BASIC CONCEPTS OF RADIATION HAZARD

The radiation you hear about and which can affect your health, is more properly called IONISING RADIATION. This radiation is made of particles, or rays, which have enough energy to break up the chemicals they hit. They do this by smashing the electrical " hooks " which hold the chemical together. The bits of the chemical with their electrical hooks dangling around are called IONS. This gives us the name ionising Radiation.

" In order to understand nuclear technology and its impact on human health, three atomic level events must be understood : fissioning, activation and ionisation. Fissioning i.e. the splitting of uranium or plutonium atom, is responsible for producing radioactive fission fragments and activation products. These in turn cause the ionisation of normal atoms, leading to a chain of microscopic events we may eventually observe as a cancer death or deformed child.

Fissioning :

Radioactive fission products are produced in nuclear reactors. They are variant forms of the ordinary chemicals which are the building blocks of all material and living things. Prior to 1943, radioactive forms of these chemicals were present in only trace quantities in South Africa, where it appears that a small nuclear fission reaction occurred spontaneously hundreds of thousands of years ago.

When a Uranium atom is split or fissioned, it does not always split in the same place. The two pieces called fragments, are chemical of lower atomic weight than uranium. Each fragment receives part of the nuclear and part of electrons of the origional large uranium atom. More than so different possible fission products are formed, each having the chemical properties usually associated with their-structure, but having the added capability of releasing ionising radiation. X-Rays, alpha particles, beta particles, gamma rays (like X-Rays) or neutrons can be released by these created chemicals. All these can cause "ionisation " i.e. knocking an electron out of its normal orbit around the nucleus of an atom, they produce two 'ions ', the negatively charged electron and the rest of the atom which now has a net positive electric charge.

The Atomic structure of fission fragments is unstable; for example , a nucleus may be proportionately heavier than usual due to inclusion of extra neutron. The atom will at sometime release the "extra " particle and return to a natural, low energy, more stable form, Every such relaase of energy is explosion on the microscopic level.

The violance of the fissioning process is such that it can also yield what are called as activation products i.e. it can cause already existing chemicals in the air, water or other nearby materials to absorb energy, change their structure slightly and become radioactive.As these high energy forms of natural material eventually return to their normal stable state, they can also release ionising radiation. About 300 different radioactive chemicals are created with each fissioning. It takes hundreds of thousands of years for all the newly formed radioactive chemicals to return to stable form.

In a nuclear power plant the fissioning takes place inside the zirconium or magnesium alloy cladding which encloses the fuel rods. Most of the fission fragments are trapped within the rods. However the activation products can be formed in the surrounding air, water,pipes and containment building. The nuclear plant itself becomes unusable with time and must eventually be dismatled and isolated as radioactive waste.

After fissioning, the fuel rods are said to be " Spent " . They contain the greatest concentration of radio-activity of any material on the planet earth, many thousand times the concentration in granite or even in uranium waste. The spent fuel rods contain gamma radiation emitters, similar to X-Ray emitters so they must not only be isolated from the biosphere, but they must also be shielded with water and thick lead wall. Direct human exposure to spent fuel rods means certain death.

In reprocessing, spent fuel rods are broken open and the outer cladding is disolved in nitric acid, the plutonium is separated out for use in nuclear weapons or fuel in nuclear breeder or mixed oxide, nuclear reactor. The remaining, highly radioactive debris is stored as liquid in large carbon or stainless steel drums, awaiting solidification and burial in permanent repository. Waste of lower radioactivity is buried in dirt trenches or as in Windscale (Sella field) in England- piped out to sea. The spent nuclear fuel rods and liquid reprocessing waste are called ' high level radioactive waste '. It has to be kept secure for thousands of years- essentially forever. Lower level waste may be equally longlived, but it is less concentrated.

In all nuclear reactions, some radioactive material- namely the chemically inert or so called 'noble' gases, radioactive carbon, water, iodine and small particulates of plutonium and other transuranics (i.e. chemicals of higher atomic number than uranium) is immediately added to

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the air, water and land of the biosphere. In the long range, all the longlived radioactive material, even that now stored and trapped, will mix with the biosphere unless each generation repackages it. Our planet earth is designed to recycle everything.

The radioactive chemical which escapes to the biosphere can combine with one another or with stable chemicals to form molecules which may be soluble or insoluble in water; which may be solids, liquids or gases at ordinary temperature and pressure, which may be able to enter into biochemical reactions or be biologically inert. The radioactive materials may be external to the body and still give off destructive penetrating radiation. They may also be taken into the body with air, food & water or through an open wound, becoming even more dangerous as they release their energy in close proximity to living cells and delicate body organs. They may remain near the place of entry into the body or travel in the blood stream or lymph fluid. They can be incorporated into tissue or bone. They may remain in the body for minutes or hours or a lifetime. In nuclear medicine for example, radioactive tracer chemical are deliberately chosen among those quickly excreted by the body. Most of the radioactive particles decay into other radioactive " daughter " products which may have very different physical, chemical or radiological properties from the parent radioactive chemical. The average number of such radioactive daughters of fission products produced before a stable chemical form is reached, is four.

Besides their ability to give off ionising radiation, many of the radioactive particles are bilogically toxic for other reasons. Radioactive lead, a daughter product of the radon gas released by uranium mining is a cause of lead poisoning and brain damage. Plutonium is biologically and chemically attracted to bone as radioactive chemical radium. Plutonium clumps on the surface of the bone, delivering a concentrated dose of alpha radiation to surrounding cells, whereas radium diffuses homogeniously in bone and thus has a lesser, localised cell damage effect. This makes plutonium because of its concentration, much more biological toxic than a comparable amount of radium.

The cellular damage caused by internally deposited radioactive particles becomes menifest as a health effect related to the particular organ damaged. The body often mistakes these dangerous substances for ordinary substances that it needs. These radioisotopes stay in the body and continue to give off harmful radiation internally. For example radionuclides lodged in the bones can damage bonemarrow or cause

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bone cancers or leukaemia, while radionuclides lodged in lungs can cause respiratory diseases. It has been found that even very low level of radiation can cause a rise in death, particularly in babies. Strangely the deaths are mainly from common diseases like pneumonia and measels, not cancer. Could it be that the fragile immune system of the body which fights diseases, is being damaged. In this way, man made radiation mimics natural radiation and causes the ageing or breakdown process to be accelerated.

Radioactive Particles and Living Cell : Penetration Power :

X-Rays and gamma rays are photons i.e. high energy light waves. When emitted by a source, for example, radium or cobalt, located outside the body, they easily pass through the body, hence they are usually called penetrating radiation. Because X-rays are penetrating, they can be used in diagnostic medicine to image human bones or human organs made opaque by a dye.

High energy gamma rays, which easily penetrate bone, would be unsuitable for such medical usage because film will be uniformly exposed. No radiation remains in the body after an X-Ray picture is taken. It is like light passing through a window. The damage it may have caused on the way through, however, remains.

Some radioactive substances give off beta particles, or electrons, as they release energy and seek a stable atomic stage. These are negatively charged particles, namely electrons, which can penetrate skin but cannot penetrate through the whole body as do X-rays and gamma rays.

Microscopic nuclear explosions of some radio-active chemicals release high energy alpha particles. An alpha particle, the nucleus of a helium atom, is a positively charged particles (two uncharged neutrons and two charged protons). It is larger in size than beta particle, like a cannon- ball relative to bullet, having correspondingly less penetrating power but more impact. Alpha particles can be stopped by human skin, but they may damage the skin in the process. Both alpha and beta particles penetrate cell membranes more easily than they penetrate skin. Hence ingesting, inhaling or absorbing radioactive chemicals capable of emitting alpha or beta particles and thereby placing them inside delicate body parts such as the lungs, heart, brain or kidneys, always poses serious threat to human health. Plutonium is an alpha

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emitter, and no quantity has been found to be too small to induce lung cancer in animals. The skin of course can stop alpha or beta radiation inside the body tissue from escaping outwards and damaging . It is impossible to detect these particles with most whole body " counters " such as are used in hospitals and nuclear installations. These counters can only detect X-Rays and gamma rays emitted from within the body.

Splitting a uranium atom also releases neutrons, which act like microscopically small bullets. Neutrons are about one fourth the size of alpha particles and have almost 2000 times the mass of an electron. If there are other fissionable atoms nearby (uranium 235 or plutonium 239, for example) these neutron projectiles may strike them, causing them to split and to release more neutrons. This process is called a chain reaction. It takes place spontaneously when fissionable material is sufficiently concentrated i.e. forms a critical mass.In a typical atom bomb fissioning is very rapid. In a nuclear reactor, water gas or the control rods function to slow down or to absorb neutrons and control the chain reaction.

Neutrons escaping from the fission reaction can penetrate the human body. They are among the most biologically destructive of the fission products. They have a short range, however, and in the absence of fissionable material they will quickly be absorbed by non radioactive materials. Some of these latter become radioactive in the process, as was noted earilier and are called activation products.

Effect on Living Cell : The chaotic state induced within a living cell when it is exposed to ionising radiation has been graphically described by Dr. Karl Z. Morgan as a "madman loose in library ". The effect of cell exposure to these microscopic explosions with the resultant sudden influx of random energy and ionisation may be either cell death or cell alteration.It can be temporary and permanent. It can leave the cell unable to produce (or replace) itself. Radiation damage can cause the cell to produce a slightly different hormone or enzyme, still leaving it able to reproduce other cells capable of generating this same altered hormone or enzyme. In time there may be millions of such altered cells. This mechanism called biological magnification,can cause some of the chronic diseases and changes we usually associate with old age. One possible specific mutation ~~nutrition~~ could be the destructions of the cell's mechanism for resting which normally causes it to cease reproductive activities after cell division. This causes runaway proliferation of cells in one place, which, if not destroyed will form tumour, either benign or malignant. The abnormal proliferation of white blood cells is characteristic of leukaemia; red blood cells proliferation results in polycythemia vera.

If the radiation damage occurs in germs cells, the sperms or ovum, it can cause defective offspring. The defective offspring will inturn produce defective sperms or ova, and the genetic 'mistake ' will be passed on to all succeding generations, reducing their quality of life until the family line terminates in sterlisation and/or death. A blighted or abnormal embryomic growth can result in what is called as hydatidiform mole instead of a baby.

Exposure to radiation is also known to reduce fertility i.e. women become unable to conceive or give birth.

Radiation can damage an embryo or foetus causing teratogenic damage.

The complete molecules making up living organisms are composed of long stands of atoms forming proteins, carbohydrates and fats. They are held together by chemical bonds involving shared electrons.If the ionising radiation displaces one of the electrons in a chemical bond, it can cause the chain of atoms to break apart, splitting the long molecule into fragments, or changing its shape by elongation. This is an ungluing of the complex chemical bonds so carefully structured to support and perpetuate life. The gradual breakdown of these molecular bounds destroys the templated used by the body to make DNA and RNA or causes abnormal cell division.

Measuring Radiation :

Glossary :

1. Alpha particle - An electrically charged (+) particle emitted from the nucleus of some radioactive chemicals of plutonium. In contains 2 protons and 2 neutrons, and is largest of the two atomic particles emitted by radioactive chemicals. It can cause ionisation.

2. Beta Particle - An electrically charged (-) particle emitted from some radioactive chemicals. It has the mass of an electron, Kryton 85, emitted from nuclear power plants, is a strong beta emitter. Beta particles can cause ionisation.

3. Curie - a measure of radioactivity. One curie equals 3.7×10^{10} nuclear transformations per second. C_i is the symbol used.

   (a) Microcurie : One millionth of a curies ($3,7 \times 10^{4}$ disintegrations per second) 1 mCi is the symbol used.

   (b) Picurie : One millionth of microcurie. (3.7×10^{-2} disintegrations per second) pCi is the symbol used.

4. Dose energy imported to matter by nuclear transformations (radioactivity)

   (a) Rad-= 100 ergs per gram. 1 GRAY= 100 rad = 10,000 ergs per gram.

   (b) Rem = radxQ where Q is a quality factor which attempts to convert rads from different types of radioactivity into a common scale of biological damage.

   1 SIEVERT = 100 rad.

5. Gamma Ray - Short wave length electromagnetic radiation released by some nuclear transformations. It is similar to X-ray and will penetrate through the human body. Iodine 131 emits gamma rays. Both gamma rays and X-rays cause ionisation.

6. Half life biological - time required for the body to eliminate one half of an administered dose of a radioactive chemical.

7. Half life physical - time required for half of a radioactive material to undergo a nuclear transformation. The chemical resulting from the transformation may be either redioactive or nonradioactive.

8. Ionisation - Sufficient energy is deposited in a neutral molecule to displace an electron, thus replacing the neutral molecule with positive and negative ions.

9. Radiation - the emission and propagation of energy through space or tissue in the form of waves. It usually refers to electromagnetic radiation, classified by its frequency, radio, infrared, visible, ultraviolet, X-ray, gamma ray and cosmic rays.

   (a) Natural background radiation- O-emission from radioactive chemicals which are not man made. These chemical include uranium, radon, potassium, and other trace elements. They are made more hazardous through human activities such as mining and milling, since this makes them more available for uptake in food, air and water.

   (b) Background radiation- included emissions, from radioactive chemicals which occur naturally and those which result from the nuclear fission process. The meaning of this term is vague.

Permissible Levels of Exposure - The US National Council on Radiation Protection and Measurement theoretically resolved by articulating the implicit reasoning behind subsequent radiation protection standards development.

1. A value judgement which reflects as it were, a measure of psychological acceeptability to an individual of bearing slightly more than a normal share of radiation induced defective genes.

2. A value judgement representing society's acceptance of incremental damage to the population gene pool, when weighed by total of occupationally exposed persons, or rather those of reproductive capacity as involved in Genetically significant Dose calculation.

3. A value judgement derived from part experience of the somatic effects of occupational exposure, supplimented by such biomedical and biological experimentation and theory as has relevance.

In short this recognises the fact that there is no safe level of exposure to joining radiation, and the search for quantifying such a safe level is in vain. A permissible level, based on a series of value judgements, must than be set, This is essentially a trade-off of health for some 'benefit '.

A permissible genetic dose (to sperm ovum), is that dose (of ionising radiation), which if it were feceived yearly by each person from conception to the average age of childbearing (taken as 30 years), would result in an acceptable burden to the whole population.

Complied from :

1. No Immediate Danger
   Prognosis for Radioactive Earth
   by Rosalie Bertell; 1985.

2. Radiation and Health by
   Bob Briscoe and Dave Amis, 1989

(Back ground paper for XVI Annual Meet of MFC).

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