaged by the field exposure. As a result of the exposure somatic cells were not able to continue cell division lacking normal code corrective mechanisms, which resulted in an increased mortality. The authors suggested, however, that circumstances under which magnetic fields act directly on DNA molecules causing their damage are unlikely due to the amount of energy required for breaking chemical bonds. Earlier research [107] carried out by Giorgi et al. proved that Drosophila melanogaster exposed to static magnetic field intensities 10 to 12 times greater than the intensity of the Earth's field had a noticeable increased size of their body. It was interesting to note that the increased size persisted in subsequent generations even if they were never exposed to any magnetic field influence. It was also found that the increase was due to the quantity of body cells, which allowed the authors to conclude that static magnetic fields affect the genes that are responsible for their proliferation. Takashima et al. conducted similar research in 2004 [108]. Groups of Drosophila melanogaster to be examined were modified by mei-41D5 mutation inhibiting repair and mei-9A mutation improving the recovery process. The authors discovered that exposure to a magnetic field of intensity of 1.986 MA·m−1 and 11.12 MA·m−1 and 24 hrs exposure time resulted in a statistically significant enhancement in the frequency of somatic recombination within postreplication individuals with the handicapped repair process. Furthermore, within the remaining individuals the frequency has not changed. These findings suggested that exposure to high density static magnetic fields induces somatic recombination in Drosophila melanogaster and that this relation is nonlinear. In 2000 Graham et al. studied the effects of low frequency magnetic fields on Drosophila melanogaster [109] focusing primarily on morphological changes. They observed that magnetic fields of frequency of 60 Hz and intensity of 1.191 A·m−1 and 63.55 A·m−1 caused a significant decrease in the mass of Drosophila melanogaster. Additionally, the individuals that were exposed to the field of a higher intensity of 63.55 A·m−1 exhibited lower stability than those exposed to 1.191 A·m−1 or than those from the control group. It was surprising to note that the individuals exposed to the field of intensity of 1.191 A·m−1 exhibit higher stability than the individuals from the control group. This allowed the authors to conclude that magnetic fields do not always have negative influence. Synthetic information from investigation results on common fruit fly Drosophila melanogaster is collected and presented in Table 7. Information on investigation results on common fruit fly Drosophila melanogaster. Type Parameters Results Literature MF 27.8 kA·m−1 (i) Variation in the wing size in later generations(ii) Unaffected wing asymmetry(iii) Varying sensitivity of the genes responsible for the size of different body parts (development of wings) [104] MF 476.6 kA·m−1 24 hrs exposure (i) Reduced by 8% number of mature individuals with altered genotype group(ii) Increased mortality of larvae probably due to MF influencing their DNA code [101] MF 397.2 A·m−1 ÷ 476.6 A·m−1 (i) Noticeable increase of the body size (persisted in later generations under no field influence)(ii) Permanent exposure affects the genes responsible for proliferation [107] MF 1.986 MA·m−1 ÷ 11.12 MA·m−1 24 hrs exposure (i) Statistically significant enhancement in frequency of somatic recombination within the postreplication individuals with the handicapped repair process(ii) Nonlinear relation between somatic recombination and field exposure [108] EMF 3–30 Hz (i) No changes in embryonic cells(ii) No teratological changes(iii) Abnormal development of embryos [98] EMF 60 Hz1.191 A·m−1 and 63.55 A·m−1 (i) Significant decrease in mass(ii) Lower stability than control group as well as group exposed to 1.191 A·m−1 (iii) Possible positive field influence [109] EMF 8.738 kA·m−1 50 Hz2 hrs ÷ 8 hrs exposure (i) Pathological changes in larvae stage exposure (differences in body elements size, wing deformation, complete underdevelopment)(ii) Pathological changes also in control groups but at lower rate(iii) Number of pathological case directly proportional to exposure time [98] EMF 900 MHz ÷ 1900 MHz2 hrs daily for 10 days (i) Significant increase in the level of hsp70 protein, SRE bindings, and ELK-1 phosphorylation of larvae exposed(ii) Increased by 50% number of mature individuals(iii) Field exposure may affect chromosomes as the salivary gland, an increased transcriptional activity of 73 of the 200 transcriptionally active regions [105] EMF 7.943 ± 4.766 mA·m−1 (modulated exposure)2.383 ± 0.238 mA·m−1 (unmodulated exposure)900 MHz (i) Decline in reproductive performance by 50% to 60% for individuals exposed to modulated fields(ii) Decline in reproductive performance by 15% to 20% for individuals exposed to the unmodulated fields(iii) Field exposure affects females more than males(iv) Lowered rate of cellular processes occurring during formation and development of gonads(v) Changes in cell proliferation rate, rate of DNA, RNA, or proteins synthesis [106] The African cawed frog Xenopus laevis has been used by scientists as a model organism for over 50 years [110]. Despite its relatively long lifespan, which may present a difficulty in laboratory examination, the major advantages of Xenopus laevis include the following: easy to breed in captivity, no special requirements for laboratory conditions, high congenital resistance to diseases, large number of eggs laid, large size of oocytes and embryos enabling easy manipulation and testing. Years of research on Xenopus laevis led to numerous discoveries of many interesting phenomena observable at the microbiological and genetic levels. These, in turn, led to the development of new micromanipulation techniques that enabled observation of microbiological changes. Exact fate mapping, hormonal regulation, study of genetic mechanisms, and accurate identification of transgenesis mechanisms allowed for precise manipulation at the microbiological level leading not only to faster but also to more accurate interpretation of observation results as well as their analysis. Xenopus laevis helped in numerous attempts to investigate the influence of electromagnetic fields and/or electromagnetic radiation of living organisms. In 2010 Severini et al. conducted research on the influence of weak electromagnetic fields on Xenopus laevis development capacity [111]. In the experiment tadpoles were exposed to electromagnetic field of frequency of 50 Hz and the intensity within the range from 50.76 A·m−1 to 60.69 A·m−1 for 60 days. As a result it was observed that the average growth rate of exposed individuals decreased in comparison with a control group. Additionally, it was noted that exposure to the electromagnetic field also accelerated the average time of metamorphosis of tadpoles by 2.4 days. In 2005, Mietchen et al. [112] examined the influence of strong static magnetic fields on Xenopus laevis cerebral cortex. They noted that some of the changes observed could be related to an egg's shell removing procedure, which is performed prior to various subsequent scientific activities. In order to verify if the removal of the egg shell has an important influence they conducted their own experiments examining both processed eggs and unprocessed eggs under static magnetic field of intensity of 7.467 MA·m−1. The results of the test revealed changes in pigmentation of the cerebral cortex only in the case of the individuals hatched from the processed eggs, while the pigmentation itself appeared to be dependent on the exposure time. They concluded that pathological changes in pigmentation result from the removal of the egg's shell, the shell seeming to support the formation of the cytoskeletal system as its original purpose. The concept that electromagnetic fields have no significant effects on the development of Xenopus laevis was also confirmed by research carried out in 1995 by a team led by Ueno et al. [113]. During their research they exposed eggs to static magnetic field of intensity of 5.036 MA·m−1 for different time intervals. The results of their experiments showed that eggs under continuous 6-hour exposure indicated no significant pathological changes in cell division after transition to tadpoles. Moreover, the same result was observed for an increased 18 hour exposure time but at a reduced intensity level of 3.574 MA·m−1. Similar conclusions were reached by Kay et al. [114], who examined the influence of electromagnetic radiation accompanying magnetic resonance imaging (MRI) procedures. Their results proved the absence of morphological and functional changes. Synthetic information from investigation results on clawed frog Xenopus laevis is collected and presented in Table 8. Information on investigation results on clawed frog Xenopus laevis. Type Parameters Results Literature EMF 50.76 A·m−1 ÷ 60.69 A·m−1 50 Hz,days of exposure (i) Decreased averaged growth rate in comparison to control group, decrease from 0.48 step/day to 0.43 step/day(ii) Accelerated average time of metamorphosis of tadpoles by 2.4 days [111] MF 7.467 MA·m−1 (i) Changes in pigmentation of the cerebral cortex in the case of removed egg shells(ii) Pigmentation of a function of the exposure time(iii) Pathological changes in pigmentation [112] MF 5.036 MA·m−1 various exposure periods (i) No pathological changes after continuous 6 hrs exposure time of eggs in cell division after transitioning to tadpoles(ii) Similar observations for 18 hrs exposure time to less intensive filed of 3.574 MA·m−1 (iii) Absence of morphological, functional changes, and the timing of development abnormalities in tested individuals [113, 114] Based on the review of research results published in the available literature and related to the influence of electromagnetic fields and/or electromagnetic radiation on living organisms the following critical conclusions can be formulated. The available literature provides scattered and ambiguous information about the safety of electromagnetic fields and/or electromagnetic radiation. The influence of electromagnetic pollution on living organisms remains undefined. There are substantial gaps in the present knowledge about the influence of electromagnetic pollution, especially in the case of experimental investigations conducted on animals. As a consequence of the above-mentioned facts the area of scientific research related to the influence of electromagnetic pollution on living organisms is very popular among scientists all around the world. One of the key problems in this kind of research is the elimination of secondary radiation sources, which proves to be a difficult task; therefore all epidemiological investigations should be followed by experimental ones. More importantly, despite the extensiveness of the research results available, no clear answers have been given yet to the question of whether electromagnetic pollution has a bad influence on living organisms. Also the answer to the opposite question whether electromagnetic fields and/or electromagnetic radiation can be beneficial to living organisms in certain cases has not been answered so far. It should be noted that all the relevant model organisms possess certain features useful in order to conduct biological research. These include resemblance to other living organisms, which allows model organisms to be considered substitutes for other organisms, including human beings. In this paper special attention has been paid to model organisms different from mammals, including bacteria E. coli and B. subtilis, nematode Caenorhabditis elegans, land snail Helix pomatia, common fruit fly Drosophila melanogaster, and clawed frog Xenopus laevis. However, it has been found by the authors that due to restricted frequency spectra investigated, as well as the intensities of electromagnetic field sources, and due to the nature of observed phenomena, the results reviewed by the authors cannot be considered as complete and cannot be extrapolated onto human beings. So far, research conducted in the area of the influence of electromagnetic fields and/or electromagnetic radiation on living organisms has no comprehensive character, so it is not possible to formulate any relationships between the electromagnetic field characteristics and the field influence. Despite the lack of sufficient empirical data resources, several interesting hypotheses were proposed in the literature, according to which electromagnetic fields affect the pineal gland and its hormone melatonin, interfering with its physiological mechanisms leading to sleep disorders, lower mood, reduced concentration, depression, and the development of certain cancers [115–119]. These hypotheses, unsupported by sufficient scientific evidence reflect explicitly the importance of the pineal gland in investigations of related mechanisms of the harmful effects of electromagnetic fields and/or electromagnetic radiation published in journals, textbooks, and even on the Internet. However, based on current knowledge these claims remain unjustified and require systematic scientific verification. The authors declare that there is no conflict of interests regarding the publication of this paper. 1.European Commission. Possible Effects of Electromagnetic Fields (EMF) on Human Health. Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR); 2007. (Public Health and Risk Assessment). [Google Scholar] 2.Szuba M., Dołowy K., Duszyński J., et al. Power Lines and Substations in Human Environment. Warsaw, Poland: Registor of PSE Operator S.A.; 2008. (Polish) [Google Scholar] 3.Grono A. J., Redlarski G., Niklas P. 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A systematic analysis of human disease-associated gene sequences in Drosophila melanogaster . Genome Research. 2001;11(6):1114–1125. doi: 10.1101/gr.169101. [DOI] [PMC free article] [PubMed] [Google Scholar] 1. A Seminar on "Study of Electromagnetic Radiation & It's effect on human" Submitted by: Name: Shuvo Saha Roy Institute: KUET Roll: 1003008 Date: 22-09-2014 Year: 4th, Term: 1st 4. Electromagnetic Pollution Electromagnetic pollution is due to frequencies below (oscillating slower than) visible light waves. Electromagnetic pollution is everywhere. Here's a short list of the main culprits: cell (and other mobile) phones computers and related equipment electrical and electronic appliances radio and TV transmitters microwave ovens house-wiring high and low voltage power lines information networks cars, motor cycles, buses, trains, planes. 5. Low Frequency EMFs Strong electromagnetic fields (EMFs) of low frequency about 50 to 60 cycles per second (hertz, or Hz). the related electromagnetic radiation (EMR) are harmful. It is easy to shield a house from electric field generated by nearby power lines but is difficult to provide shielding from magnetic field that they generate. The magnetic field can be shielded by burring the transmission lines but the cost is very high. Stray currents and radiating fields can still be emitted from electric wires even if appliances are switched off. AC electric fields do not disappear when an appliance is switched off, only AC magnetic fields disappear. 6. HIGH FREQUENCY EMFs High frequency electromagnetic fields are generated by the cell phones, microwaves and antennas. High frequency EMFs is due to Radio Frequency energy in the frequency range of LF, MF, HF, VHF, UHF or microwave and is often referred to as radio energy. The term RF energy is used for all the frequencies between 30 kHz and 300GHz. Following are the biological effects of RF energy: The biological effect of RF energy depends upon the rate of absorption of energy. The RF energy heats up the tissues in a similar manner a microwave oven heats the food. It can be dangerous in case of prolong exposure.