DOWNLOAD PDF PRINCIPLES FOR LIMITING EXPOSURE OF THE PUBLIC TO NATURAL SOURCES OF RADIATION

Chapter 1 : Ionizing radiation - Wikipedia

principles for limiting exposure of the public to natural sources of radiation 7 an upper bound has been used by the Commission in the limitation of exposure to artificial sources (ICRP,).

Displayed background gamma radiation level is 9. Cloud chambers used by early researchers first detected cosmic rays and other background radiation. They can be used to visualize the background radiation Radioactive material is found throughout nature. Detectable amounts occur naturally in soil , rocks, water, air, and vegetation, from which it is inhaled and ingested into the body. In addition to this internal exposure, humans also receive external exposure from radioactive materials that remain outside the body and from cosmic radiation from space. The worldwide average natural dose to humans is about 2. In some rich countries, like the US and Japan, artificial exposure is, on average, greater than the natural exposure, due to greater access to medical imaging. This exposure is in most cases of little or no concern to society, but in certain situations the introduction of health protection measures needs to be considered, for example when working with uranium and thorium ores and other Naturally Occurring Radioactive Material NORM. These situations have become the focus of greater attention by the Agency in recent years. Environmental radioactivity Terrestrial radiation, for the purpose of the table above, only includes sources that remain external to the body. The major radionuclides of concern are potassium , uranium and thorium and their decay products, some of which, like radium and radon are intensely radioactive but occur in low concentrations. Most of these sources have been decreasing, due to radioactive decay since the formation of the Earth, because there is no significant amount currently transported to the Earth. Thus, the present activity on earth from uranium is only half as much as it originally was because of its 4. But during the time that humans have existed the amount of radiation has decreased very little. Many shorter half-life and thus more intensely radioactive isotopes have not decayed out of the terrestrial environment because of their on-going natural production. Examples of these are radium decay product of thorium in decay chain of uranium and radon a decay product of radium in said chain. However, many of their daughter products are strong gamma emitters. Conversely, coastal areas and areas by the side of fresh water may have an additional contribution from dispersed sediment. Radon and its isotopes , parent radionuclides , and decay products all contribute to an average inhaled dose of 1. Radon is unevenly distributed and varies with weather, such that much higher doses apply to many areas of the world, where it represents a significant health hazard. Concentrations over times the world average have been found inside buildings in Scandinavia, the United States, Iran, and the Czech Republic. Radon seeps out of these ores into the atmosphere or into ground water or infiltrates into buildings. It can be inhaled into the lungs, along with its decay products , where they will reside for a period of time after exposure. Although radon is naturally occurring, exposure can be enhanced or diminished by human activity, notably house construction. A poorly sealed basement in an otherwise well insulated house can result in the accumulation of radon within the dwelling, exposing its residents to high concentrations. The widespread construction of well insulated and sealed homes in the northern industrialized world has led to radon becoming the primary source of background radiation in some localities in northern North America and Europe. Some building materials, for example lightweight concrete with alum shale , phosphogypsum and Italian tuff , may emanate radon if they contain radium and are porous to gas. Radon has a short half-life 4 days and decays into other solid particulate radium-series radioactive nuclides. These radioactive particles are inhaled and remain lodged in the lungs, causing continued exposure. Radon is thus assumed to be the second leading cause of lung cancer after smoking , and accounts for 15, to 22, cancer deaths per year in the US alone. The atmospheric background varies greatly with wind direction and meteorological conditions. Radon also can be released from the ground in bursts and then form "radon clouds" capable of traveling tens of kilometers. Cosmic ray Estimate of the maximum dose of radiation received at an altitude of 12 km January 20, , following a violent solar flare. The doses are expressed in microsieverts per hour. The Earth and all living things on it are constantly bombarded by radiation from outer space. This radiation primarily consists of positively charged ions from protons to iron and larger nuclei derived sources outside our solar system. This radiation interacts with atoms in the atmosphere to create an air shower of secondary radiation, including X-rays , muons , protons , alpha particles , pions , electrons , and neutrons. The immediate dose from cosmic radiation is largely from muons, neutrons, and electrons, and this dose varies in different parts of the world based largely on the geomagnetic field and altitude. For example, the city of Denver in the United States at meters elevation receives a cosmic ray dose roughly twice that of a location at sea level. During their flights airline crews typically get an additional occupational dose between 2. Similarly, cosmic rays cause higher background exposure in astronauts than in humans on the surface of Earth. Outside low Earth orbit, as experienced by the Apollo astronauts who traveled to the Moon , this background radiation is much more intense, and represents a considerable obstacle to potential future long term human exploration of the moon or Mars. Cosmic rays also cause elemental transmutation in the atmosphere, in which secondary radiation generated by the cosmic rays combines with atomic nuclei in the atmosphere to generate different nuclides. Many so-called cosmogenic nuclides can be produced, but probably the most notable is carbon , which is produced by interactions with nitrogen atoms. The production of these nuclides varies slightly with short-term variations in solar cosmic ray flux, but is considered practically constant over long scales of thousands to millions of years. The constant production, incorporation into organisms and relatively short half-life of carbon are the principles used in radiocarbon dating of ancient biological materials, such as wooden artifacts or human remains. At higher altitudes there is also the contribution of continuous bremsstrahlung spectrum. Excluding internal contamination by external radioactive material, these two are largest components of internal radiation exposure from biologically functional components of the human body. About 4, nuclei of 40K per second [16] decay per second, and a similar number of 14C. The energy of beta particles produced by 40K is about 10 times that from the beta particles from 14C decay. However, a 14C atom is in the genetic information of about half the cells, while potassium is not a component of DNA. The decay of a 14C atom inside DNA in one person happens about 50 times per second, changing a carbon atom to one of nitrogen. Epidemiological studies are underway to identify health effects associated with the high radiation levels in Ramsar. It is much too early to draw unambiguous statistically significant conclusions. At sea level, the production of neutrons is about 20 neutrons per second per kilogram of material interacting with the cosmic rays or, about â€” neutrons per square meter per second. The flux is dependent on geomagnetic latitude, with a maximum near the magnetic poles. At solar minimums, due to lower solar magnetic field shielding, the flux is about twice as high vs the solar maximum. It also dramatically increases during solar flares. In the vicinity of larger heavier objects, e. This reading includes natural background from cosmic and terrestrial sources. Atmospheric nuclear testing[edit] Per capita thyroid doses in the continental United States resulting from all exposure routes from all atmospheric nuclear tests conducted at the Nevada Test Site from â€” Atmospheric 14C, New Zealand [30] and Austria. Atmospheric nuclear weapon tests almost doubled the concentration of 14C in the Northern Hemisphere. Some of this contamination is local, rendering the immediate surroundings highly radioactive, while some of it is carried longer distances as nuclear fallout ; some of this material is dispersed worldwide. The increase in background radiation due to these tests peaked in at about 0. The Limited Test Ban Treaty of prohibited above-ground tests, thus by the year the worldwide dose from these tests has decreased to only 0. This includes both offsite "natural background radiation" and any medical radiation doses. This value is not typically measured or known from surveys, such that variations in the total dose to individual workers is not known. This can be a significant confounding factor in assessing radiation exposure effects in a population of workers who may have significantly different natural background and medical radiation doses. This is most significant when the occupational doses are very low. At an IAEA conference in , it was recommended that occupational doses below 1â€"2 mSv per year do not warrant regulatory scrutiny. Events classified on the International Nuclear Event Scale as incidents typically do not release any additional radioactive substances into the environment. Large releases of radioactivity from nuclear reactors are extremely rare. To the present day, there were two major civilian accidents â€” the Chernobyl accident and the Fukushima I nuclear accidents â€” which caused substantial contamination. The Chernobyl accident was the only one to cause immediate deaths. Total doses from the Chernobyl accident ranged from 10 to 50 mSv over 20 years for the inhabitants of the affected areas, with most of the dose received in the first years after the disaster, and over mSv for liquidators. There were 28 deaths from acute radiation syndrome. Thyroid doses for children were below 50 mSv. In addition to the civilian accidents described above, several accidents at early nuclear weapons facilities â€” such as the Windscale fire , the contamination of the Techa River by the nuclear waste from the Mayak compound, and the Kyshtym disaster at the same compound â€” released substantial radioactivity into the environment. The Windscale fire resulted in thyroid doses of 5â€”20 mSv for adults and 10â€”60 mSv for children. Other[edit] Coal plants emit radiation in the form of radioactive fly ash which is inhaled and ingested by neighbours, and incorporated into crops. Other sources of dose uptake[edit] Medical[edit] The global average human exposure to artificial radiation is 0. Radiation treatment for various diseases also accounts for some dose, both in individuals and in those around them. Consumer items[edit] Cigarettes contain polonium, originating from the decay products of radon, which stick to tobacco leaves. This dose is not readily comparable to the radiation protection limits, since the latter deal with whole body doses, while the dose from smoking is delivered to a very small portion of the body. This background contribution, which is established as a stable value by multiple measurements, usually before and after sample measurement, is subtracted from the rate measured when the sample is being measured. This is in accordance with the International Atomic Energy Agency definition of background as being "Dose or dose rate or an observed measure related to the dose or dose rate attributable to all sources other than the one s specified. An example of this is a scintillation detector used for surface contamination monitoring. In an elevated gamma background the scintillator material will be affected by the background gamma, which will add to the reading obtained from any contamination which is being monitored. In extreme cases it will make the instrument unusable as the background swamps the lower level of radiation from the contamination. In such instruments the background can be continually monitored in the "Ready" state, and subtracted from any reading obtained when being used in "Measuring" mode. Regular Radiation measurement is carried out at multiple levels. Government agencies compile radiation readings as part of environmental monitoring mandates, often making the readings available to the public and sometimes in near-real-time. Collaborative groups and private individuals may also make real-time readings available to the public. The former is usually more compact and affordable and reacts to several radiation types, while the latter is more complex and can detect specific radiation energies and types. Readings indicate radiation levels from all sources including background, and real-time readings are in general unvalidated, but correlation between independent detectors increases confidence in measured levels. List of near-real-time government radiation measurement sites, employing multiple instrument types:

Chapter 2 : What is Radiation?

Recommended citation ICRP, Principles for Limiting Exposure of the Public to Natural Sources of Radiation. ICRP Publication Ann. ICRP 14 (1).

It helps saves lives and provides great benefits to mankind in innumerable ways. Radiation is no different than other tools. If used improperly it can be hazardous to health or cause injury. But, if proper precautions are followed radiation can be used safely to achieve superior results. We will briefly introduce some basic radiation safety concepts and principles as they apply to the use of portable nuclear gauges. While the human body can sense and take actions to prevent injury by many physical agents, such as heat and noise, it cannot sense radiation. Therefore, it is important to understand the nature of radiation, its sources, and how to protect yourself and others. A Brief History In , a German physicist named Wilhelm Roentgen fortuitously discovered X-rays while experimenting with evacuated glass tubes through which an electric current was passed. Roentgen discovered he could take a picture of the bones in his hand with the mysterious new rays. Henri Becquerel of France discovered natural radioactivity a year later. In , Pierre and Marie Curie isolated the first radioactive elements, radium and polonium The momentous discoveries of these physicists led to a rapid advancement of scientific knowledge about radiation and radioactivity, as well as to many practical uses. Types of Radiation For purposes of radiation safety, only radiation with the capability to cause ionization is of concern. Ionization occurs when electrons are dislodged from a neutral atom. When this happens an atom becomes positively charged and some energy is transferred. Ionization is the process by which radiation affects the human body and by which it can be detected as well. There are four basic types of ionizing radiation: The main properties of each type of radiation are briefly discussed below. Alpha particles consist of two protons and two neutrons and carry a positive charge. They are emitted with high energy from the nucleus of heavy elements during radioactive decay, but lose energy rapidly in passing through material. A couple sheets of paper are sufficient to stop most alpha particles. Since they cannot penetrate even the outer dead layer of our skin, they are not an external hazard. Beta particles are electrons emitted from nucleus of atoms at nearly the speed of light. They have a very small mass compared to protons or neutrons and carry a negative charge. Gamma rays are electromagnetic energy waves emitted from the nucleus of atoms and have no charge. X-rays are the same as gamma rays, except they originate outside the nucleus from processes involving electrons. Other familiar types of electromagnetic wave radiation include: These differ from X-rays and gamma rays only in wave frequency and energy. Gamma rays are much more penetrating than alpha or beta particles. Neutrons are elementary particles which are emitted during certain types of nuclear reactions. Neutrons have no charge and are also highly penetrating. Units of Measure for Radiation The primary quantity of interest in radiation protection is dose equivalent. It so happens that some types of radiation produce greater effects on the body than others for the same amount of energy absorbed absorbed dose. To account for this, a Quality Factor QF is assigned to each type of radiation to express its relative effectiveness in producing damage. Dose equivalent is the product of the absorbed dose and the QF for that type of radiation. It expresses the risk of harm resulting from exposure to different types of radiation on a common scale. The basic unit of dose equivalent is the rem. Natural Sources of Radiation Radiation is emitted by radioactive elements naturally present in the soil, water, and air. The major sources include potassium, uranium, and thorium By virtue of their presence in the environment, radionuclides are found all the way up the food chain to humans. The human body contains a number of radioactive elements, including potassium, radium, and carbon Building materials, like granite, contain radioactive thorium Cosmic rays from outer space are another significant natural source of radiation. The atmosphere screens out most of the cosmic rays, but some still penetrate to ground level. The dose from cosmic rays increases with altitude. For example, people living in mile-high Denver receive about twice as much dose from cosmic rays as people living at sea level. The interaction of cosmic rays with nitrogen in the atmosphere also produces radioactive carbon and tritium H

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Man Made Sources of Radiation Man-made radiation is produced directly through the operation of devices like X-ray machines, particle accelerators, and nuclear reactors. Accelerators and nuclear reactors may also produce man-made radioactive elements that emit radiation. Many man-made nuclides are used in medicine, industry, and research. For example, moisture-density gauges use the man-made sources: Uses of Radiation and Radioactive Materials Radiation and radioactive materials have many uses in medicine, industry, education, agriculture, consumer products, scientific research, and many other fields. Here is a partial list of current uses:

Chapter 3 : Radiation Sources and Doses | Radiation Protection | US EPA

Time: For people who are exposed to radiation in addition to natural background radiation, limiting or minimizing the exposure time reduces the dose from the radiation source. Distance: Just as the heat from a fire is less intense the further away you are, so the intensity and dose of radiation decreases dramatically as you increase your.

Applying the precautionary principle and setting cautious limits Annual exposure limits beyond medicine and natural radioactivity These annual limits for exposure of the population are those of the public health code. These limits apply to the total effective dose or equivalent received outside of natural radioactivity and medicine, including those resulting from nuclear activities. For the skin, it is the average dose per cm2 of skin, regardless of the display surface. ASN per year maximum admissible effective dose resulting from human activities outside the natural radioactivity and expositions for medical reasons. This is a "whole body dose". For exposures of an organ or tissue, equivalent doses are considered. It compares with the average exposure outside medical and natural radioactivity which was of 0. For people who work with ionizing radiation, the limit is mSv for a set of 5 consecutive years, where the maximum for one year must not exceed 50 mSv. The same goes for total equivalent doses. Their surpassing is unacceptable in principle. These limits, however, lend themselves to some confusion. The fact that the natural and medical exposures are excluded is generally forgotten or omitted. In a developped european country like Frnance, the French population is exposed each yar to an averge effective dose of 3. The limit of 1 mSv per year might seem excessive, compared with 0. Annual exposure limits for workers Annual exposure limits for people needing to be exposed to radiation because of their activity, particularly nuclear workers and staff of nuclear medicine. In the case of pregnant women, it is the exposure of the unborn child. Exemptions in advance justified are allowed in some areas of work and for a limited period. They require a special permit. These special exposures must not exceed two times the legal annual exposure limit. ASN Source On the other hand, exposure to radiation of natural and medical origin varies considerably from person to person. These variations, especially because of diagnoses and medical treatments, blithely exceed the limit for the third leading cause of exposure If one applied a limit of 1 mSv to these two causes, we could not undergo a scan, we should abandon aircraft, mountain climbing, avoid living in Brittany or in Corsica. The cells of our body do not differentiate between rays of a natural or medical origin and that of a nuclear power plant. If fluctuations in the exposure of a person to person exceed 1 mSv because of habitat or medical diagnostics and treatments that prolong our lives, it seems illusory to reduce an already low limit since the third source exposure is minor in comparison. The limit makes sense only if very low doses trigger cancers: But the effect of low doses is highly uncertain and it is quite possible that they have no effect. However because of the uncertainty on the low dose effects, one applies the precautionary principle. The principle of limitation in the event of a radiological accident Finally, one must provide exceptional measures for radioprotection of the population in case of accident or radiological emergency. Actions and counter measures are implemented according to the nature and extent of exposure. In the case of nuclear accidents, intervention levels expressed in terms of doses are used as benchmarks for governments to decide on a case by case, the actions to put in place: Access to page in french.

Chapter 4 : Radiation | Nuclear Radiation | Ionizing Radiation | Health Effects - World Nuclear Association

1. Ann ICRP. ;14(1) Principles for limiting exposure of the public to natural sources of radiation. [No authors listed] PMID:

Contact What is Radiation? Radiation is energy that travels in invisible waves or rays. Exposure to radiation is an everyday occurrence â€” in fact, it has always been a part of life on Earth. Radiation can be natural or man-made. The sun emits ultraviolet rays that can cause sunburn. Granite, a common rock used in kitchen counters, is a natural source of radiation. Doctors use X-rays and MRIs to see inside patients with broken bones and other problems. A microwave uses a form of radiation to cook food. Understanding Types of Radiation There are two types of radiation: Both types can be harmful in excessive amounts. Fortunately, scientists, nuclear engineers and doctors understand radiation and know how to harness its benefits and protect us from its dangers. For example, microwave ovens use non-ionizing radiation to cook food. The radiation vibrates water contained in food, which creates heat. That heat cooks the food. Ionizing radiation emits enough energy to change the structure of an atom, which can damage biological cells. For instance, a sunburn is a type of radiation damage. In nuclear facilities, technicians focus on four types of ionizing radiation: Alpha radiation is too weak to penetrate most objects. Beta radiation is stronger, while gamma radiation is the strongest. Neutrons can penetrate many objects, but are slowed by water. Measuring Radiation Radiation doses are measured in an international unit called a Sievert Sv. Typically, radiation doses are so low that they are measured in milliSieverts mSv or one-thousandth of a Sievert. Because exposure to radiation happens every day, it is helpful to understand the average amount of radiation that people receive from natural and man-made sources. For instance, the average annual radiation dose that a person receives from food and water is nearly 0. At the same time, the average annual radiation dose that the public receives from nuclear power is 0. Managing Radiation in Nuclear Energy Plants The nuclear energy industry follows international best practices and standards to protect the public, workers and the environment. Modern nuclear energy plants use many barriers to protect people from radiation. Every barrier provides another layer of protection. In addition, the intensity of radiation decreases with distance from the source. Nuclear energy plants add distance from radioactive sources by incorporating large open spaces around the facility that the public cannot enter. Radiation Protection All restricted areas of the plant are clearly marked. In addition, there are three simple ways to limit exposure to radiation. Barriers made of steel, concrete or water provide protection from radiation. This is why the reactor is inside several layers of thick walls made of steel and concrete. It is also why used fuel is stored in concrete and steel-lined pools of water. The less time a person spends near a source of radiation, the less radiation they receive. The farther away a person is from a source of radiation, the less radiation they receive. This is one of the reasons why there are restricted areas of the plant.

Chapter 5 : Radioactivity : Doses legal limits

Additional Physical Format: Online version: Principles for limiting exposure of the public to natural sources of radiation. Pergamon, (OCoLC)

Background Radiation Background radiation Background radiationRadiation that is always in the environment. The majority of background radiation occurs naturally and a small fraction comes from man-made elements. Naturally occurring radioactive minerals in the ground, soil, and water produce background radiation. The human body even contains some of these naturally-occurring radioactive minerals. There can be large variances in natural background radiation levels from place to place, as well as changes in the same location over time. Dose Calculator This interactive online dose calculator will estimate your yearly dose from the most common sources of ionizing radiation. Some particles make it to the ground, while others interact with the atmosphere to create different types of radiation. Radiation levels increase as you get closer to the source, so the amount of cosmic radiation generally increases with elevation. The higher the altitude, the higher the dose. Radium, Cesium, and Strontium are examples of radionuclides. Learn more about radioactive decay. Terrestrial radiation levels vary by location, but areas with higher concentrations of uranium and thorium in surface soils generally have higher dose levels. Traces of radioactive materials can be found in the body, mainly naturally occurring potassium Our bodies contain small amounts of radiation because the the body metabolizes the non-radioactive and radioactive forms of potassium and other elements in the same way. Nuclear reactors emit small amounts of radioactive elements. Learn more about radiation and consumer products. Top of Page Average U. Internal in your body. Terrestrial in the ground. This total does not include the dose from radiation therapy used in the treatment of cancer, which is typically many times larger.

Chapter 6 : Principles for limiting exposure of the public to natural sources of radiation.

The recent recommendation for limiting the exposure of the public to natural sources of radiation is one of the more important statements of principle by the International Commission on Radiological Protection in recent years.

Different types of electromagnetic radiation The total absorption coefficient of lead atomic number 82 for gamma rays, plotted versus gamma energy, and the contributions by the three effects. Here, the photoelectric effect dominates at low energy. Above 5 MeV, pair production starts to dominate. Even though photons are electrically neutral, they can ionize atoms directly through the photoelectric effect and the Compton effect. Either of those interactions will cause the ejection of an electron from an atom at relativistic speeds, turning that electron into a beta particle secondary beta particle that will ionize many other atoms. Since most of the affected atoms are ionized directly by the secondary beta particles, photons are called indirectly ionizing radiation. It is otherwise called x-rays if produced outside the nucleus. The generic term photon is therefore used to describe both. Modern technologies and discoveries have resulted in an overlap between X-ray and gamma energies. In many fields they are functionally identical, differing for terrestrial studies only in origin of the radiation. In astronomy, however, where radiation origin often cannot be reliably determined, the old energy division has been preserved, with X-rays defined as being between about eV and keV, and gamma rays as being of any energy above to keV, regardless of source. Most astronomical " gamma-ray astronomy " are known not to originate in nuclear radioactive processes but, rather, result from processes like those that produce astronomical X-rays, except driven by much more energetic electrons. Photoelectric absorption is the dominant mechanism in organic materials for photon energies below keV, typical of classical X-ray tube originated X-rays. At energies beyond keV, photons ionize matter increasingly through the Compton effect , and then indirectly through pair production at energies beyond 5 MeV. The accompanying interaction diagram shows two Compton scatterings happening sequentially. In every scattering event, the gamma ray transfers energy to an electron, and it continues on its path in a different direction and with reduced energy. Definition boundary for lower-energy photons[edit] See also: Ultraviolet The lowest ionization energy of any element is 3. However, US Federal Communications Commission material defines ionizing radiation as that with a photon energy greater than 10 eV equivalent to a far ultraviolet wavelength of nanometers. Thus, X-ray radiation is always ionizing, but only extreme-ultraviolet radiation can be considered ionizing under all definitions. As noted, the biological effect of ionizing radiation on cells somewhat resembles that of a broader spectrum of molecularly damaging radiation, which overlaps ionizing radiation and extends beyond, to somewhat lower energies into all regions of UV and sometimes visible light in some systems such as photosynthetic systems in leaves. Although DNA is always susceptible to damage by ionizing radiation, the DNA molecule may also be damaged by radiation with enough energy to excite certain molecular bonds to form thymine dimers. This energy may be less than ionizing, but near to it. A good example is ultraviolet spectrum energy which begins at about 3. Thus, the mid and lower ultraviolet electromagnetic spectrum is damaging to biological tissues as a result of electronic excitation in molecules which falls short of ionization, but produces similar non-thermal effects. To some extent, visible light and also ultraviolet A UVA which is closest to visible energies, have been proven to result in formation of reactive oxygen species in skin, which cause indirect damage since these are electronically excited molecules which can inflict reactive damage, although they do not cause sunburn erythema. The small circles show where ionization occurs. Neutron and neutron radiation Neutrons have zero electrical charge and thus often do not directly cause ionization in a single step or interaction with matter. However, fast neutrons will interact with the protons in hydrogen via LET , and this mechanism scatters the nuclei of the materials in the target area, causing direct ionization of the hydrogen atoms. When neutrons strike the hydrogen nuclei, proton radiation fast protons results. These protons are themselves ionizing because they are of high energy, are charged, and interact with the electrons in matter. Neutrons that strike other nuclei besides hydrogen will transfer less energy to the other particle if LET does occur. But, for many nuclei struck by neutrons, inelastic scattering occurs. Whether elastic or inelastic scatter occurs is dependent on the speed of the neutron, whether fast or thermal or somewhere in between. It is also dependent on the nuclei it strikes and its neutron cross section. In inelastic scattering, neutrons are readily absorbed in a process called neutron capture and attributes to the neutron activation of the nucleus. Neutron interactions with most types of matter in this manner usually produce radioactive nuclei. The abundant oxygen nucleus, for example, undergoes neutron activation, rapidly decays by a proton emission forming nitrogen , which decays to oxygen The short-lived nitrogen decay emits a powerful beta ray. This process can be written as: For the best shielding of neutrons, hydrocarbons that have an abundance of hydrogen are used. In fissile materials, secondary neutrons may produce nuclear chain reactions , causing a larger amount of ionization from the daughter products of fission. Outside the nucleus, free neutrons are unstable and have a mean lifetime of 14 minutes, 42 seconds. Free neutrons decay by emission of an electron and an electron antineutrino to become a proton, a process known as beta decay: Such photons always have enough energy to qualify as ionizing radiation.

Chapter 7 : Troxler Electronic Laboratories > Safety > Radiation Safety Primer

The recent recommendation for limiting the exposure of the public to natural sources of radiation is one of the more important statements of principle by the International Commission on.

Chapter 8 : Background radiation - Wikipedia

natural sources of radiation The Agency's Statute was approved on 23 October by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July