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RADIATION OF ELECTROMAGNETIC FIELDS AT RADIO FREQUENCIES

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ABSTRACT

The sources of radio frequency radiation (radio and TV transmitters, radars, microwave ovens, portable radio transciever equipment) are presented first. Then, the impacts of RF (Radio Frequency) and MW (Micro Wave) radiations on humans are presented. The absorption factors of radio frequency and microwave emissions by human body are also presented.

Key words: *Radio Frequency Radiation, Absorption factors.*

INTRODUCTION

Electromagnetic radiation consists of waves of electric and magnetic energy moving together (that is, radiating) through space at the speed of light (Figure 1).

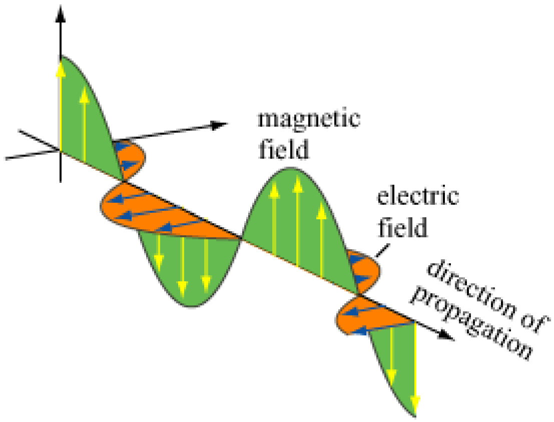

Figure 1. An electro-magnetic wave consists of an electric field and a magnetic field changing together in time and space.(https://www.google.rs/search?q=electromagnetic+wave+figure&tbm)

Taken together, all forms of electromagnetic energy are referred to as the electromagnetic spectrum (Figure 2). Radio waves and microwaves emitted by transmitting antennas are one form of electromagnetic energy. Often the term electromagnetic field or radiofrequency (RF) field may be used to indicate the presence of electromagnetic or RF energy.

An RF field has both an electric and a magnetic component (electric field and magnetic field), and it is often convenient to express the intensity of the RF environment at a given location in terms of units specific for each component(V.Šinik , S. Janković, Z. Despotović-2011). For example, the unit "volts per meter" (V/m) is used to measure the strength of the electric field and the unit "amperes per meter" (A/m) is used to express the strength of the magnetic field.

RF waves can be characterized by a wavelength and a frequency. The number of cycles per second is known as the frequency, which is measured in Hertz (Hz).

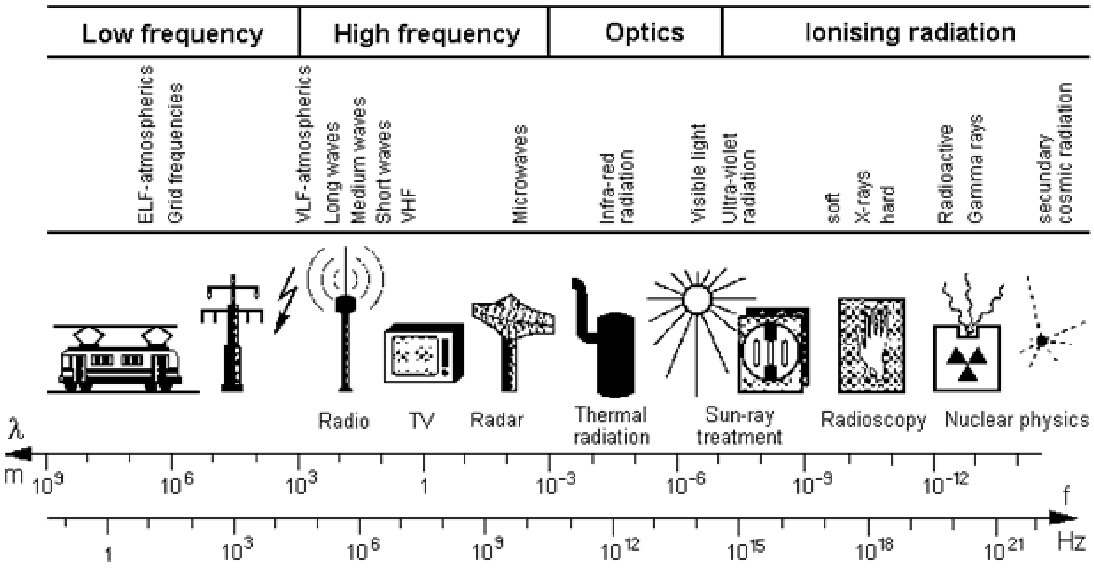

Figure 2. Electromagnetic Spectrum: (https://www.google.rs/search?q=electromagnetic+wave+figure&tbm)

The wavelength is the distance covered by one complete cycle of the electromagnetic wave, while the frequency is the number of electromagnetic waves passing a given point in one second. Different forms of electromagnetic energy are categorized by their wavelengths and frequencies. The RF part of the electromagnetic spectrum is generally defined as that part of the spectrum where electromagnetic waves have frequencies in the range of about 3 kilohertz (3 kHz) to 300 gigahertz (300 GHz).

THE SOURCES OF RADIOFREQUENCY RADIATION

Radiofrequency (or RF) Radiation refers to electromagnetic fields with frequencies between300 kHz and 300 MHz, while " Microwave (or MW) Radiation " (Figure 3) covers fields from 300 MHz to 300 GHz. Since they have similar characteristics, RF and MW radiation are usually treated together. As well, the lower-frequency boundary of RF radiation is often extended to 10 kHz, or even to 3 kHz, in order to include emissions from commonly used devices.

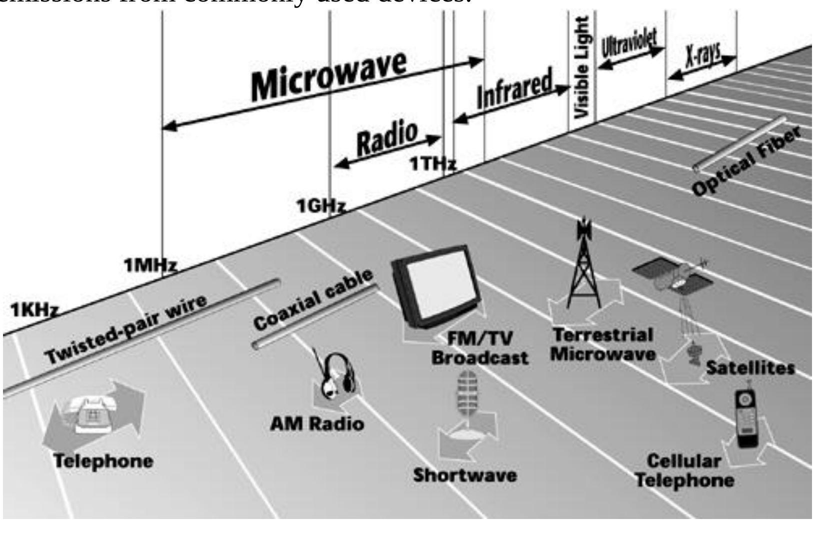

Figure 3. Microwave devices and the electromagnetic spectrum(https://www.google.rs/search?q=electromagnetic+wave+figure&tbm)

Radio and TV transmitters

A radio and TV transmitter (Figure 4) is usually part of a communication system which uses electromagnetic waves to transport information over a distance.

Figure 4. Big television and radio tower with several parabolic antenna on high quote (mountain) - Roncola (Italy)(http://www.123rf.com/photo_10872365_big-television-and-radio-tower-with-several-parabolic-antenna-on-high-quote-mountain--roncola-italy.html)

In electronics and telecommunications a transmitter or radio transmitter is an electronic device which, with the aid of an antenna, produces radio waves. Transfer of information (speech, music, image, computer data etc.) by radio can be presented in its simplest form with block - diagram as on Figure 5.

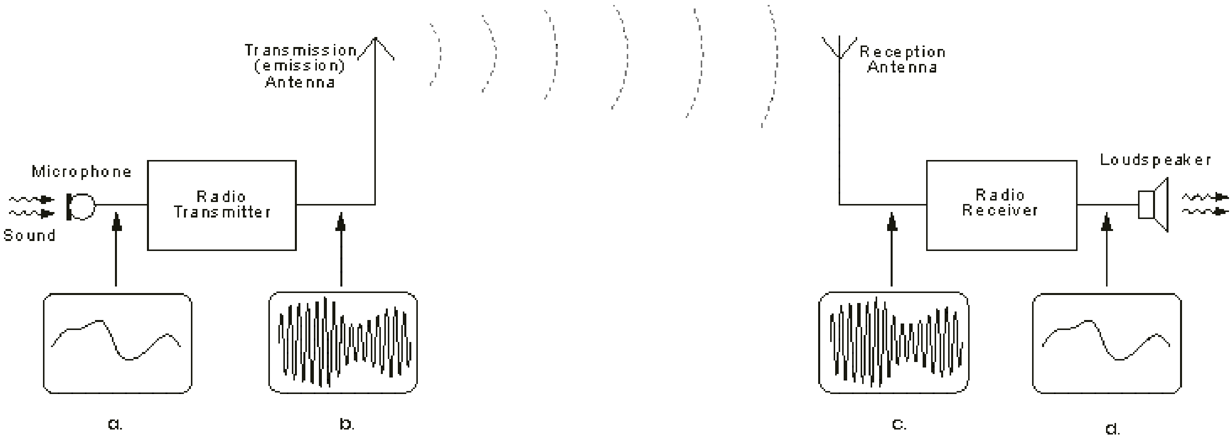

Figure 5. Radio transmission. Block diagram (https://www.google.rs/search?q=Radio+and+TV+transmitters+fig&sa=N&tbm=isch&tbo=u&source=univ&ei=XV0sUuSsOsHrswbj54DICw&ved=0CFAQsAQ4Cg&biw=1332&bih=576)

When antennas are located on tall columns, access by the general population to the base of the columns may be permitted if the exposure is less than the permitted levels. Small antennas of local television and radio stations are frequently located on the tops of tall buildings (skyscrapers), and in such cases the supervision of roof access is required.

Radar (***RA**dio **D**etection **A**nd **R**anging)*(Figure.6) is an object detection system which uses radio waves to determine the range, altitude, direction, or speed of objects. It can be used to detect aircraft, ships, spacecraft, guided missiles, motor vehicles, weather formations, and terrain. The radar dish or antenna transmits pulses of radio waves or microwaves which bounce off any object in their path. The object returns a tiny part of the wave's energy to a dish or antenna which is usually located at the same site as the transmitter (http://en.wikipedia.org/wiki/Radar).

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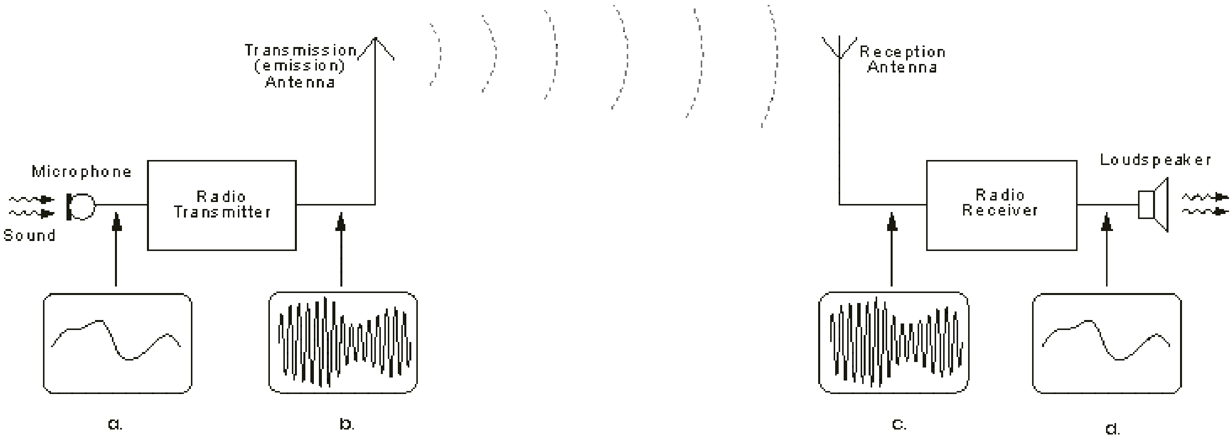

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The modern uses of radar are highly diverse, including air traffic control, radar astronomy, air-defense systems, antimissile systems; marine radars to locate landmarks and other ships; aircraft anti-collision systems; ocean surveillance systems, outer space surveillance and rendezvous systems; meteorological precipitation monitoring; altimetry and flight control systems; guided missile target locating systems; and ground-penetrating radar for geological observations. High tech radar systems are associated with digital signal processing and are capable of extracting useful information from very high noise levels.

Figure 6. Some of the types of radar systems(http://en.wikipedia.org/wiki/Radar)

Radars usually operate at radio frequencies (RF) between 300 MHz and 15 GHz. They generate EMFs that are called RF fields. RF fields within this part of the electromagnetic spectrum are known to interact differently with human body.

RF fields below 10 GHz (to 1 MHz) penetrate exposed tissues and produce heating due to energy absorption. The depth of penetration depends on the frequency of the field and is greater for lower frequencies. Absorption of RF fields in tissues is measured as a Specific Absorption Rate (SAR) within a given tissue mass. The unit of SAR is watts per kilogram (W/kg). SAR is the quantity used to measure the "dose" of RF fields between about 1 MHz and 10 GHz. An SAR of at least 4 W/kg is needed to produce known adverse health effects in people exposed to RF fields in this frequency range (http://www.who.int/peh-emf/publications/facts/fs226/en/).

RF fields above 10 GHz are absorbed at the skin surface, with very little of the energy penetrating into the underlying tissues. The basic dosimetric quantity for RF fields above 10 GHz is the intensity of the field measured as power density in watts per square metre (W/m2) or for weak fields in milliwatts per square metre (mW/m2) or microwatts per square metre (μW/m2). Exposure to RF fields above 10 GHz at power densities over 1000 W/m2 are known to produce adverse health effects, such as eye cataracts and skin burns.

Microwave oven

A microwave oven(Figure.7) works by passing non-ionizing microwave radiation through the food. Microwave radiation is between common radio and infrared frequencies, being usually at 2.45 GHz of or, in large industrial/commercial ovens, at 915 MHz.

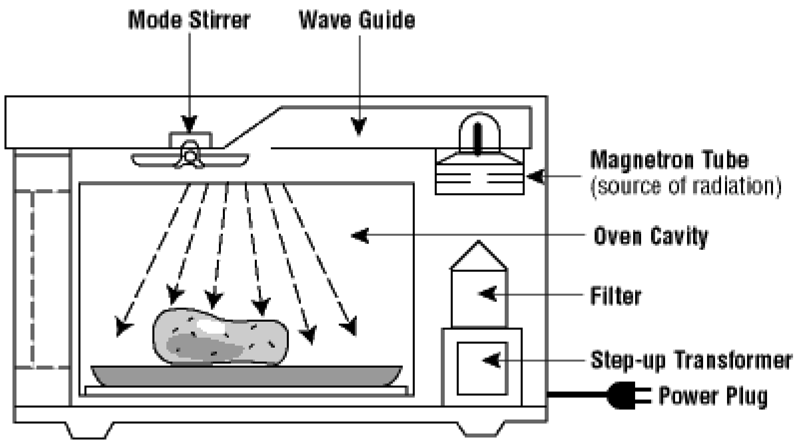

Figure 7. Microwave oven
(http://ccinfoweb.com/oshanswers/phys_agents/microwave_ovens.html)

A microwave oven consists of: a high voltage power source, a high voltage capacitor (connected to the magnetron, transformer and via a diode to the case),a cavity magnetron (which converts high-voltage electric energy to microwave radiation), a magnetron control circuit (usually with a microcontroller), a waveguide (to control the direction of the microwaves), a cooking chamber

Water, fat, and other substances in the food absorb energy from the microwaves in a process called dielectric heating. Many molecules are electric dipoles, meaning that they have a partial positive charge at one end and a partial negative charge at the other, and therefore rotate as they try to align themselves with the alternating electric field of the microwaves. Rotating molecules hit other molecules and put them into motion, thus dispersing energy.

A microwave oven converts only part of its electrical input into microwave energy. Additional power is used to operate the lamps, AC power transformer, magnetron cooling fan, food turntable motor and the control circuits. Such wasted heat, along with heat from the product being microwaved, is exhausted as warm air through cooling vents.

Portable radio transciever

A walkie-talkie (more formally known as a handheld transceiver) is a hand-held, portable, two-way radio transceiver. Walkie-talkies are widely used in any setting where portable radio communications are necessary, including business, public safety, military, outdoor recreation, and the like, and devices are available at numerous price points from inexpensive analog units sold as toys up to ruggedized (i.e. waterproof or intrinsically safe) analog and digital units for use on boats or in heavy industry. Most countries allow the sale of walkie-talkies for, at least, business, marine communications, and some limited personal uses such as CB radio, as well as for amateur radio designs. Walkie-talkies, thanks to increasing use of miniaturized electronics, can be made very small, with some personal two-way UHF radio models being smaller than a deck of cards (though VHF and HF units can be substantially larger due to the need for larger antennas and battery packs).

Figure 8. Portable radio transciever(http://en.wikipedia.org/wiki/Walkie-talkie)

HEALTH EFFECTS FROM RADIOFREQUENCY ELECTROMAGNETIC FIELD

At the international level are given guidelines Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz) by the International Body for the Protection of Non-Ionizing Radiation Protection (ICNIRP, International Commission on Non-Ionizing Radiation Protection) which are defined limits on the amount of time-varying electric and magnetic fields in open space, especially for general and working population.

The basics of EM interaction with materials were elucidated over a century ago and stated as the well-known Maxwell’s equations. The application of these basics to biological systems, however, is very difficult because of the extreme complexity and multiple levels of organization in living organisms, in addition to the wide range of electrical properties of biological tissues.

There are many factors to be taken in determining how the RF / MT energy absorbed in the body, such as:
- Dielectric compositions
- The size of the body,
- The shape and orientation of the body and polarization fields,
- The complexity (similar to zones) RF / MT field

Interaction of electromagnetic field (EMF) with environment and with tissue of human beings is still under discussion and many research teams are investigating it. Biological tissues are modeled by their permittivity and conductivity. The complex permittivity (ε) of a biological tissue is given by:

$$\underline{\varepsilon} = \varepsilon_r \cdot \varepsilon_0 + j\frac{\sigma}{2\pi f}$$

where, σ (S/m) is the conductivity of tissue in siemens per meter and ε_0 = 8:854x10^{-12} F/m.
Electrical conductivity and permittivity vary with the type of body tissue and also depend on the frequency of the applied field.

Table 1: Electrical conductivity of body tissue

Tissue type	Conductivity (S/m) 150 MHz	450 MHz	900 MHz	1,800 MHz
Muscle	0.73	0.81	0.94	1.3
Skin (wet)	0.56	0.69	0.85	1.2
Blood	1.2	1.4	1.5	2.0
Grey brain matter	0.60	0.76	0.94	1.4
White brain matter	0.35	0.46	0.59	0.92
Fat	0.07	0.083	0.11	0.19
Bone	0.070	0.096	0.14	0.28
Liver	0.53	0.68	0.86	1.3

Each object, whether it is a case or a living being, when found in the RF / MW field, can under certain conditions, to enter into resonance with the source of such a field. If the object is a person, its resonant frequency is primarily dependent on the height of the body.

Three different cases:
- when the body is less than the size of the wavelength,
- when they are approximately equal in their size and
- when the body is much larger than the size of the wavelength.

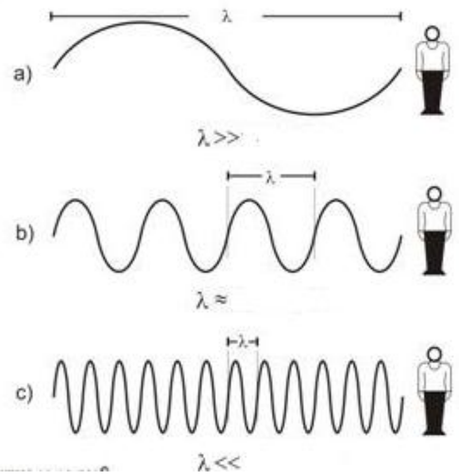

Figure 9. Size of the human body in relation to the wavelength of the electromagnetic wave

In cases where a body size smaller than the wavelength (Figure 9-a), there is little absorption.

When the wavelength is approximately equal to the size of the body (Figure 9-b), it appears the greatest absorption of the unequal distribution of power. Therefore, it may appear " hot spots" in certain parts of the body.

When the wavelength is smaller than the size of the body (Figure 9-b), the absorption is smaller, while the heating is limited to the irradiated surface.

At RF and microwave frequencies, electromagnetic fields penetrate into human body. These fields interact with biological tissue in several ways. The most important interaction can be explained in terms of energy transfer from the electromagnetic field to the tissue material. One measure of this macroscopic effect is the time-averaged absorbed power.

Specific absorption rate (SAR) is a measure of the rate at which energy is absorbed by the human body when exposed to a radio frequency (RF) electromagnetic field; although, it can also refer to absorption of other forms of energy by tissue.

A quantity usually used is known as SAR and has dimension W/kg. SAR can be defined as:

$$SAR = \frac{1}{2} \cdot \frac{\omega \varepsilon_0 \varepsilon_r}{\rho} |E|^2$$

with ω the angular frequency , ε_0 the permittivity of free space, ε_r the imaginary part of the relative complex permittivity, ρ the tissue density in kg/m3 and E is the peak value of the total field inside the tissue material(Savroulacks, P-2003).

We can see that the SAR depends on dielectric parameters therefore the materials of phantoms have to have similar dielectric parameters as human tissues. The human head consists of several tissues, which have different electrical characteristics and form complex-shaped boundaries. The electrical characteristics of human tissues are very different from the normal propagation medium (air), but not so different between each other. For values of SAR are recommended maximum values by committee INCRIP, this value is 2 W/kg in EU(SSI’S Independent Expert Group on Electromagnetic Fields).

CONCLUSION

The most important use for RF energy is in providing telecommunications services. Radio and television broadcasting, cellular telephones, radio communications for police and fire departments, amateur radio, microwave point-to-point links, and satellite communications are just a few of the many telecommunications applications. Microwave ovens are a good example of a noncommunication use of RF energy. Other important noncommunication uses of RF energy are radar and for industrial heating and sealing. Radar is a valuable tool used in many applications from traffic enforcement to air traffic control and military applications. Industrial heaters and sealers generate RF radiation that rapidly heats the material being processed in the same way that a microwave oven cooks food. These devices have many uses in industry, including molding plastic materials, gluing wood products, sealing items such as shoes and pocketbooks, and processing food products.

REFERENCES

https://www.google.rs/search?q=electromagnetic+wave+figure&tbm

International Commision on Non-Ionising Radiation Protection (ICNIRP) Guidelines: Guidelines for Limiting Exposure to Time Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz), Health Physics, Vol. 74,4 (1998) 494-522

Directive 2004/40/EC of the European Parliament and of the Council of 29 April 2004 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields),Official Journal of the European Union L 159 of 30 April 2004

Council Directive 98/34/EC of 22 June 1998, laying down a procedure for the provision of information in the field of technical standards and regulations (Official Journal L 204 of 21.07.98) (former Directive 83/189/EEC).

Savroulacks, P.: Biological Effect of Electromagnetic Fields. Springer-Verlag Berlin Heidelberg 2003, ISBN 3-540-429891

SSI’S Independent Expert Group on Electromagnetic Fields: Health Council of the Netherlands, Mobile Phones; an Evaluation of Health Effects. 2002, No. 2002/01E, ISBN: 90- 554-9411-9

http://www.123rf.com/photo_10872365_big-television-and-radio-tower-with-several-parabolic-antenna-

https://www.google.rs/search?q=Radio+and+TV+transmitters+fig&sa=N&tbm=isch&tbo=u&source=univ

http://en.wikipedia.org/wiki/Radar

http://www.mmust.elimu.net/BSC%28ELEC_COMM%29/Year_5/ELC-544E

http://www.who.int/peh-emf/publications/facts/fs226/en/

http://en.wikipedia.org/wiki/Transmitter

http://www.mikroe.com/old/books/rrbook/chapter2/chapter2.htm

http://www.radartutorial.eu/01.basics/rb04.en.html

http://ccinfoweb.com/oshanswers/phys_agents/microwave_ovens.html

institutions can be used by local urban and environment authorities in order to control pollutants emissions in urban or industrial areas, with an emphasis on sustainable and eco-friendly urban development. The advantage of numerical simulations is given by fast results, low cost and possibility to evaluate different pollution reduction scenarios.

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REFERENCES

Apascaritei, M., Popescu, F. Ionel, I., (2009), Air pollution level in urban region of Bucharest and in rural region, *SSE’09 Proceedings of the 11th WSEAS International Conference on Sustainability in Science Engineering*, pp. 330-335, Timisoara, Vol.2, may 2009, Timisoara

Cimorelli, A.J., et.al, (2004), AERMOD. Description of model formulation, EPA-454/R-03-004

Ionel I.; a.o. (2008). Method for determination of an emission factor for a surface source, *Optoelectronics and Advances Materials – Rapid Comunications,* Vol. 2, No. 12, 2008, 851-854, ISSN 1842-6573

Popescu F.; Ionel I.; Ungureanu C.; (2009). Air Quality Monitoring in the City of Timisoara. *Journal of Environmental Protection and Ecology,* Vol. 10, 2009, 1-13, ISSN 1311-5065

Popescu F. (2009). Advantages in the use of biodiesel in an urban fleet. Case study: major crossroads in Timisoara city, *Journal of Environmental Protection and Ecology,* Vol. 10, 2009, 182-191, ISSN 1311-5065

Silva L.T., Mendes F.G., Ramos A.R., (2010), Urban air dispersion model of a mid-sized city. Validation methodology. *WSEAS Transaction on Environment and Development*, Issue 1, Vol. 6., 2010, pp. 1-10

*** (2006) EMEP/CORINAIR Emission Inventory Guidebook, Technical report No 11, Published by European Environment Agency, 2006, http://www.eea.europa.eu/publications/EMEPCORINAIR4/