Health Hazards of Nuclear Cycle

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RADIATION is dangerous. Exactly how dangerous even experts are unsure. The more we learn about it, the more we become aware how greatly the hazard has been underestimated in the past. Karl Morgan, a founder of the health physics profession in the United States, stated, "... there is no safe level of exposure and there is no dose of radiation so low that the risk of a malignancy is zero" in *Bulletin of Atomic Scientists*, September 1978 issue. He further admitted that earlier theories of radiation effects underestimated the damage now being suffered in human populations.

Until 1934, the safe level of radiation exposures permitted to workers in radiation-related occupations was assumed by the scientists to be 52 rems per year. With the growth in understanding of the harmful effects, the level of permissible radiation dose has continually dropped. In 1934, the safe dose for the workers became 36 rem; and in 1950, a new exposure level of 15 rem per year was recommended by the International Commission on Radiological Protection (ICRP) which in 1957 reduced the exposure limit to the current level of 5 rem per year for a worker. However a double standard operates for nuclear workers and for the public—a maximum of 0.5 rem per year for any individual member of the public. And contrary to so much new research that has documented the harmful effects of current permissible exposure levels, ICRP in 1973 has recommended an increase in radiation exposure levels.

In this article, I shall explore the nature and effects of radiation especially low levels of radiation and its relation to nuclear technology.

Radiation and Radiobiology

Everything in the universe is composed of elements—the smallest particle of an element is an atom. The majority of these elements are stable, i e, they do not transform into their elements. Some atoms are unstable and emit particles and energy to transform into newer elements until they have changed to a stable form.

An atom consists of a central nucleus which contains almost all the mass of the atom and which is positively charged; and a surrounding cloud of planetary electrons of very little mass which are negatively charged. Normally an atom is electrically neutral and there is an exact balance between the central positive charge and the surrounding negative charge. The central atomic nucleus consists of two kinds of particles—protons and neutrons—both are very nearly of the same mass but protons have positive electrical charge whereas neutrons are electrically neutral.

Between neutrons and protons in close contact, there are very strong forces which are capable of binding them together into a stable nucleus. The stability however depends upon a rather precise ratio of neutrons to protons. If there are too many or too few neutrons the nucleus will be unstable and will remedy the situation by spontaneously changing the ratio. This can be done in the following ways.

There can be emission of a chunk of nuclear matter called particle which consists of two neutrons and two protons and in so doing the nucleus loses two positive charges. This is radiation.

Alternatively, the neutron can spontaneously change into a proton or vice-versa. In order to conserve electric charge, a P-particle is emitted which consists of an electron (if a neutron becomes a proton) or its positive analogue, a positron (if a proton becomes a neutron). This is B-radiation.

There can also be r-radiation which is a high energy electromagnetic radiation similar to x-rays. As we have seen, a substance containing unstable atoms may emit, B or r radiation by which the radioactive atoms approach stability and the process is referred to as radioactive decay. This is independent of all physical and chemical circumstances and is measured by its physical 'half-life' i e, the time in which one half of the atoms will decay. The half-life may be fraction of a second or it may be millions of years.

This spontaneous transmutation from a less-stable to a more stable state releases energy which is used in propelling the x or B-particles with considerable speed. Being electrically charged, these high speed particles interfere with the electron clouds of atoms through which they pass and change the electrical charge of the atom within a cell by disrupting its structure. This is ionisation.

We cannot sense radiation, it is invisible to the naked eye, we cannot touch, smell or taste it. But a chaotic state can be induced within a living cell when it is exposed to ionising radiation. With the sudden influx of random energy and ionisation, there may be cellular death or varying degrees of damage. This damage can be temporary or permanent.

The delicate but fantastically organised chemical substances in the biological cells can be subjected to a wide variety of types and degrees of injury. Here I shall only enumerate some major consequences. The most catastrophic result which the human body experiences in one generation is probably cancer. The cell nucleus (its store of genetic information) is damaged but the cell survives and multiplies in its perturbed form over a number of years and forms a group of cells that eventually appears as cancer. What happens between the initial radiation injury and the ultimate appearance of a cancer is still a mystery the identification of which is contemporary biology's major challenge.

Damage to Somatic Cells: Chromosomes of the cell nucleus are the targets of ionising radiation. They are considered to carry all the information to control cellular activities like growth, cell division and production of biologically important chemicals like enzymes, hormones. Ceres are the units of information within the chromosome and are composed of DNA. If the ionising radiation displaces one of the electrons in the chemical bond of DNA or RNA, there will be alteration of information-carrying chemical structure in a single gene which in turn misdirects the activities within a cell. There can be abnormal and unregulated cell-division which will produce cancer or leukaemia.

Rapidly dividing cells are more vulnerable to radiation damage. Thus an embryo or foetus suffers most while developing in the mother's womb and may be born with congenital malformation. The cell may start producing a slightly different hormone or enzyme than it was originally designed to produce which in turn may produce millions of such altered cells. This can have many adverse effects on the body such as hastening the aging process, lowering resistance to disease and precipitating psychological stress.

Damage to Germ Cells: It has even more far reaching consequences and may be transmitted to all future generations. We are probably fortunate if the damge to the sex chromosomes is such that they fail to fertilise or if fertilised the unborn baby is miscarried. But with the low level ionising radiation, we are more unfortunate. The health effects upon new generations, carried through mutated genes of human sex cells, are far more serious and pose a maddening threat.

Genetic mutations occur due to natural sources of radiation and other known and unknown causes. They form an equilibrium of beneficial and detrimental genes in the human genetic pool. Indeed, some mutations may be beneficials, but the prevailing genetic opinion indicates that any increase in the mutation rate will create a great deal of human suffering in new generations with serious physical and mental diseases. The detrimental genes if dominant are removed quickly through early death and if recessive will remain indefinitely in the genetic pool affecting generations after generations until they gradually disappear.

Geneticists and medical experts are today of the opinion that major serious human diseases like diabetes mellitus, atherosclerosis and associated heart diseases, rheumatoid arthritis, schizophrenia are genetically determined. They are known now as multigene diseases which comprise over 50 per cent of all diseases compared to earlier single-gene rare diseases like haemophilia, sickle-cell anaemia, cystic fibrosis, etc.

Sources of Radiation Pollution

There are several sources of radiation artificial and natural. In this context, the anatomy of the nuclear fuel cycle will be dealt with to understand this greatest problem of environmental pollution. Yet, other sources of radiation have to be considered with equal seriousness.

Background Radiation: Genetic disorders, diseases and deaths caused by natural radiations are no different from those caused by artifical radiation. It is estimated that 5-10 per cent of diseases due to genetic mutations are by natural radiation.

Cosmic rays from outer space and ultra-violet rays from the sun still penetrate through the present thick ozone layer of the atmosphere though it is much less than what it used to be in the past. They are gamma radiation in nature. Then, some rock strata in the earth containing uranium, radium, carbon-14, etc, release natural radiation and show high incidence of health problems in those areas. The connection between high natural radioactivity of coastal Kerala and higher incidence of Down's Syndrome in that state is well known.

Medical X-rays and Radiotherapy: This diagnostic and therapeutic procedure is one of the artificial sources of gamma-radiation. X-rays emit low level radiation, yet they are not any more considered safe. They have been several studies which have established the connection between X-rays and leukaemia, cancer and other health problems. Drs. Irwin Bross and Rosalie Bertell, analysing X-ray data of 13 million people in three states in the USA, have shown that there is significant genetic damage, large increases in leukaemia and increased susceptibility to infectious diseases as a result of relatively low doses of radiation.

Nuclear Weapons and Test Fall-Out: A 15 kiloton uranium-235 bomb was dropped in Hiroshima in August 1945 killing between 80,000-200,000 people followed by a plutonium bomb over Nagasaki with similar results. Within five years there were increases in leukaemias, cancers and mutation-induced medical disorders from radio-active fall-out. These continued to appear even 22 years after the Hiroshima-Nagasaki bombing. Without going into today's picture of nuclear weapons, it is worth noting that fall-out from test explosions by USA, USSR, France and other countries has polluted the environment with radio-active materials to such an extent that it is comparable to several Hiroshimas all round the globe.

Nuclear Industry and Radiation

The nuclear industry is the major source of artificial radiation which will be polluting our environment for many thousands of years. It is not only the reactor but the whole chain beginning from mining to fuel fabrication to reprocessing of spent fuel and waste disposal that is tremendously dangerous and there is no way of keeping the workers and the public out of radiation exposure even with the normal running of the fuel cycle. It is worth noting here that there is no safe level of radiation exposure.

Mining and Milling: The fuel cycle begins with the mining of uranium where uranium ore is extracted from the rock strata by open cast or underground method. In this process, radium-226 and radioactive gas, radon-222 which are alpha emitters are released. Radon has very short half-live (3.8 days) and is extremely radioactive and when inhaled causes lung cancer. American Indians in USA, black Africans of South Africa/Namibia, aborginal Australians, farmers in France and weaker sections in other countries have been affected most having not only been driven off their land but also having to live near these dangerously polluted mines and by working as miners.

Though the high probability of lung cancer deaths among the uranium miners was well known for a long time, no studies had been conducted until recently. Safety standards and miners' health have been neglected; compensations were denied and experts from the AEC (US) even testified that radon gas levels in the uranium mines were below a threshold level for human health damage! According to US Public Service 1978, out of 100 uranium miners being monitored from one uranium mine in New Mexico, 25 have already died of cancer while still in their forties, and a further 20 are suffering from cancer. In the report of the Australian Atomic

Energy Commission, 1975, the incidence of leukaemia/cancer among white Australian miners has been found to be six times the expected norm.

With the tragic consequences of radon gas and after many unnecessary miner deaths from lung cancer, only in 1967 were safety standards and improved ventilation of the mines introduced in US mines. Yet the uranium mining standards are not and cannot be sufficiently protective of the miner's health.

In the process of milling, i e, crushing the ore finely to extract uranium, radon gas is again released affecting the health of the workers. Milling results in vast quantities of radioactive waste products—tailings—dumped beside the mills without sufficient care. Air, surface water and the ground water are contaminated by the radon gas, radioactive particles and some highly poisonous heavy metals like mercury, lead, arsenic in the tailings. Ironically, in Colorado, they were once used as landfill or building materials for homes, schools, roads, hospitals and an airport. We have very little knowledge about the state of our uranium mine at Jadugoda, Bihar. Proper epidemiological study and health monitoring of the mining community by a team of medical experts, biologists an geneticists is of utmost importance.

Enrichment and Fuel Fabrication: For the fuel of light water reactor (like Tarapur plant), uranium ore has to be enriched to increase the content of uranium-235 by approximately 3 per cent. The process is complex, expensive and uses enormous amounts of energy. There is routine releases of radioactivity to the environment; nonetheless, solid liquid and gaseous wastes are created in huge quantity. Increases in leukaemia rates have been reported in the communities around the enrichment plants. We'll discuss the problem of nuclear waste separately.

Once uranium has been sufficiently enriched, it is sent to a fabrication plant where enriched uranium is assembled into fuel rods for reactor. During the fabrication, there is routine release of radioactivity affecting workers and to the atmosphere permitted as 'acceptable' limit.

Nuclear Reactors: A tremendous amount of heat is generated from the fission of fuel rods and this in turn generates electricity from a steam turbine as in a conventional power station. Nuclear reactors are thus a very complicated and expensive means of boiling water. Apart from the serious radiation pollution, there is thermal pollution and damage to ecological balance as two-thirds of the heat is discarded into the environment. A range of radioactive elements is produced of which only few like iodine-131, cesium-137, strontium-90, plutonium-239, are considered in the discussions.

Reactors are constructed with multiple barriers in order to keep the radioactive release as low as possible and within the containment building. Yet with the stress of heat and pressure, splits and holes occur allowing radioactivity to escape. In addition to occasional serious accidents, there is routine release of vast quantity of radioactive waste from the nuclear reactors. Of the radioactive elements produced in a nuclear reactor, plutonium is the most toxic with a long half-life of 24,000 years. Single particles weighing one-millionth of a gram, so small that they can only be seen under a microscope, can cause cancer of the lung if inhaled. Apart from causing cancer, it is concentrated by the testicles and ovaries where it will inevitably cause genetic mutations which will be passed on to future generations. Yet each operating nuclear reactor produces between 400 and 600 pounds of plutonium each year in its normal operations. Strontium-90 chemically resembles calcium and is absorbed by bones and causes bone cancer and leukaemia, Dodine-131 concentrates in the thyroid gland to cause thyroid cancer.

There have been several studies by the radiation research scientists and medical experts to evaluate the hazards of radiation at the workplace. Perhaps the most extensive study yet undertaken was that of Thomas Mancuso of the University of Pittsburg at the Hanford Atomic Works in USA. This study was independently analysed and assessed by Alice Stewart and her assistant George Nkeale, a mathematician. Stewart, a medical expert from Birmingham, had first documented the health effects of low level radiation of medical X-rays on the human foetus. Mancuso-Stewart-Nkeale study evaluated astonishing results of cancer and other radiation related hazards of Hanford workers; and US authorities terminated Mancuso's funding for follow-up study and there were even attempts to confiscate his Hanford data. Mancuso concluded that the dose required to double a person's risk of cancer *is less than half the internationally accepted limit (33.7 rad against nuclear industry's estimate of 500 rad exposure)*. Unfortunately, all these studies are yet to make an impact on the industrial and military nuclear world.

Reprocessing: In reprocessing, spent fuel rods are broken open and outer cladding is dissolved in nitric acid to separate plutonium and unspent uranium. The plutonium is separated out for use in nuclear weapons or for fuel in a breeder reactor. The process is extremely hazardous and apart from the release of highly radioactive gaseous and liquid effluents, releases routinely nitrous oxide to the air causing acid rain. There is severe occupational threat to health in reprocessing facilities and also serious environmental threat due to production of highly toxic radioactive waste.

Reprocessing has more or less been abandoned in US. Commercial reprocessing plants there have been shut down for years due to faulty technique and excessive contamination. The large reprocessing plants in operation in UK (Windscale) and France are no exception regarding radiation contamination and risk to the workers despite claims by the authorities of safe running. Besides, the Irish Sea and the surrounding environment have been heavily contaminated because of routine dumping of waste produced at these plants. The actual situation at the reprocessing plant at Tarapur is not known; it is said that the plant is inoperative due to contamination.

Waste: As we have seen, nuclear fuel cycle generates vast quantities of radioactive waste at all stages. They have been divided into three categories—high, intermediate and low level, by the concerned international and national authorities. Low level wastes are considered as a low hazard potential. Referring to earlier discussion, it appears that a 50 per cent increase in genetic disorder and diseases are considered by

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about the level of risk from Sizewell B's proposed PWR. The numbers used in risk analysis talk only about the hardware failing. When operators are mentioned, the chance of 'operator error' is used entirely as if operators were hardware, albeit defective. At nuclear plants we must expect that the real failure rates will be dependent on the social system that organises it:

Real responses of thinking, waged operators
—Workers may be on strike in a minor accident sequence.
—Management commitment to a training programme may lapse.
—Complex but infrequent modes of failure may happen in too short a time for anyone to cope.

Smoothly running quality assurance programme
—Subcontractors may falsify quality inspections (and have done so).

Smoothly running maintenance programmes
—Non-unionised temporary maintenance workers may rebel against 'burning out' practices.

Effective inspection programmes
—Inspectors close to the industry may be lax, believing risks low. (Hendrie, chief US regulator, was sacked after Harrisburg.)

'The techbology'
—Like each car, each reactor has its own unique history of construction and maintenance.
—When politicians like Reagan (or an 'over-regulated' industry) change standards, the PWRs built and maintained may be different.

In non-nuclear safety there is an increasing tendency to follow the assessment methods developed in the nuclear energy debate. In fire safety, asbestos control and chemical plant safety we see use of 'cost-benefit analysis', 'reasonably practicable reductions', 'engineering risk assessments'. These all rest on the idea of balancing costs of reducing 'the risk' against supposed benefit of using the technology.

There are many obvious questions to raise about these schemes: Who benefits from the product? How do you measure the cost of life? Our approach goes further by challenging the scientific definition of 'the risks' that were measured in the first place and that were assumed to exist in the technology as a thing, not as an organising system. Through our approach, the question of control over the risk can be made central to the debate even before monetary costs are raised. Indeed, the particular social construction of nuclear risks turns out to be less a cost than itself a benefit to nuclear management.

The numbers game has often led environmentalists and hazards campaigners into a blind alley of demanding 'zero risk'—an idealistic and unrealistic focus. This quandary points to the real difficulties with either rejecting or accepting a (supposedly apolitical) 'balance' between health 'costs' versus industrial 'benefits'. That kind of choice usually confronts us as utterly compelling, universal rational. For example, could socialist societies delay reconstruction programmes until all industry is conclusively proven 'safe'? Our approach offers a way out of the quandary: while defending the primacy of health, we can assert the issue of control as central to any 'acceptability' of hazards in the name of wider benefits.

In conclusion: Beware the 'low-risk' technology of safety science, which serves to usurp control over hazards and thus guarantee management's safety from workers. The important safety question facing workers and communities is not some precise, numerical level of safety. Rather it is how we can gain detailed control over deciding which risks we take, so that we are confident, at all times, they're worth the benefit. How do we transform alien hazards?

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the international atomic energy authorities as a small hazard.

Safe management of radioactive waste is an unanswerable problem of the age because toxic products are not only highly lethal but remain radioactive for several million years. The more we go nuclear, the more we are adding to the problem of survival of our future generations.

There have been some romantic suggestions disposing of toxic waste from the earth by rocket into space or deep burial under the Antaractic ice but no adequate solution has yet been devised. Uptil now only high level radioactive wastes are stored in carbon or steel-concrete tanks which last 30-50 years; and low and intermediate level wastes are either dumped into the sea or buried underground in concrete silos. Proposals bave been made to solidify the highly toxic waste in glass blocks to be stored in shafts drilled in the seabed or under hard rock.

All the attempts and plans are far from reaching any real solution. There have been leaks from the storage sites contaminating the surface and ground water and the atmosphere and causing serious health hazards. We know very little about India's waste management programme.

The operation of a nuclear reactor generates astronomical quantities of radioactive waste of different types and of varying half-lifes ranging from a few seconds to a few thousand years. The amount of radioactivity produced from these elements is in direct proportion to the operation of the reactors. Even after Chernobyl which has put a big question mark on the future of nuclear power, India's nuclear policy is unchanged. We have an optimistic plan of 10,000 MW electricity from nuclear plants by 2000 AD! It is estimated that one year's operation of a 1000 MW nuclear plant generates fission products equal to that of a 23 megaton fission bomb; that is more than 1,000 bombs of the Hiroshima size.

Safe, permanent and absolute isolation of these radioactive poisons from the environment is the only condition for nuclear power to be acceptable. And this is simply not realistic. There is no disagreement today about how much radioactive poison is produced by the nuclear power plants. There is little or no disagreement about how lethal these poisons are. The disagreement lies in the quality and quantity of routine release of radioactive elements during all steps of the nuclear fuel cycle. Will the nuclear advocates give a satisfactory answer to this? No, they cannot and will not. The only answer is:

STOP NUCLEAR POWER