SPECIAL ISSUE

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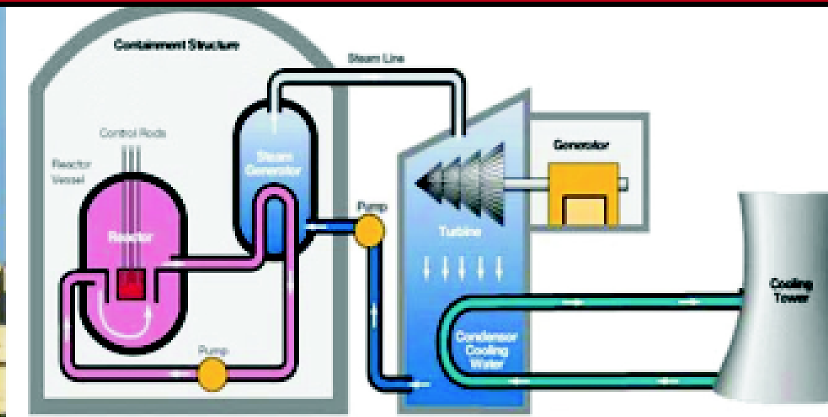
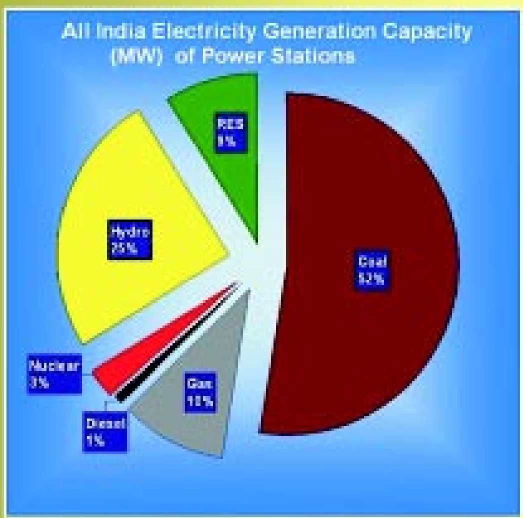
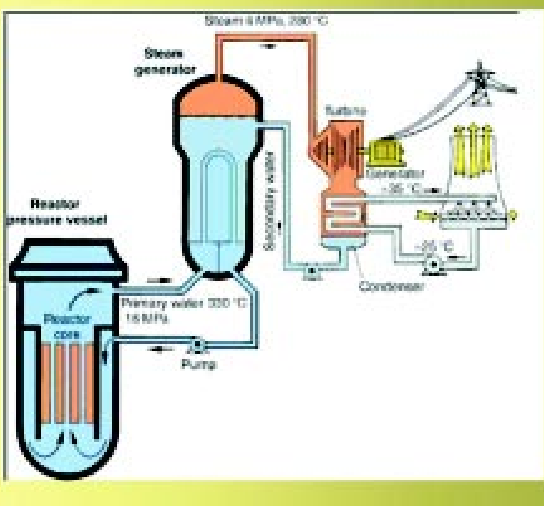


The Mysore Association, Bombay

A view of Kundamkulam Nuclear Power Plant



A view of the Jaitapur Nuclear Power Plant



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This special Issue of Nesaru on Nuclear Energy is edited by Mr. M.A.N. Prasad

- Girija Shastri

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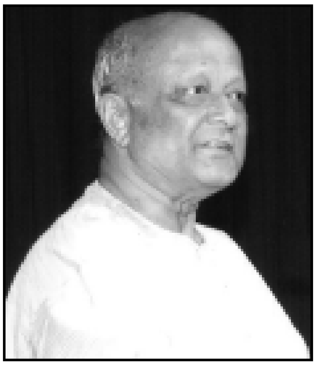
Message From President



It gives me great pleasure that a special issue of Nesaru is brought out focusing on the various aspects of Nuclear power. I am sure our readers will find this to be a Treasure House of useful information.

This is the age of information and knowledge; and it is necessary that we as citizens and stakeholders in the various activities, are properly informed and exercise a well informed choice. I am happy that our Nesaru has taken a lead in this direction and look forward to its continuing to play such leading role in the days ahead also, with your encouragement and support.

Best wishes!

V. Ramabhadra
President - The Mysore Association, Bombay

From the Editor

You might be wondering what Nesaru has got to do with Nuclear power? Well let me tell you that the Mysore Association has the unique advantage over other social & cultural organizations in the fact that it has a large number of scientists from the Atomic Energy Establishments among its members and the on going debates and controversies on the subject of nuclear power made us think why not we get these scientist friends to let us know more about the subject, through a special issue of our magazine Nesaru.

With the various happenings and developments in our country in the recent times, we were also thinking that there is a need for a well informed debate in the country and social organizations should play a positive role in the dissemination of information so that we as citizens can make well informed choices.

As a result, we have made a start in terms of having a debate and dissemination of information with this special issue of Nesaru on Nuclear Power. We hope to bring such special issues periodically in the future.

Man has over the centuries been using technology to make his living easier and the quality of his life better. Every technology has two sides to it – the beneficial part and the ill effects part. There could perhaps be no technology that is absolutely free of ill effects. Hence, the general guiding principle in the evaluation of any technology has been, how far the benefits out weigh the disadvantages or ill effects? Often, when a new technology emerges, we get to know of some of its ill effects only with the passage of time. We keep alert to such possibilities and modify the usage / safety practices based on such learning. This is an on going process and the price of safety is constant vigil.

Often the public opinion tends to swing from one extreme to the other, stoked by lack of information, misinformation, vested interests and many other factors. Open minded debate on the issue helps in clearing doubts, better and improved understanding of the subject leading to a wider perspective. There will be a greater transparency, building credibility and co-operation among all. Our leaders – whether they are the law makers, or administrators, or eminent social personalities - have to address towards building greater mutual trust among the stake holders and get the support and cooperation of all concerned in taking the nation forward in the path of progress and growth.

Here is a small effort in this direction. We are grateful to all our friends who have readily agreed to our request and contributed articles in this issue, or helped us in putting this issue together. This effort will become meaningful or successful only when you actively participate in this debate and give us your feedback, which will be very valuable for us in bringing out meaningful special issues.

– M.A.N.Prasad

Dr. A.N. Prasad, after graduation in Mechanical Engineering from Bangalore in 1996 has done postgraduate courses in Power Engineering and Nuclear Engineering in India and USA.

Prasad started his professional career at a time when the country's nuclear programme was still in its early stages of formulation under the leadership of Dr. Homi Bhabha, its founding father. Over the years, he got deeply involved in R&D pertaining not only to peaceful applications of nuclear energy in its various facets, but also in some of the highly sensitive strategic areas having national security implications. In particular he has made pioneering contribution in the indigenous development of technologies, particularly spent fuel reprocessing for separation of plutonium, a highly strategic fissile material used for nuclear weapons and advanced reactor fuels as well as very highly radioactive waste management. With the setting up of the first reprocessing plant at Trombay as early as in 1964, India proudly became the fifth country in the world after USA, Russia, UK and France, all Nuclear Weapon States, to acquire this technology, ahead of China and others like Belgium, Germany, Japan and so on.

After holding various responsible positions, Prasad was appointed by the Govt. of India as Director of the prestigious Bhabha Atomic Research Center (BARC), a large world renowned multidisciplinary R&D Institution and Member, Indian Atomic Energy Commission.

Immediately after retirement from BARC in 1996, he was invited by the International Atomic Energy Agency, Vienna to serve as Advisor and Senior Consultant on various programmes related to the Departments of Technical cooperation, Safeguards and Nuclear Fuel Cycle.

On his return to India in the year 2000, Prasad was invited to join the New York based newly constituted United Nations Monitoring, Verification and Inspection Commission (UNMOVIC) as a member of the College of Commissioners to oversee disarmament of Iraq of its Weapons of Mass Destruction, particularly chemical and biological weapons as well as long-range missiles, till the Commission was wound up in 2007 in the aftermath of American military action on Iraq.

Having spent his entire professional career on development of technological capability for long-term energy independence and national security, Dr.Prasad is passionate about realizing this goal through mobilization of expertise in national R&D and academic institutions of higher learning, roping in Indian industry in a big way.

Dr Prasad during his long illustrious career has received a number of Awards from Professional Bodies and has been honoured by Universities. He has delivered a number of Convocation Addresses. He was a member of the Bombay University Senate as Chancellor's nominee during 1990s.

Dr Prasad was an active member of the Mysore Association and proudly recalls his tenure as Managing Committee member and Honorary Secretary in the 1960s, during which time a programme was initiated for rising funds for major restructuring of the Association building which ultimately became a reality.

Preface

We are all aware, energy is the key to development and is the basis on which the economic system rests. The per capita consumption of energy is regarded as an index of a country's progress. Today, industrialized countries account for major part of the global energy consumption. But the energy requirements of developing countries like India are increasing at a faster rate than those of the developed countries. This is partly due to large rate of population growth in these countries and partly due to their increasing need for industrialization as a means to provide at least a minimum standard of living to their teeming millions.

Unfortunately in India, in spite of all the planning, there is a significant growing gap between the demand for electricity and installed capacity which is stunting progress and quality of life. What choices do we have?

Our reserves of coal estimated to last for about 60 to 100 years are poor in quality, with high ash content, and unevenly distributed mainly in the eastern and central parts of the country. Transportation of coal to centers of power generation located far and wide in different parts of the country would impose an enormous strain on our already overloaded railway system. More over burning of fossil fuels in large quantities has severe environmental consequences like greenhouse effect and acid rains.

✍ **Dr. A. N. Prasad**

This has been brought to sharp focus in the deliberations of the so called 'Earth Summits on Environment' in recent years. The problem is so near and real, there could be binding international agreement on limiting burning of fossil fuel in every country to control greenhouse gas emissions. Though electricity generation based on natural gas is being considered on a limited scale based on contemporary availability, this cannot be a long term solution. Since our oil resources are scarce, its use has to be limited to transportation sector and petrochemical industries. So far as hydel power is concerned, all the easily available potential has already been tapped and those that remain untapped are situated in relatively inaccessible locations. Hydel power is also subjected to the vicissitudes of truant and erratic monsoons in our country that make it a very unreliable source of power. Moreover, hydel power also has its own socio-ecological consequences, namely the large scale deforestation, submergence of vast areas of forest and farm land, problems of rehabilitation of large population.

Non conventional energy sources like solar, wind, tidal, biogas and biomass have their own limitations and their contribution at present is just nominal though there is scope for harnessing them further.

That leaves nuclear energy as an important option. Major advantage of nuclear power generation system is that it relies on a natural resource that has very high energy content. If properly managed, it can confer a strong degree of energy autonomy to a country like India, that does not possess alternate sources. It is for this reason, our policy planners decided on the nuclear option pretty early. India is now proud to be one of the very few countries that possess a fully integrated

Nuclear Fuel Cycle, starting from prospecting and mining of nuclear minerals to fuel material production, fuel fabrication, power reactor operation, reprocessing of spent fuel for recycling byproduct plutonium in fast reactors or in nuclear weapons, and safe management of all types of radioactive wastes generated in these activities.

Peaceful uses of nuclear energy are not restricted to the tapping of electrical power from the atom. Using radioisotopes and ionizing radiations in the fields of agriculture, industry and medicine is another important application in which Bhabha Atomic Research Centre has made substantial contribution. Seeds produced in BARC by crop mutations induced by ionizing radiations are being used in many parts of the country for increased yield and quality. Radioisotopes produced in BARC are being used by hundreds of hospitals for diagnostic and therapeutic applications including cancer. Non destructive testing of welds, castings, sewage treatment, food preservation, sterilization of medical kits and many other fields are using radioisotopes extensively. All this information needs to be disseminated to the public so that the people will realize the full potential of nuclear energy. At the public level there is a general feeling of unease associated with a wide range of real and imaginary fears about radiation. It is extremely difficult for many people to keep the munificent uses of the atom clearly separated in their minds from its potential for malevolence. It is the responsibility of academicians, scientists and engineers to dispel such misgivings people have on nuclear energy and convince them that nuclear energy, far from destroying their life supporting systems on this planet, promises to enrich their lives with minimum acceptable risks - risks much lower than what they are already exposed in their normal activities in life.

It is in this context, I consider this effort by the Mysore Association, Mumbai as most thoughtful and laudable in bringing out this special issue. The authors are highly experienced and knowledgeable scientists who have spent their entire professional careers in pursuing the country's nuclear programmes. In view of intense debates going on in the country regarding safety of nuclear energy after the Fukushima disaster in Japan, naturally there is more stress by way of the number of articles dealing with nuclear and environmental safety issues comprehensively as well as regulatory aspects. There are also articles on how the nuclear reactor works and management of nuclear waste. All the articles are written in a way easy to understand and I am sure the readers will greatly benefit from them which could help in having a constructive debate in the future.

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ಅಸೋಸಿಯೇಶನ್‌ನ ಜಾಲತಾಣದ ಉದ್ಘಾಟನೆ

ತನ್ನದೇ ಆದ ಒಂದು ಜಾಲತಾಣವನ್ನು ಹೊಂದಬೇಕು ಎಂದಿದ್ದು 'ಮೈಸೂರು ಅಸೋಸಿಯೇಶನ್'ನ ಬಹುದಿನದ ಬಯಕೆ, ಬೇಡಿಕೆ ಈದೀಗ ನನಸಾಗಿದೆ. ಅಸೋಸಿಯೇಶನ್‌ನ ಆರಾಧ್ಯದೈವ ಗಣಪನ ಪ್ರತಿಷ್ಠಾಪನ ವಾರ್ಷಿಕೋತ್ಸವ ಹಾಗೂ ಅಕ್ಷಯ ತೃತೀಯ ಶುಭದಿನದ ಸಂದರ್ಭದಲ್ಲಿ ಬಹು ಸಂಖ್ಯೆಯಲ್ಲಿ ನರೆದಿದ್ದ ಸದಸ್ಯರುಗಳ ಸಮ್ಮುಖದಲ್ಲಿ ಉಪಾಧ್ಯಕ್ಷರಾದ ಶ್ರೀಯುತ ನಾರಾಯಣ ಜಾಗೀರದಾರ್ ರವರಿಂದ ಅಧಿಕೃತವಾಗಿ ಉದ್ಘಾಟಿಸಲ್ಪಟ್ಟಿತು.

ಶ್ರೀಯುತ ಮಂಜುನಾಥಯ್ಯನವರು ಪ್ರಾಸ್ತಾವಿಕವಾಗಿ ಈ ಸಿಹಿಸುದ್ದಿಯನ್ನು ಘೋಷಿಸಿದ ನಂತರ, ಈ ಸಾಧನೆಯ ಮುಖ್ಯ ರೂವಾರಿಯಾದ ಶ್ರೀ ನಾರಾಯಣ ನವಿಲೇಕರ್‌ರವರು ಜಾಲತಾಣ, ಅದರ ಉಪ ಅಂಗಗಳು ಹಾಗೂ ವಿಶೇಷತೆಗಳ ಬಗ್ಗೆ ಪರದೆಯ ಮೇಲೆ ಪ್ರಾತ್ಯಾಕ್ಷಿತೆಯನ್ನು ನೀಡಿದರು.

ಕನ್ನಡ ಹಾಗೂ ಇಂಗ್ಲೀಷ್ ಎರಡೂ ಭಾಷೆಗಳಲ್ಲೂ ಬಳಸಬಹುದಾದ ಈ ಜಾಲತಾಣದ ಮುಖಪುಟದಲ್ಲಿ ಅಸೋಸಿಯೇಶನ್‌ನ ಲಾಂಛನ ಹಾಗೂ ದೇದಿಪ್ಯಮಾನವಾದ ಮೈಸೂರು ಅರಮನೆಯ ಅಂದ ಕಂಗೊಳಿಸುತ್ತಿದೆ out of sight is out of mind ಎನ್ನುವ ಇಂಗ್ಲೀಷ್ ಗಾದೆಯಂತೆ: ಕಾಲಕ್ರಮೇಣ, ಕಾರ್ಯಕಾರಣ ನಿಮಿತ್ತವಾಗಿ ದೂರದ ಉಪನಗರಗಳಿಗೂ ಹೊರ ರಾಜ್ಯಗಳಿಗೂ ಅಥವಾ

(ಪುಟ 25ಕ್ಕೆ)

Dr. V. Meenakshisundaram

Dr. V. Meenakshisundaram after graduation in physics joined Safety Research Laboratory, Indira Gandhi Centre for Atomic Research (IGCAR) in the year 1975. He obtained his doctorate degree in Physics from Bombay University for his research work in the area of radiation transport. His other areas of research include radiation protection and environmental radioactivity. He made major contributions to the development and application of "Gammatography" technique for non-destructive testing of shield integrity of reactor components and structures. He was Station Health Physicist, Fast Breeder Test Reactor (FBTR) at Kalpakkam. He was given the BEST SCIENTIST award by Kalpakkam Science & Technology Committee in the field of 'Applied Sciences' for the year 1997-1998. He has 127 research publications to his credit. He has represented India in the International Workshop on "Radon Monitoring in radio protection, environmental radioactivity and Earth Sciences" conducted by IAEA held at ICTP, Trieste, Italy. He presented four technical papers in the 12th International conference on Radiation Protection (IRPA-12) held in Argentina. He has been a recognized faculty member in various academic institutions like Bharathiyar, Bharathidasan, Madras and Mangalore universities. He was associated with the AERB's safety review of all the fuel cycle facilities of IGCAR. At the time of retirement in 2011 he was Head, Radiation Safety Section, Radiological Safety Division, Indira Gandhi Centre for Atomic Research (IGCAR).

NUCLEAR ENERGY?

1.0 Introduction

Rapid industrial growth and growing use of electrically operated domestic appliances have increased the demand for electrical energy all over the globe, particularly in the developing countries. India is not an exception to that. Things that were considered luxury yesterday have turned essentials today, even in an average Indian's home. Explosion of population is yet another reason for the increase in the demand. India's population is expected to rise to 1.5 billion by the year 2050. While the world average per capita electricity consumption is about 2500 kWh per annum, for OECD (Organization for Economic Co-operation and Development) countries the corresponding number is about 8000; India is way below the 1000 mark (600 kWh). All India average energy shortage is 8.8%, while the all-India average peaking shortage is 15%. Of late, India has witnessed an impressive growth rate in GDP. The development aspirations of its populace demand that this growth rate be sustained for a long enough time so as to enable them to have a decent quality of life. This requires matching growth in the availability of energy, particularly electricity.

2.0 Energy Sources

We use energy in the form of electricity for industrial, commercial

✍ **Dr. V. Meenakshisundaram**

and domestic purposes. When it comes to generation of power on a large-scale, hydel sources, coal, oil, natural gas and nuclear are the ones, which rule the world. World's fossil sources of energy are only finite and their geographical distribution is highly skewed leading to a concern about energy security. Besides there is also the fear

that uncontrolled utilization of fossil fuels would disturb the CO_2 balance in the atmosphere with disastrous consequences on the environment. In spite of the strong accent on the development of new and renewable sources of energy, they appear to be only a useful supplement but not a substitute for central electricity generation in the foreseeable future. Owing to these reasons, there is an increasing realisation, atleast in the expert circles, that nuclear energy is one of the few sustainable and environmentally benign options and foreclosing this option for electricity generation can lead to energy crisis, seriously affecting the industrial growth, particularly in developing countries. But, for this option to be acceptable by the society at large, it is necessary to analyse the reasons for whatever reservations public has regarding nuclear energy, especially the risks involved, if any. These aspects are discussed elsewhere in this booklet.

2.1 Available Resources for electricity generation

For those countries blessed with adequate resources, coal is undoubtedly the most reliable fuel and will remain so for many decades. Globally available Oil and natural gas will not last for more than a generation even at current levels of usage. In

Resource	Quantity	Potential (GWe-yr)
Coal	206 billion tons (Total)	41,000
	75 billion tons (Proven)	15,000
Oil	0.75 billion ton	300
Natural Gas	692 billion Cu.m.	250
Hydro	84 GW at 60% PLF	84 GW at 60% PLF
Nuclear (Uranium)	78,000 tons metal	In PHWRs# - 420
Nuclear (Thorium)	518,000 tons metal	In FBRs$ - 54,000 In In Breeders-3,58,000

India, about 70% of our electricity is generated through coal and oil resources, 27% through hydel sources and the rest through other sources. It is not always possible for us to follow other countries. Therefore, we need to make our own decisions considering the availability of indigenous resources and our energy requirements. The table below gives the natural resources we have in India along with their electricity generation capacity.

If India's per capita electricity were to rise to say 5000 units per year and India's population is expected to rise to 1.5 billion by the year 2050, total energy demand would rise to 7500 billion units per year. Expressed in terms of units given in the Table below, it amounts to 856 GWe-yr. If India produce 70% of electricity using coal fired plants, and use 70% of presently known total coal reserves for power production, coal reserves would not last for whole of this century, rather not even three quarters of this century. This is a very optimistic estimate as the calorific value used in the calculations of energy potential in the Table is on the high side since Indian coal has very low calorific value and the calculations are based on the total reserves and not mineable reserves. Therefore, to ensure long-term availability of energy, India has to look at other sources of energy. Fuel resource position points to nuclear fuel resource as a definite candidate for consideration from the standpoint of higher quantum of electricity generation and its sustainability. It should also be borne in mind that the development of other core sectors such as steel and cement are also dependent on coal.

[#] PHWR – Pressurised Heavy Water Reactor; [$]FBR – Fast Breeder Reactor

FBRs are also utilised to multiply the fissile material inventory besides producing electricity. Here, the unburnt ^{238}U in PHWR is getting converted into ^{239}Pu fissile / fuel material and hence the potential becomes much higher.

2.2 What are the disadvantages / risks associated with the use of the different energy sources?

All the available options for generation of electricity have certain amount of risk and / or disadvantages. The risks due to radiation in general are covered in a separate article published in this booklet and hence not covered here. The risks / disadvantages due to use of fossil fuels, hydel and other sources including the renewables are given in brief to obtain a proper perspective of risks vis-à-vis the nuclear.

The risk to human health from the environmental impact due to mining of the enormous amount of coal as well as the pollutants resulting from the burning of the coal and the associated accident risks are well known. In India, most of the coal deposits are under forest land and mining entails significant destruction of forest cover. Further, about two-thirds of Indian coal is from open cast mining. This causes land degradation as a result of the dug pit and the overburden dumps outside the mine. Open cast as well as underground mining is known to have affected the water table resulting in drying up of wells in the surrounding environs. Coal is the most carbon-intensive fossil fuel (share of CO_2 emission is 43% upto 2008) followed by natural gas whose share of CO_2 emission is 19% upto 2008. During the past 20 years alone, about three quarters of human-caused emissions came from burning the fossil fuels. For a 1 GWe year operation, a coal based station would reject to the environment in a year, 7.5 million tons of CO_2 one lakh tons of SO_2, 25 thousand tons of NO_2 and two million tons of flyash. Greenhouse gases trap heat from the sun and warm the planet's surface, known as Greenhouse effect and due to this there is an increase in existing terrestrial temperature and this in turn can produce catastrophic consequences on our environment such as melting of polar ice, inundation of large tracts of lands besides change in weather and rain fall pattern. It is also clear now that sulphur present in coal and oil causes rain water to become acidic (acid rain) affecting the flora and fauna and has led to destruction of forests and fish life. For one year operation of a 1000 MWe power station, 3, 000, 000 tons of coal is required. In the case of a nuclear reactor, 50 tons of fuel would be adequate (one gram of fissionable uranium can produce a million times more heat than one gram of coal).

Major contribution to the negative impact in the case of hydroelectric power arises from the very installation of power system. Till recently, hydroelectric power, which is essentially a form of renewable source of energy, was considered to be environmentally benign. Hydro projects necessitate construction of large dams and massive impounding of water and hence highly susceptible to seismic activity. Experience over the decades have shown that apart from large scale fatalities in case of dam bursts, one must take into account the consequent inundation of large tracts of lands for construction of the dam– mostly rich forest land – and reduction of soil fertility downstream as the alluvial soil is trapped in the reservoir. Also, the construction of dams involve in displacement of persons causing severe social, economic and cultural problems. Environmentalists associate with large dams a number of detrimental effects such as soil erosion, land slips, sedimentation and seismicity. The risk to life associated with hydroelectricity is due to dam bursts or dam over topping. Many dam bursts did occur (Example: Vajont-Italy, Koyna, Machhu and Hirakud in India…) and more than 10000 fatalities are reported. As compared to hydel power, the land requirement for nuclear power is insignificant.

Renewable energy sources such as solar, wind, geo thermal, biomass etc., are ecologically quite attractive. However, as on today, technology-wise, renewable energy sources are not suitable for large scale exploitations, i.e., they can only be a supplement and NOT a substitute. These sources heavily depend on the vagaries of the weather and at best are only minor sources of energy. To generate same amount of electrical energy in a year, the installed capacity of solar and wind power need to be about four times higher. Even if the capital cost per MWe is the same as nuclear, the overall investment cost would be much higher. Also, they require large area of land etc.

3.0 Need for sustainable development

Electrical generation, with per capita of 5000 kWh magnitude (i.e., roughly ten times the current generation), calls for a careful examination of all issues related to sustainability, including diversity of energy supply sources and technologies, severity of supplies, self-sufficiency, security of energy infrastructure, effect on local, regional and global environments and demand side management. The concept of sustainability calls for the exploitation of available resources to improve the quality of life of people without harming the interests of future generations, both from the point of the availability of resources and of the degradation of the environment beyond the inherent corrective capability of natural processes. While the environmental burden has to be kept within the limits of self-correction and be geographically well-distributed, people's development aspirations have to be given a place of supreme importance. After all, 'poverty is the biggest pollution' and is the source for several conflicts.

The threat to global climate has presented the world a dual challenge of increasing access to electricity in adequate measure in the developing countries and at the same time, reduction in emission of CO_2. Notwithstanding the important role of renewable and other clean energy technologies, given the magnitude of the problem, it appears that nuclear power is an inevitable option at the present state of development of advanced energy technologies which can meet the development of aspirations of the large fraction of world population, while at the same time conforming to the criteria of sustainability. With the rapidly depleting fluid hydro-carbon fuels, the transportation sector would soon lead to a sharp increase in demand for nuclear energy as a sustainable and environmentally benign primary energy source. It is ironic that in spite of its large energy potential with the capability to meet the worldwide energy needs sustainably and without any significant real environment impact, the unfounded misconceptions still dominate and have become impediments to sustainable development, We the people of India should recognise sooner our responsibility in this regard.

Sustainability of long-term economic growth is critically dependent on our ability to meet our energy requirements of the future. When a country of the size of India begins to grow at the rate of 9% per annum, with the prospect of even higher rates of growth, energy becomes a critical issue. Our proven resources of coal, oil, gas and hydropower are totally insufficient to meet our requirements. Though Government of India is liberally importing the coal, the landed price of coal is much higher and adds enormously to the cost of electricity. India needs energy from all known and likely sources of energy. The energy we generate has to be affordable not only in terms of its financial cost, but in terms of the cost to our environment. Nuclear power is one of the important and environmentally benign constituents of the overall energy mix.

4.0 Status of nuclear power technology in India

Comprehensive expertise in all aspects of nuclear fuel cycle and Pressurized Heavy Water Reactors (PHWR) has been acquired through self reliant means. PHWRs which constitute the mainstay of I stage of our nuclear power program are the most efficient systems in terms of uranium utilization and would enable about 10 GWe of nuclear installed capacity with our modest indigenous uranium resources. Department of Atomic Energy (DAE) have now embarked on the construction of Fast Breeder Reactors (II stage of our program) based on Plutonium bred from indigenously available uranium. This is a part of the strategy of India's three-stage program aimed eventually at exploitation of our vast thorium resources. With decades of R&D in our labs and industries, India has come a long way and the current efforts are aimed at further improving the economy, enhancing safety and expanding the program to meet the increasing electricity demand in the country. Towards energy growth scenario, development work on metallic fuels is in full swing, which has short doubling time and can ensure a fast enough growth in nuclear installed capacity. Hydro and non-conventional potential being limited, the remaining demand has to be met by fossil fuels. The results indicate that it is possible to have one quarter of the contribution coming from nuclear by the middle of the century, if the fast reactor growth follows the course outlined. Even after the growth projected by the study, there will be shortages and the country will continue to import energy as at present. New technologies have to be deployed to reduce energy imports.

5.0 Why do some people have reservations about nuclear power stations?

The reservations are due to

- Fear of radiation and of radioactive materials
- Confusion with nuclear weapons
- Fear of Nuclear accidents and
- Perceived higher cost of nuclear power

The fact is that thousands of scientists around the world have spent their entire professional life studying

(Contd. 14)

Shri R. Shankar Singh after obtaining Masters Degree in Nuclear Physics from Mysore University joined the Department of Atomic Energy through the Officers Training School in 1959. He was deputed to Argonne National Laboratory, USA for advanced training in Nuclear Science and Technology in 1964.

He was associated with the fast reactor programme right from its inception. His areas of specialization include fast reactor physics, nuclear data evaluation, core physics design, radiation transport, reactor shielding and safety analysis. He was deputed to ANL, USA and Cadarache, France for design of Fast Breeder Test Reactor (FBTR) at Kalpakkam. He led the reactor physics group that took successfully FBTR to first criticality and subsequently to power operations. He was also associated with safety review of Prototype Fast Breeder Reactor (500 MWe).He has to his credit more than 100 research publications. He was Head Reactor Physics Division at Indira Gandhi Centre for Atomic Research when he retired in 1996.

NUCLEAR POWER REACTORS

✍ **R. Shankar Singh**

1. Principles of Nuclear Power Reactors

For a long time it was believed that atom can not be broken up into smaller particles. But the scientific discoveries made around the beginning of the 20th century showed that atom in fact consists of a central positively charged nucleus with negatively charged light electrons orbiting around the nucleus. The nucleus in turn was found to contain protons and neutrons.

Hydrogen is the lightest atom and uranium the heaviest atom known to occur in nature. Natural uranium consists of two types of atoms, U-238 (99.3%) and U-235 (0.7%) which are known as isotopes of uranium. Hydrogen also has an isotope deuterium (D) which is heavier. Water (H_2O) contains atoms of hydrogen and oxygen bound together while heavy water (D_2O) atoms of deuterium and oxygen are bound together.

The nucleus of U-235 can break up easily into two fragments when struck by a neutron. This process is known as nuclear fission. The two fission fragments which are radioactive fly apart with tremendous speed due to the large energy released in the fission process. As they collide with other toms in uranium lump, they heat up the lump and this is how energy released in fission is converted to heat.

It is found that in the fission process two or three free neutrons are also released. When one of these neutron collides with another uranium nucleus, that nucleus can also break up. In this manner using one neutron from every fission, we can cause another fission and this is known as chain reaction. Heat can be produced at a sustained rate if the chain reaction is maintained steady. Some free neutrons are captured by U-238 nuclei which get converted to new nuclei Pu-239 (Plutonium) which are also fissionable like U-235. Plutonium does not occur in nature.

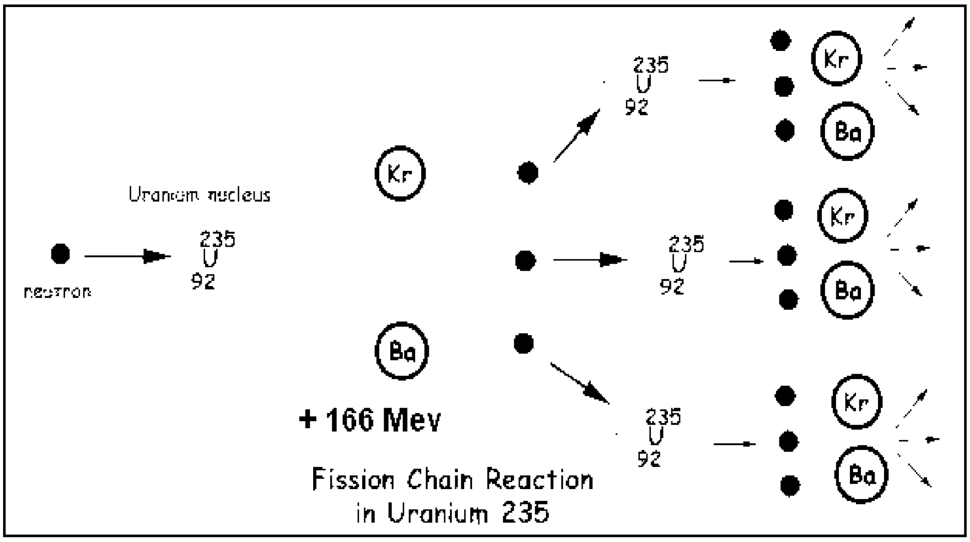
Basically all power stations adopt the same method to produce electricity. A turbine is made to rotate and the generator attached to the turbine shaft produces electricity. In hydroelectric power station, the turbine is rotated by the flowing water. In a thermal power station steam which rolls the turbine is produced by heating water in a boiler which uses coal or oil as the fuel. In a nuclear power station the steam is produced by the heat generated in fission process in the reactor.

2. Reactor System

A schematic diagram of a nuclear power reactor is shown in Fig.1. The main components of the reactor are described below.

i) Reactor Core and Fuel

Reactor is the main unit of the nuclear power station. The reactor consists of a large cylindrical vessel containing the core which is the heart of the reactor. The core has uranium fuel in the form of rods. Fuel rod is made up of a clad tube which covers the metal or oxide fuel in the form of pellets or pins. These fuel rods are tied to gether in the form of bundles which are placed in fuel channels.



Fission Chain Reaction in Uranium 235

Coolant is passed around the fuel tubes to extract the heat generated in fission. The coolant could be heavy water or ordinary water depending on the type of reactor. The first generation reactors in our nuclear power programme have been Pressurised Heavy Water Reactors (PHWR) which use natural uranium as fuel and heavy water as moderator and coolant. The function of the moderator is to slow down the fast neutrons produced in the fission, as the slow neutrons have a better chance to cause fission of U-235 nuclei. Heavy water flowing around the fuel bundles extracts the heat generated in them. The hot heavy water is taken to a boiler where it turns ordinary water into steam. The steam drives the turbine to produce electricity. The whole reactor system is located in a containment building to prevent any leakage of radioactivity to the environment.

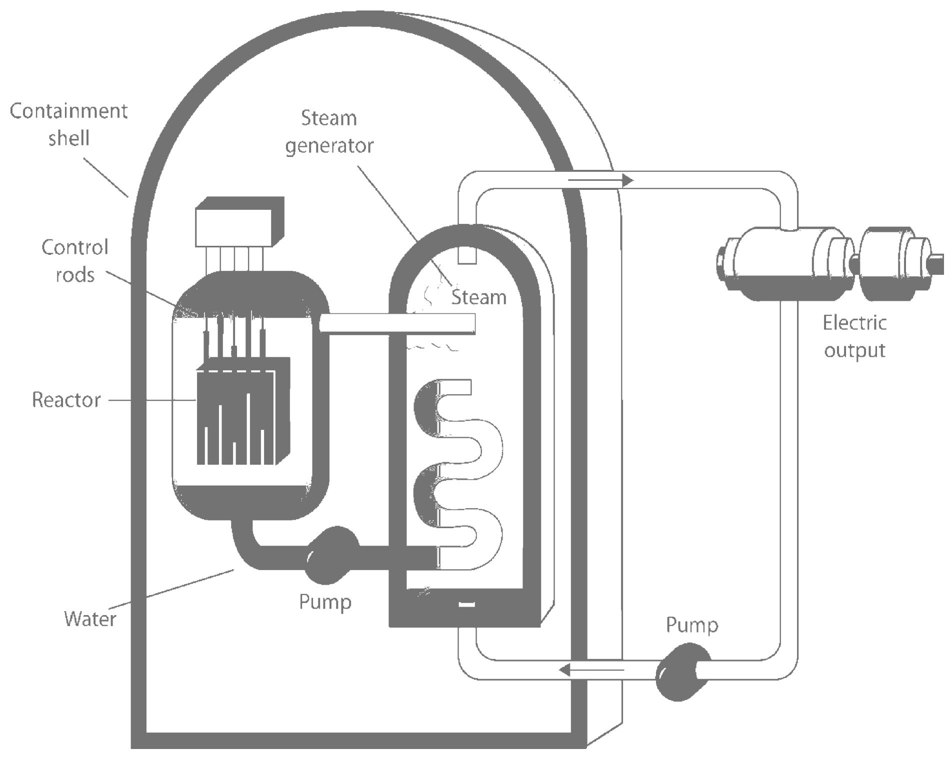


Fig.1 Schematic of a nuclear power reactor

ii) Control Rods

The fission rate in a nuclear reactor is controlled by using neutron absorbing materials like cadmium or boron in the form of rods. By suitable movement of the rods the fission rate can be made to increase or decrease or kept steady at a prescribed level. It is possible to use solution of boron for rapid injection into the core to shut down the reactor, in addition to dropping all control rods into the core when a situation demands.

iii) Shielding

Nuclear radiations like beta and gamma rays are emitted during the fission reaction in addition to fast neutrons. The fission products formed during fission are radioactive and continue to emit radiation even after the reactor is shut down.

Radiation leaking out of the core poses harm to the personnel working around. Suitable shielding materials such as steel, lead, concrete etc. are provided around the reactor core and its coolant systems to absorb the radiations to ensure that the radiation levels in the working environment are too low to be harmful to operating personnel.

3. Reactor Operation and Control

Operation of the nuclear power reactors involves two aspects namely regulation of power generation to maintain it at a safe and steady level and secondly total shutdown of the reactor when required.

The power is controlled by control rods made up of boron. When these rods are introduced into the reactor core, the chain reaction slows down and the heat generation or power drops. If the control rods are slightly pulled out of the core, the chain reaction picks up and the power rises. Reactor operation at a desired power level is thus carried out using the control rods.

Shut down of the reactor is achieved by multiple mechanisms. Shutdown rods of boron are quickly dropped into the core. In heavy water reactors, moderator heavy water is drained out of the reactor vessel quickly. In the absence of the heavy water, there is a huge decrease in the number of slow neutrons and the chain reaction ceases totally. Further a s a back up measure, solution of boron is injected into the reactor to shut down the reactor completely.

All these operations are carried out with the control instrumentation provided in a control room which is located away from reactor building.

2. Reactor Safety

Safety of nuclear reactors has received the utmost attention and care by the nuclear community.

Safety of a reactor is ensured by parallel approaches at different levels adopting the principle of " Defence in Depth". Safety provisions are made in three stages.

i) At the first level, inherent safety features are made use of which do not call for any mechanical equipment to operate or require human intervention. Additionally designed and engineered safety features are provided.
ii) The second step is to incorporate diverse and redundant instrumentation to monitor the occurrence of fault condition and provide protective devices to take prompt actions to prevent any plant damage or radioactivity release.
iii) At the third level, adequate

containment is provided around the reactor systems to prevent any leak of radioactivity to the environment in case the protective devices mentioned in second stage fail to work.

These provisions are detailed below. Inherent safety features involve certain physical processes like thermal expansion of fuel, moderator, coolant and structures due to increase in temperature and the following decease in density which will lead to slowing down of chain reaction. If any abnormal increase in power of reactor and the consequent increase in temperature of various components occur, chain reaction automatically comes down without any human intervention.

Several engineering features are incorporated in the design of the reactor systems and components which enhance the safety of the reactor. These are discussed below.

i) Provision of multiple barriers to prevent leakage of radioactivity to the environment is made. Fig 2. Shows the barriers in a typical nuclear reactor. These include fuel matrix itself, the clad, the coolant system and reactor vessel, primary and secondary containments. Uranium fuel is packed in a clad tube which is sealed at both ends. If development of any leak in the tube occurs, the defective tube is quickly identified and removed from the reactor. Radioactive materials released if any are still contained in the coolant flowing around the tube. The piping work, pumps and valves used in the coolant system are highly leak tight. As a further barrier, the reactor and the coolant system are housed in a massive containment building.

ii) Uninterrupted flow of coolant through the core is ensured by providing two or three pumps where ever one would have been adequate. As an additional measure of precaution against the failure any pipe, other pathways are provided to send the coolant to the core. Provision of emergency cooling system for the removal of decay heat generated from fission products using natural convection process is made when reactor is shut down.

iii) Multiple monitoring and protection systems are provided. The instruments that monitor the power levels are provided in triplicate so that even if one fails two others are available to indicate the status . In the same way the devices which shut down the reactor are also provided in triplicate. Their operational status is checked everyday.

To ensure that electrical power is always available for all the instruments and equipment which maintain the reactor in safe condition, four different and independent supply lines are provided where one will do, Finally even if the diesel generators do not operate, a battery bank can supply essential power for several hours.

Safety provisions made in nuclear power plans are indeed unmatched by any other industry. □

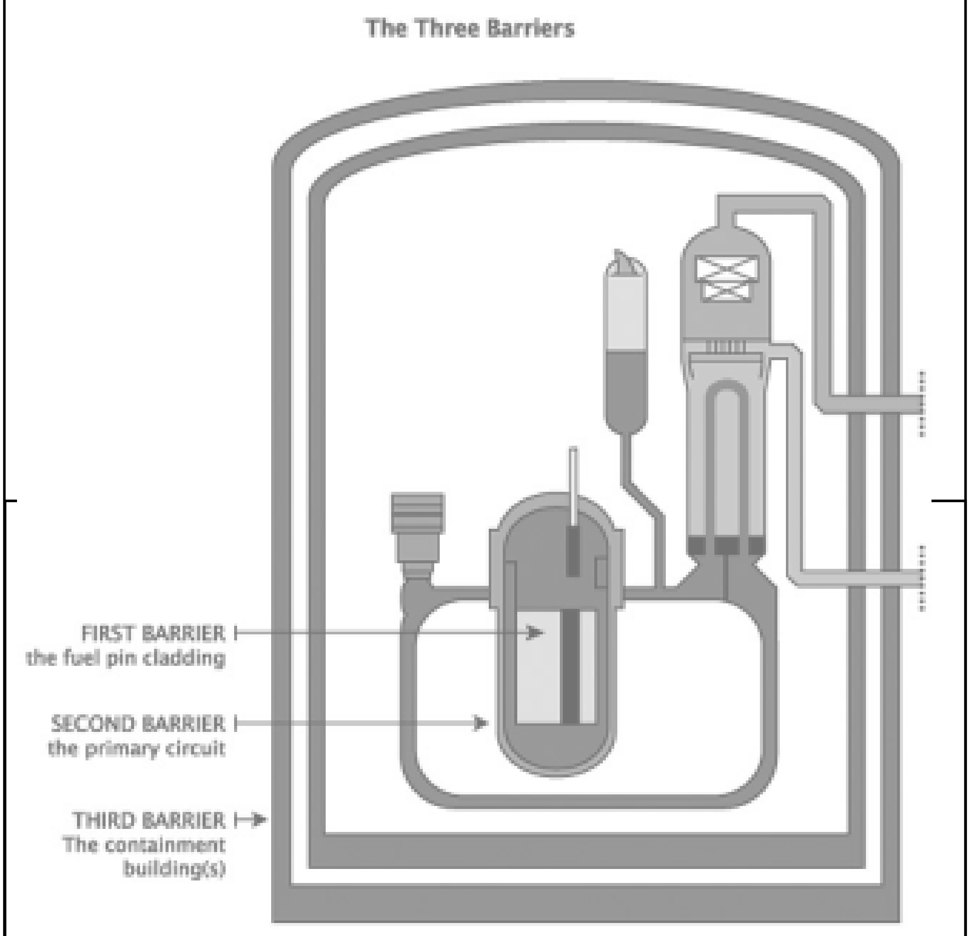


Fig.2 Barriers against release of radioactivity

SAFETY FEATURES IN NUCLEAR POWER PLANTS

1.0 INTRODUCTION

There are about 434 Nuclear Power Plants (NPPs) operating the world over and about 64 NPPs are currently under construction. The design of NPPs has evolved over a long period of time and several generations of reactors are commonly distinguished. Generation I reactors, mainly prototype reactors, were developed in the 1950 – 60s. Most of the reactors currently in operation the world over are Generation II reactors. Generation III and III^{+} are the advanced reactors with enhanced safety features and severe accident management schemes, which are under construction and planning the world over, including in India.

This article brings out the objectives and principles of nuclear safety and illustrates salient safety features in the advanced reactors.

2.0 NUCLEAR SAFETY

The main objective of nuclear safety is to protect people and the environment from the harmful effects of ionizing radiation.

In an NPP, heat generated in nuclear fission process is used to produce steam which rotates the turbo generator to produce electricity. Nuclear fuel, containing uranium oxide, fabricated in the form of pellets and enclosed in tubes, is housed in the reactor. Nuclear fission, while producing heat, generates fission products which are radioactive. These fission products are contained within the fuel pellet matrix enclosed in the fuel tubes. Therefore, maintaining integrity of the fuel during normal operation and during any off-normal operation is important to achieve the objective of nuclear safety. Accordingly, following are the fundamental safety functions in NPPs.

- Control of fission chain reaction (known as reactivity control)
- Maintaining adequate cooling of the fuel (known as core cooling)
- Containing radioactivity (known as confinement).

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He has more than 25 years experience in Design, Development, Planning, Construction and Commissioning of Nuclear Power Plants. He is currently working as Chief Engineer (LWR Design) in Nuclear Power Corporation of India Ltd and is involved in safety review and analysis of various advanced reactors being constructed and proposed to be built in India.

3.0 DESIGN AND SAFETY APPROACH

The design of a NPP is carried out meticulously in order to ensure that the three safety functions mentioned above are always achieved. Central to this approach is the theme of 'Defense-in-Depth (DiD)'. In simple terms, DiD means provision of multiple levels of defense against failure in an NPP. Off-normal conditions in an NPP may be due to, for example, an equipment failure. Implementation of DiD ensures prevention of such failures in the first place and provision for detection, control and mitigation in successive levels.

In a NPP, systems and equipment are engineered to carry out the three fundamental safety functions. It is also possible to have inherent nuclear characteristics favourable towards nuclear safety. For example, an increase in power level produces a nuclear feed back that actually reduces the neutron population thereby reducing the power increase. Such features are known as 'inherent safety features'.

The safety systems are designed as 'active' or 'passive' systems. To illustrate these terms, let us take the example of circulation of a liquid in a loop. One of the ways of achieving circulation is by using a pump. Energy required for the pump is given from an electrical source. A system with such arrangement is known as an 'active system'. The liquid can also be circulated by natural convection in a loop containing a heat source and a heat sink. If the equipment providing heat sink (i.e. cooling) is at a sufficiently higher elevation, then the hot liquid from the heat source will rise up and the colder liquid (after dissipating heat in the heat sink) will come down due to the difference in the densities, thereby creating a natural convection flow. A system with such an arrangement is known as a 'passive system', indicating that no external source of energy is required for its function.

Active systems are provided with back-up power source through Diesel Generators (DG). Also, active systems are configured in multiple circuits i.e. more then one circuits are provided (say 2, 3 or 4 circuits). The safety function can be achieved with any one circuit operating. This enhances reliability.

Passive systems as described earlier, do not contain any active components. Therefore, unavailability of power supply does not impair the performance of passive systems.

4.0 SAFETY FEATURES IN ADVANCED REACTORS

The advanced reactors belonging to Generation III and III+ currently under construction and in planning, including those in India, employ different designs of safety systems with enhanced reliability and thereby increased assurance towards prevention and mitigation of accidents.

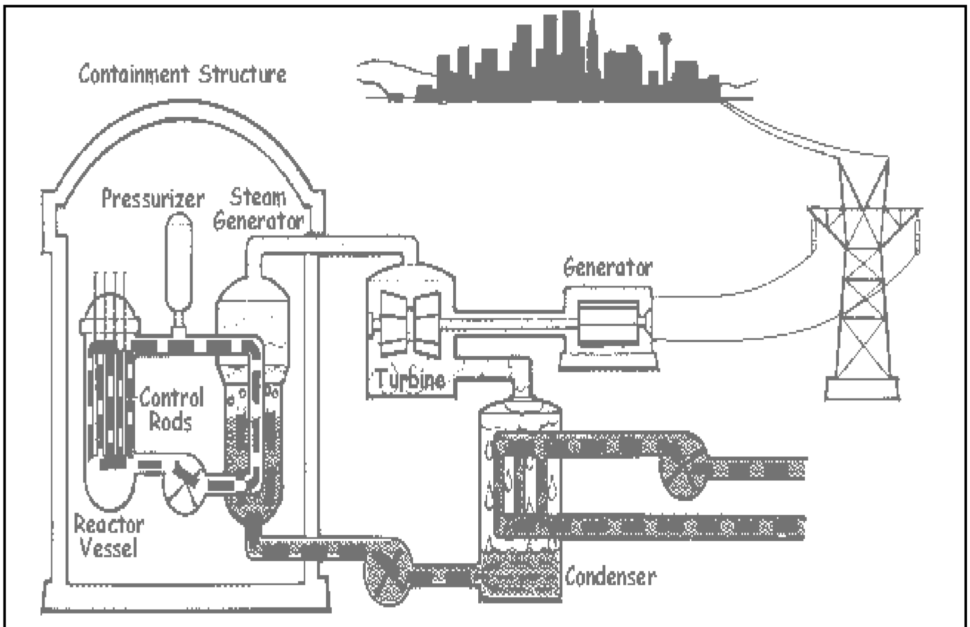
In this section, we will look at salient safety features of VVER-1000 NPPs, which are currently under construction in Kudankulam, Tamilnadu.

4.1 INTRODUCTION TO VVER-1000 REACTORS

VVER-1000 reactors are water moderated, water cooled reactors. These are Pressurised Water Reactors (PWRs), the dominant type of reactors worldwide.

A PWR consists of a Reactor vessel which houses the nuclear fuel and water as moderator and coolant. The coolant carries away the heat generated in the fuel and is circulated in a closed loop. The heat is transferred to another closed loop circuit, known as the secondary cycle, to produce steam in a heat exchanging equipment called Steam Generator (SG). The coolant temperature being high (about 320^0C), it is kept pressurized to maintain in the liquid phase.

The steam produced in the SG is used to rotate the turbine which, in turn, drives the generator to produce electricity. The steam from the turbine is led to a condenser where it is cooled and condensed. The condensate is pumped back to the SG, thus forming a closed loop. Cooling and condensation of the steam in the condenser is by water drawn from the sea. With such an arrangement of cooling systems, contamination of sea water is eliminated.



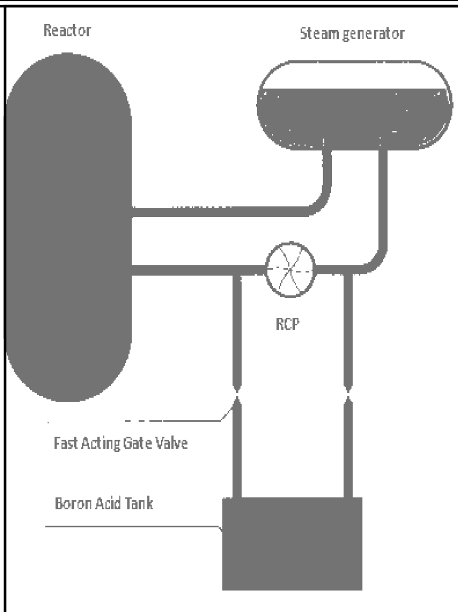
PRESSURISED WATER REACTOR

4.2 SAFETY FEATURES IN VVER-1000 REACTORS

VVER-1000 reactors, under construction in Kudankulam, Tamilnadu incorporates innovative and robust safety systems for carrying out the three fundamental safety functions. Let us examine these systems.

4.2.1 Systems for control of fission chain reaction

The reactor is provided with 103 Control Rods made of neutron absorbing material boron. In case of a requirement, these rods fall under gravity into the reactor to shut down the reactor and are, thus, 'passive' systems. Further, based on a postulated scenario, wherein the rods are assumed to be not dropping, additional systems have been provided to carry out the same safety function. These additional systems employ liquid neutron absorber and different principle of actuation. With such diverse systems available, overall reliability of accomplishing the safety function is very high. One such system viz., Quick Boron Injection System (QBIS) is depicted in the following figure.



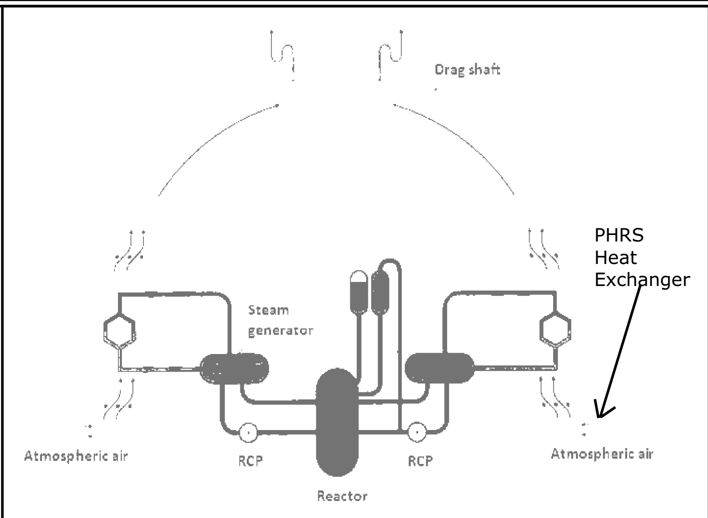
QUICK BORON INJECTION SYSTEM

Reactor Coolant Pump

Boric acid solution (liquid neutron absorber) from a tank is swept into the reactor by the coolant flow. The Reactor Coolant Pumps (RCP), by virtue of a flywheel attached to it, continues to rotate for a while (coasting down) even after power supply failure, thereby maintaining cooling of the fuel. The pump coasting down flow is adequate for sweeping the boric acid to the reactor for achieving the reactor shut down.

4.2.2 Systems for cooling of fuel

During normal operation, fuel is cooled by the forced circulation of the coolant using RCPs. In case of unavailability of the pumps (typically due to power supply failure) the



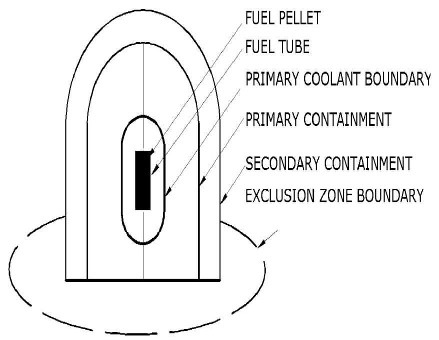
PASSIVE HEAT REMOVAL SYSTEM

reactor is shutdown. The residual heat in the fuel, known as decay heat, is removed by dedicated Residual Heat Removal System which is provided with DG power supply. This system is configured as four redundant circuits. Functioning of a single circuit is adequate to fulfill the safety function. In a very unlikely scenario of even the DGs not operating, the decay heat can be removed by an innovative Passive Heat Removal System (PHRS), a schematic of which is given below: Let us understand the functioning of PHRS. In the assumed scenario, the coolant circulation continues due to natural convection, as mentioned earlier. The heat is transferred to the water in the SG which turns into steam. In order to continue the heat removal process, the steam needs to be cooled & condensed and brought back to the SGs. With the help of PHRS, the steam is cooled by atmospheric air forming a natural draught across the heat exchanger, as depicted in the figure. This system does not require any external energy source (passive) and also does not need water source for cooling. Such a system allows coping with extreme events resulting in loss of complete power supply at the site and unavailability of cooling water sources.

4.2.3 Systems for containing radioactivity

The Primary source of radioactivity is the fuel containing fission products. There are multiple barriers against the release of radioactivity as depicted in the figure below.

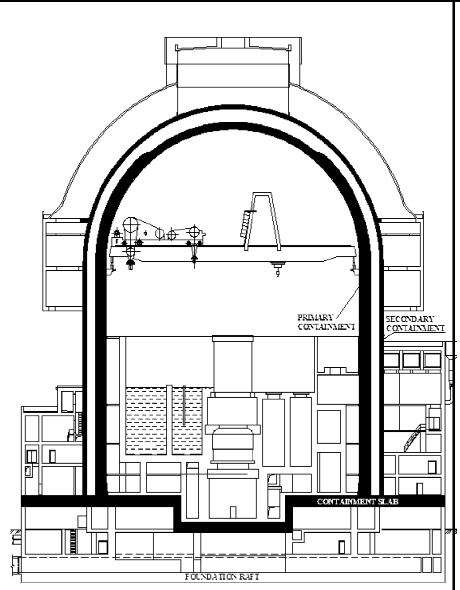
Reactor building, consisting of double containments, provides the physical barrier and contains radioactivity released due to any breach in the fuel tube and the coolant circuit. The primary containment is designed to withstand the pressure and temperature resulting from a postulated break in the coolant system. The primary containment is enveloped by a



MULTIPLE BARRIERS TO ESCAPE OF RADIOACTIVITY

secondary containment. The secondary containment is designed to protect the primary containment from a possible airplane impact.

In addition to the above barriers, the design provides for containing and cooling of the melted core that may come out of the reactor vessel in case of a hypothetical scenario involving multiple failures. This provision, shown pictorially below, known as 'core catcher', ensures that the radioactivity is confined within the containment boundary without any impact on the public domain, even in case of such an unlikely severe accident.



REACTOR BUILDING

4.2.4 Inherent safety features

The VVER-1000 reactors have inherently safe nuclear characteristics. Increase in reactor power or coolant temperature results in a negative nuclear feedback leading to reduction in neutron population and consequent reduction in power. Similarly, loss of coolant, for example due to a break in the coolant system pipeline, results in a negative nuclear feedback leading to reduced fission chain reactions and consequently reducing the reactor power. These self regulating features play an important role in the safety of the reactor.

4.2.5 The above discussion on the VVER-1000 reactors, under construction at Kudankulam, highlights the advanced safety systems incorporated in the design which ensure high levels of safe operation and public safety.

4.3 As envisaged in the Indian nuclear power programme, apart from the VVER-1000 reactors, NPCIL is pursuing other advanced reactors, viz., EPR (1650MWe) from Areva, France, AP1000 (1100MWe) from Westinghouse Electric Company, USA, and ESBWR (1590MWe) from General Electric, USA. These reactors also have advanced design of safety systems to ensure high levels of safe operation and public safety.

ಬೈಜಿಕ ವಿದ್ಯುತ್ ಸ್ಥಾವರಗಳ ಸುರಕ್ಷತೆ

ಇಂದು ಬೈಜಿಕ ವಿದ್ಯುತ್ ಸ್ಥಾವರಗಳ ಸುರಕ್ಷತೆಯ ಬಗ್ಗೆ ಜನರ ಮನಸ್ಸಿನಲ್ಲಿ ದ್ವಂದ್ವ ಅಭಿಪ್ರಾಯಗಳಿವೆ. ಅವು ಪರಿಸರಸ್ನೇಹಿ ಎಂದು ಕೆಲವರು ಪರಿಗಣಿಸಿದರೆ, ಮತ್ತೆ ಕೆಲವರು, ಅವು ಮನುಕುಲದ ನಾಶಕ್ಕೇ ಕಾರಣ ವಾಗಬಹುದೆಂದು ಭಯ ವ್ಯಕ್ತಪಡಿ ಸುತ್ತಾರೆ. ಇವರ ಭಯಕ್ಕೆ ಮೂರು ಕಾರಣಗಳನ್ನು ಗುರುತಿಸ ಬಹುದು:

೧) ಬೈಜಿಕ ಸ್ಥಾವರ ಕಾರ್ಯ ನಿರ್ವಹಿಸುವಾಗ ಸ್ವಲ್ಪಮಟ್ಟಿಗೆ ವಿಕಿರಣ ಧಾತುಗಳನ್ನು ಪರಿಸರಕ್ಕೆ ಬಿಡುತ್ತದೆ.

೨) ಬೈಜಿಕ ಸ್ಥಾವರದಲ್ಲಿ ಅಪಘಾತ ಸಂಭವಿಸಿದರೆ, ಅಧಿಕ ಮೊತ್ತದಲ್ಲಿ ವಿಕಿರಣ ಧಾತುಗಳು ಬಿಡುಗಡೆ ಯಾಗಿ ಪರಿಸರಕ್ಕೂ ಅಲ್ಲಿನ ಜೀವ ಸಂಕುಲಕ್ಕೂ ಹಾನಿಯಾಗಬಹುದು.

೩) ಬೈಜಿಕ ಸ್ಥಾವರದಲ್ಲಿ ಉತ್ಪತ್ತಿಯಾಗುವ ಕೆಲವು ತ್ಯಾಜ್ಯ ವಸ್ತುಗಳ ವಿಕಿರಣ ಶೀಲತೆಯ ಅರ್ಧಾಯು ಬಹು ದೀರ್ಘವಾಗಿದ್ದು ಅವು ಗಳಿಂದ ಪರಿಸರಕ್ಕೆ ಹಾನಿಯುಂಟಾಗದಂತೆ ಸಹಸ್ರಾರು ವರ್ಷಗಳವರೆಗೆ ಎಚ್ಚರಿಕೆ ವಹಿಸ ಬೇಕಾಗುತ್ತದೆ.

ಆರಂಭದಿಂದಲೇ ವಿಜ್ಞಾನಿಗಳು ಬೈಜಿಕ ಸ್ಥಾವರದ ವಿನ್ಯಾಸ, ರಚನೆ ಹಾಗೂ ಕಾರ್ಯಶೀಲತೆ ಇವು ಗಳಲ್ಲಿ ಸುರಕ್ಷತೆಗೆ ಪ್ರಥಮ ಆದ್ಯತೆ ನೀಡಿದ್ದಾರೆ. ಇಂದಿನ ಬೈಜಿಕ ಸ್ಥಾವರಗಳ ಸುರಕ್ಷತೆ ಯನ್ನು ಎರಡು ಆಧಾರ ಸ್ತಂಭಗಳ ಮೇಲೆ ಯೋಜಿಸ ಲಾಗಿದೆ:

೧) ಅಪಘಾತ ಸಂಭಾವ್ಯತೆಯನ್ನು ಆದಷ್ಟು ಕಡಿಮೆ ಮಾಡುವುದು,

೨) ಹಾಗಿದ್ದೂ ಅಪಘಾತ ಸಂಭವಿಸಿದರೆ ಅದರ ದುಷ್ಪರಿಣಾಮವನ್ನು ಉಪಶಮನಗೊಳಿಸುವುದು.

ಅಪಘಾತದ ಸಂಭಾವ್ಯತೆ ಕಡಿಮೆಯಾಗಬೇಕಾದರೆ ಇಂಧನದ ತಾಪ ಒಂದು ಎಲ್ಲೆ ಮೀರದಂತೆ ಜಾಗ್ರತೆ ವಹಿಸಬೇಕು. ಅದಕ್ಕಾಗಿ ಇಂಧನದಲ್ಲಿ ವಿದಳನ ಸಾಂದ್ರತೆಯನ್ನು ಬಹಳ ಎಚ್ಚರಿಕೆಯಿಂದ ನಿಯಂತ್ರಿ ಸುವಂತಿರ ಬೇಕು. ಅಲ್ಲದೆ, ಇಂಧನ ತಂಪುಕಾರಿಯ ಪ್ರಚಲನೆಯಲ್ಲಿ ಯಾವ ರೀತಿಯ ಅಡಚಣೆಯೂ ಉಂಟಾಗಬಾರದು, ಹಾಗೂ ತುರ್ತು ತಂಪುಕಾರಿಯು ಸದಾ ಕಾರ್ಯಸಿದ್ಧವಾಗಿರಬೇಕು. ಅಪಘಾತದ ಪರಿಣಾಮಗಳನ್ನು ಉಪಶಮನ ಗೊಳಿಸಲು ಇಂಧನದಿಂದ ಬಿಡುಗಡೆಯಾದ ವಿಕಿರಣ ದ್ರವ್ಯ ಯಾವ ಸಂದರ್ಭದಲ್ಲಿಯೂ ರೀಯಾಕ್ಟರ್ ಕಟ್ಟಡದಿಂದ ಹೊರ ಬಂದು ಪರಿಸರವನ್ನು ಸೇರದಂತೆ ಪ್ರತಿಬಂಧ ಹಾಕಬೇಕು.

ಈ ಗುರಿಗಳನ್ನು ಸಾಧಿಸಲು ಇಂದಿನ ಬೈಜಿಕ ಘಟಕಗಳಲ್ಲಿ ಸುರಕ್ಷತೆ ಯನ್ನು ಮೂರು ಹಂತಗಳಲ್ಲಿ ಅಭಿವೃದ್ಧಿಪಡಿಸಲಾಗುತ್ತದೆ:

೧) ಸಹಜ ಸುರಕ್ಷತೆ,

೨) ವಿನ್ಯಾಸ ಸುರಕ್ಷತೆ, ಮತ್ತು

೩) ರಚನಾ ಸುರಕ್ಷತೆ.

ಮುಂಬಯಿನ ಭಾಭಾ ಪರಮಾಣು ಅನುಸಂಧಾನ ಕೇಂದ್ರದ ವಿಕಿರಣ ಸಂರಕ್ಷಣಾ ವಿಭಾಗದಲ್ಲಿ ೪೦ ವರ್ಷಗಳ ಕಾಲ ಸೇವೆ ಸಲ್ಲಿಸಿ ನಿವೃತ್ತರಾದರು. ನಿವೃತ್ತಿಯ ನಂತರ ಬೆಂಗಳೂರಿನಲ್ಲಿ ನೆಲಸಿದ್ದು, ಸುಮಾರು ೩೫೦ಕ್ಕೂ ಹೆಚ್ಚು ಜನಪ್ರಿಯ ವಿಜ್ಞಾನ ಲೇಖನಗಳನ್ನು ಇಂಗ್ಲಿಷ್ ಮತ್ತು ಕನ್ನಡದಲ್ಲಿ ರಚಿಸಿ ಪ್ರಕಟಿಸಿದ್ದಾರೆ. ಅಲ್ಲದೆ ಕೆಲವು ಸಣ್ಣ ಕತೆಗಳು, ಹಾಸ್ಯ ಲೇಖನಗಳು, ವಿಜ್ಞಾನಿಗಳ ಜೀವನ ಚರಿತ್ರೆಗಳನ್ನೂ ಪ್ರಕಟಿಸಿ ದ್ದಾರೆ. ಇವರ, ೨೦೧೦ರಲ್ಲಿ ಪ್ರಕಟವಾದ ಬೈಜಿಕ ವಿದ್ಯುತ್: ಒಂದು ಪರಿಚಯ ಪುಸ್ತಕದಿಂದ (ಪ್ರಕಾಶಕರು –ನವಕರ್ನಾಟಕ ಪಬ್ಲಿಕೇಷನ್ಸ್ ಪ್ರೈವೆಟ್ ಲಿಮಿಟೆಡ್, ಬೆಂಗಳೂರು) ಈ ಭಾಗಗಳನ್ನು ಅಳವಡಿಸಿಕೊಂಡಿದೆ.

ಸಹಜ ಸುರಕ್ಷತೆ:

ಭಾರಜಲ ಮಂದಕದೊಂದಿಗೆ ನೈಸರ್ಗಿಕ ಯುರೇನಿಯಮ್‌ನ್ನು ಇಂಧನವಾಗಿ ಬಳಸಬಹು ದಾದರೂ, ಅದರಲ್ಲಿ ವಿದಳನ ಶೀಲ ಯುರೇನಿ ಯಮ್–೨೩೫ ಕೇವಲ ಶೇಕಡ ೦.೭ ಇರುವುದರಿಂದ ವಿದಳನ ಗತಿ ಬಹಳ ಕಡಿಮೆ ಇರುತ್ತದೆ. ಹಾಗಾಗಿ ಅಂತಹ ರಿಯಾಕ್ಟರ್‌ಗಳನ್ನು ನಿಯಂತ್ರಿಸುವುದು ಸುಲಭ. ಅಲ್ಲದೇ ಆ ಸಂಯೋಜನೆಯಲ್ಲಿ ಇಂಧನ ತಾಪದ ಏರಿಕೆಯಿಂದ ವಿದಳನ ಸಾಂದ್ರತೆ ಏರುವುದಿಲ್ಲ. ಬದಲಾಗಿ ಕಡಿಮೆಯಾಗುತ್ತದೆ. ನೀರು ಹತ್ತಿ ಉರಿಯುವುದಿಲ್ಲವಾದ್ದರಿಂದ ರಿಯಾಕ್ಟರ್ ಯಾವಾಗಲೂ ಸಮಸ್ಥಿತಿಯನ್ನು ಕಾಪಾಡಿಕೊಳ್ಳಲು ಸಾಧ್ಯವಾಗುತ್ತದೆ.

ಬೈಜಿಕಕ್ರಿಯಾಕಾರಿಯ ನಿರ್ಮಾಣದಲ್ಲಿ ಅಡಕವಾಗಿರುವ ಸುರಕ್ಷತೆಯ ಬಗ್ಗೆ ಒಂದು ಪಕ್ಷಿ ನೋಟ ಬೇಕೆನಿಸಿದರೆ ಒಮ್ಮೆ ಕ್ರಿಯಾಕಾರಿಯ ನಿಯಂತ್ರಣಾ ಕೊಠಡಿಯನ್ನು ಪ್ರವೇಶಿಸಿ. ಅಲ್ಲಿ ನಿಮಗೆ ಕಾಣುವುದೇನು? ಕ್ರಿಯಾಕಾರಿಯ ತಾಪ, ವತ್ತಡ, ವಿಕಿರಣ ತೀವ್ರತೆ, ನ್ಯೂಟ್ರಾನ್ ಸಂಖ್ಯೆ, ತಂಪುಕಾರಿ ಹಾಗೂ ಮಂದಕಾರಿಯ ಕವಾಟಗಳು ಮತ್ತು ಪಂಪುಗಳ ಕ್ರಿಯಾಶೀಲತೆ ಇತ್ಯಾದಿಗಳ ಬಗ್ಗೆ ನಿರಂತರವಾಗಿ ಮಾಹಿತಿ ಒದಗಿಸುವ ಬಣ್ಣಬಣ್ಣದ ಮಿನುಗು ದೀಪಗಳು, ಮೀಟರ್‌ಗಳು, ಕಂಪ್ಯೂಟರ್‌ಗಳು. ಯಾವುದೇ ವಿಷಯ ಪೂರ್ವ ನಿರ್ಧಾರಿತ ಸ್ತರದಿಂದ ವಿಚಲನವಾದರೆ ನಿಯಂತ್ರಣ ಅಧಿಕಾರಿಗಳಿಗೆ ಕೂಡಲೆ ಅಲಾರಮ್ ಮೂಲಕ ಎಚ್ಚರಿಕೆ ಕೊಡುವುದಲ್ಲದೆ, ಅದನ್ನು ತಂತಾನೇ ಸರಿಪಡಿಸುವ ವ್ಯವಸ್ಥೆಯೂ ಇದೆ. ಅದೊಂದು ಉನ್ನತ ತಾಂತ್ರಿಕತೆಯ ಸಾದೃಶ್ಯ. ಇಷ್ಟೆಲ್ಲ ನಿಗ ವಹಿಸಿದರೂ ಅನಿರೀಕ್ಷಿತ ಘಟನೆಗಳು ಸಂಭವಿ ಸುವ ಸಾಧ್ಯತೆ ಇರುತ್ತದೆ; ಸಂಭವಿಸಿವೆ. ಅವುಗಳಲ್ಲಿ ಹೆಚ್ಚಿನವು ಮಾನವನ ಅಜಾಗರೂಕತೆಯಿಂದಾಗಿ ಉಂಟಾದದ್ದು.

ವಿನ್ಯಾಸ ಸುರಕ್ಷತೆ :

ಯಾವುದೇ ವ್ಯವಸ್ಥೆಯನ್ನು ಎಂದೂ ವಿಫಲವಾಗ ದಂತೆ ರಚಿಸಲು ಸಾಧ್ಯವಿಲ್ಲ. ಆದ್ದರಿಂದ ಎಲ್ಲ ಸಂದರ್ಭಗಳಲ್ಲಿಯೂ ಸುರಕ್ಷತಾ ವ್ಯವಸ್ಥೆ ಕಾರ್ಯ ಸಿದ್ಧವಾಗಿರಬೇಕಾದರೆ ಒಂದಕ್ಕಿಂತ ಹೆಚ್ಚು, ಸ್ವತಂತ್ರ ವ್ಯವಸ್ಥೆಗಳನ್ನು ನಿರ್ಮಿಸಬೇಕಾಗುತ್ತದೆ. ಆಗ ಒಂದು ವ್ಯವಸ್ಥೆ ವಿಫಲವಾದರೆ, ಮತ್ತೊಂದು ಕಾರ್ಯ ನಿರ್ವಹಿಸಲು ಸಿದ್ಧವಿರುತ್ತದೆ. ಇದಕ್ಕೆ ಗಾಢ ರಕ್ಷಣೆ (Defense in depth) ಎನ್ನುತಾರೆ. ಈ ತತ್ವವನ್ನು ಬೈಜಿಕ ಸ್ಥಾವರಗಳಲ್ಲಿ ವಿಪುಲವಾಗಿ ಬಳಸ ಲಾಗುತ್ತದೆ.

ರಚನಾ ಸುರಕ್ಷತೆ:

ಭಾರತದ ರೀಆಕ್ಟರ್‌ಗಳಲ್ಲಿ ತುರ್ತು ಸ್ಥಿತಿಯಲ್ಲಿ ನಿಷ್ಕ್ರಿಯಗೊಳಿಸಲು ಕ್ಯಾಡ್ಮಿಯಮ್ ಸರಳುಗಳಲ್ಲದೆ, ಪರ್ಯಾಯವಾಗಿ ಲೀಥಿಯಮ್ ಪೆಂಟೋ ಬೋರೇಟ್ ದ್ರವ ತುಂಬಿದ ಕೊಳವೆಗಳನ್ನೂ ಅಳವಡಿಸಲಾಗಿದೆ. ಬೋರಾನ್ ಮತ್ತು ಲೀಥಿಯಮ್ ಧಾತುಗಳು, ಕ್ಯಾಡ್ಮಿಯಮ್‌ನಂತೆ ನ್ಯೂಟ್ರಾನ್ ಗಳನ್ನು ಹೀರಿ, ವಿದಳನ ಕ್ರಿಯೆಯನ್ನು ಸ್ಥಗಿತ ಗೊಳಿಸಬಲ್ಲವು. ಅದೇ ರೀತಿ ತಂಪುಕಾರಿ ಹಾಗೂ ತುರ್ತು ತಂಪುಕಾರಿಗಳಲ್ಲಿಯೂ ಪರ್ಯಾಯ ವ್ಯವಸ್ಥೆ ಇರುವುದರಿಂದ ಪರಿಸ್ಥಿತಿ ಕೈ ಮೀರಿ ಹೋಗದಂತೆ ತಡೆಯಲು ಸಾಧ್ಯ. ಭಾರತದಲ್ಲಿ ಹೊಸದಾಗಿ ನಿರ್ಮಾಣವಾಗುತ್ತಿರುವ ೫೦೦ ಮೆಗವಾಟ್ ವಿದ್ಯುತ್ ಘಟಕಗಳಲ್ಲಿ ಎಲ್ಲ ರೀತಿಯ ಸುರಕ್ಷಾ ಸಾಧನಗಳ ಎರಡು ಸ್ವತಂತ್ರ ಗುಂಪುಗಳಿಗೆ ಅವಕಾಶವಿದೆ.

✍ ಡಾ. ಎಂ.ಎಸ್.ಎಸ್. ಮೂರ್ತಿ
ಪಿ.ಎಚ್‌ಡಿ.Radiation, Biophysics.

ಪ್ರತಿಬಂಧಕ:

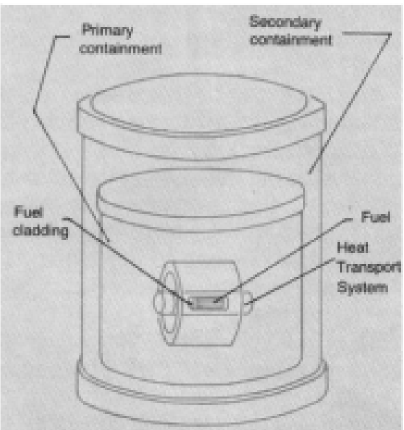
ಈ ಎಲ್ಲ ಸುರಕ್ಷಾ ವ್ಯವಸ್ಥೆಗಳನ್ನೂ ಮೀರಿ ಅಪಘಾತ ಸಂಭವಿಸಿದರೆ, ವಿಕಿರಣ ದ್ರವ್ಯ ಪರಿಸರ ಸೇರದಂತೆ ತಡೆಯಲು ನಾಲ್ಕು ಹಂತಗಳಲ್ಲಿ ಪ್ರತಿಬಂಧ ವ್ಯವಸ್ಥೆ ಇದೆ:

೧) ಇಂಧನವು ಸಣ್ಣಸಣ್ಣ ಗೋಲಿಗಳ ರೂಪದಲ್ಲಿ ರುತ್ತದೆ. ಹಾಗಾಗಿ ಅದರಲ್ಲಿ ಉತ್ಪತ್ತಿ ಯಾಗುವ ವಿಕಿರಣ ಧಾತುಗಳು ಅದರಲ್ಲೇ ಬಂಧಿತವಾಗುತ್ತವೆ.

೨) ಇಂಧನ ಗೋಲಿಗಳನ್ನು ಜ಼ಿರ್ಕೋನಿಯಮ್ ಅಥವಾ ಸ್ಟೈನ್‌ಲೆಸ್ ಸ್ಟೀಲ್ ಕೊಳವೆಗಳ ಲ್ಲಿಟ್ಟು ಭದ್ರಪಡಿಸಲಾಗಿರುತ್ತದೆ. ಇದು ಎರಡನೇ ಹಂತದ ಪ್ರತಿಬಂಧ.

೩) ಅನೇಕ ಇಂಧನ ಸರಳುಗಳನ್ನು ಉಕ್ಕಿನ ಕೊಳವೆಯಲ್ಲಿಟ್ಟು ಅವುಗಳ ಮೂಲಕ ಕೇವಲ ತಂಪುಕಾರಿ ಮಾತ್ರ ಸಂಪರ್ಕ ವಾಗುವಂತೆ ವಿನ್ಯಾಸ ಮಾಡಲಾ ಗಿರುತ್ತದೆ. ಇದು ಮೂರನೇ ಹಂತದ ಪ್ರತಿಬಂಧ. ವಿಕಿರಣ ಧಾತುಗಳು ಇಂಧನ ಸಂಕೀರ್ಣ ತೆಯಿಂದ ಹೊರಬರಬೇಕಾದರೆ ಈ ಪ್ರತಿಬಂಧ ಗಳನ್ನೂ ಭೇದಿಸಬೇಕಾಗುತ್ತದೆ.

೪) ಕೊನೆಯ ಹಂತದಲ್ಲಿ ರಿಯಾಕ್ಟರ್‌ಸುತ್ತ ಎರಡು ಪದರಗಳ ಒಂದು ಬೃಹತ್ ಆವರಣ ಇರುತ್ತದೆ. ವಿಶೇಷ ಕಾಂಕ್ರೀಟಿನಿಂದ ರಚಿಸಲ್ಪಟ್ಟ ಈ ಕಟ್ಟಡಕ್ಕೆ, ಅಪಘಾತದಲ್ಲಿ ಇಂಧನ ಕರಗಿ, ವಿಕಿರಣ ದ್ರವ್ಯ ಇಂಧನ ದಿಂದ ಹೊರಬಂದರೆ ಅದು ಪರಿಸರವನ್ನು ಸೇರ ದಂತೆ ತಡೆಯುವ ಸಾಮರ್ಥ್ಯವಿರುತ್ತದೆ. ಅಲ್ಲದೇ ತುರ್ತು ಪರಿಸ್ಥಿತಿಯಲ್ಲಿ ಕಟ್ಟಡದ ಒಳಗಿನ ಒತ್ತಡವನ್ನು ಕಡಿಮೆ ಮಾಡಲು ತಂಪುಕಾರಿಯನ್ನು ಚುಮುಕಿಸುವ ವ್ಯವಸ್ಥೆ ಯನ್ನೂ ಅಳವಡಿಸಿರಲಾಗುತ್ತದೆ.



ಅಪಘಾತ ಪರಿಸ್ಥಿತಿ ಕೈ ಮೀರದಂತೆ ತಡೆಗಟ್ಟಲು ಐದು ಪ್ರತಿಬಂಧಕಗಳು

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radiation. There is more known to us about radiation and its effects than about many other common pollutants, which are carcinogenic and cause mutations. Radiation has always been present in the environment and like everything else around us is harmful if the exposures are excessive. But radiation, like fire, can be handled safely. The design of the reactors is such they can never explode like a nuclear weapon and the chance of an accident is extremely unlikely. Yet there is a comprehensive emergency preparedness plan to handle such event should the need arise.

As far as the perceived higher cost of nuclear power, Nuclear power is cost competitive with other forms of electricity generation. Fuel costs for nuclear plants are a minor proportion of total generating costs, though capital costs are greater than those for coal-fired plants. While assessing the cost of nuclear energy, costs for spent fuel management, decommissioning and waste disposal are taken into account. These costs, while usually external for other technologies, are very much internal for nuclear power. A 2005 OECD study showed that nuclear power had increased its competitiveness over the previous seven years. The principal changes since 1998 were, increased nuclear plant capacity factors and rising gas prices. The study did not factor in any costs for carbon emissions from fossil fuel generators.

6.0 Concluding Remarks

The electricity generation capacity in India has to be increased atleast to the world average per capita level of 2500 kWh for a decent living standard. Coal and nuclear energy are the only resources to meet the objective. Coal for another 70 years? Coal is a much-needed precious material for other industries too, especially steel industries and it is wrong to deplete its sources for production of electricity alone. Also, we have to keep something for our future generations too. The Planning Commission document on energy assumes import of coal to fuel to a third of the coal based generation of electricity over the next three or four decades; that would be a great blow to energy security. Besides, there would be definite pressure internationally to cut carbon emission. Renewable resources will take a long time for development to become a viable resource on a larger scale. However, deployment of these, wherever possible, should be implemented. Nuclear energy especially from Fast Breeder Reactors can play a major role in providing energy security with negligible levels of radioactivity releases.

It is impossible to speak of a world with zero risk. All the electricity generating systems involve certain amount of risk. Nuclear energy is no more risky than other electricity generation systems; if anything, it is significantly less. However, it has a serious problem – problem of public perception.

The increased dependence on energy in current life styles calls for exploitation of every feasible resource. Nuclear power plants offer an option with the least possible impact on the environment. Because they obviate increase of CO_2 levels in the atmosphere and global warming through green house effect; because they avoid discharge of SO_2 and acid rain; because they require relatively small areas of land and allow trees to grow unhindered in their neighbourhood. It is an option that deserves deepest consideration.

Radiation Effects and Nuclear Power Production

Dr. D.V. Gopinath after graduation in Physics from University of Mysore joined the Atomic Energy Establishment, Trombay in 1955 and obtained his Ph.D in the area of radiation physics. He led a strong theoretical group working on nuclear and radiological safety of nuclear facilities. His seminal work on the transport of gamma rays in bulk media had received international acclaim.

Later he moved to Indira Gandhi centre for Atomic Research in Kalpakkam and established the Safety Research Laboratory, the first of its kind in the world back in 1975, and contributed significantly to the successful commissioning of Fast Breeder Test Reactor. He, along with his group, evolved an elaborate and comprehensive Radiation Emergency Plan for Kalpakkam facilities which became a model for all the DAE installations. He returned to Bhabha Atomic Research Centre, Trombay as Director Health, Safety and Environment Group and Bio-Medical Group. He was chairman of several committees related to the safety and environment. He has been an accredited guide for doctoral programme in many universities and has more than 90 research publications to his credit. He was Chairman of the National Safety Council Committee on Management of Cyclone Emergencies in Industries. After his retirement from DAE in 1993, he held Sir. M.Visveswaraiah Chair at University of Mysore and later L&T chair at IITB, Mumbai. He was the Founder secretary and later president of Indian Society for Radiation Physics. Currently he is heading "Energy & Environment "which provides consultancy services to industries on issues related to energy conservation and environmental protection.

✍ D. V. Gopinath
(Energy and Environment, Mysore)

1. Introduction

Nuclear energy as a source of electric power has had a promising start; it promised an unlimited, safe and environmentally benign source of energy. It opened up a most promising future for the developed as well as developing countries and assured that they will never be halted in their industrial development by lack of sufficient power. But over the decades, nuclear energy started facing a unique and essentially non-technical problem; a problem of perception. On the one hand, claims continue to prevail that it can provide an unlimited source of energy to meet the ever-growing demands of power with minimum risk to the operating personnel, general public and the environment. On the other, there has also been a view, rather vocal at that, that it is environmentally disastrous and endangers the health of not only the operating personnel and the public of the present generation, but those of our progeny too. Notwithstanding such reservations and discordance in perceptions, presently there are 433 nuclear power reactors operating with an installed capacity of about 366,600 MWe, distributed over 30 countries and meeting about 16% of the world's electricity requirement. Besides, 65 power reactors are under construction.

There has been ever-growing demand for electricity particularly in the developing countries. World's fossil sources of energy, the main stay for the present electricity generation, are only finite and their geographical distribution is highly skewed leading to the concern about energy security for several countries. Besides, there is also the fear that uncontrolled utilization of fossil fuels would disturb the CO_2 balance in the atmosphere with disastrous consequences on the environment. In spite of the strong accent on the development of new and renewable sources of energy, they appear to be only a useful supplement but not a substitute for central electricity generation in the foreseeable future. Owing to these reasons there has been a strong rethinking on our energy options and rediscovery of nuclear energy as a viable and environmentally benign option. In the light of this, nuclear power programme was getting revived in several countries where it had been stopped or slowed down. India too, because of its compulsions to meet the power requirements of its galloping industrial progress and also to ensure energy security, embarked on an ambitious expansion of its nuclear power programme. It is at this stage that the incident at Fukushima nuclear power plant in Japan has occurred, creating considerable concern amongst the public. The present paper addresses such concerns and reservations; to what extent they are fact and experience based and to what extent they have come about because of our perceptions and assumptions.

Since all the public concern about nuclear energy has been essentially due to the very large quantities of radioactivity and the associated ionising radiation, it may be in order to provide a brief description of radiation, its effects and its role in nuclear power production.

2. Radiation and its Effects

2.1 Radiation Exposures

Some elements in nature spontaneously disintegrate emitting high energy radiations known as Alpha (α), Beta (β) and Gamma (γ) rays. This phenomenon is known as 'Radioactivity'. The radiations so emitted, while passing through matter, can knock out electrons from the neutral atoms or molecules. This process, which results in free electrons and electron-deficient atoms or molecules called 'Positive ions', is known as Ionisation and the radiations themselves are called ionising radiations. In the process of ionisation, the radiations deposit a part of their energy into the matter and it is this energy which is responsible for all the radiation effects. Quantitatively speaking, exposure to ionising radiation is reckoned in terms of the amount of energy imparted by the radiation to the material through which it is passing. It is termed as Radiation dose and expressed in "GRAY". One GRAY (Gy) corresponds to the deposition of 1 Joule of energy in 1 Kg of the exposed material. It is well established that for the same amount of energy deposited, different types of ionising radiation can induce varying degrees of biological effects. To account for this feature, while talking about radiation dose to the living systems, Gy is multiplied by the radiation-type-dependent "Quality Factor" and resulting quantity is expressed in Sieverts (Sv). For gamma radiation, which is of widest concern, 'Quality Factor' is unity and hence Gy and Sv are synonymously used. As the magnitudes of Gy and Sv are very large compared to the exposures normally encountered, their sub-units, milli Gray (mGy=10^{-3} Gy), micro Gray (μGy=10^{-6}Gy), milli Sievert (mSv=10^{-3} Sv) and micro Sievert (μSv=10^{-6}Sv) are frequently employed. There are two other quantities which are frequently referred while dealing with radiation effects, cumulative dose and collective dose. A person may receive different radiation doses at different times. The sum of all such doses is the 'Cumulative dose' for the individual. Similarly in a society different persons may receive different doses. Sum of all such personal doses is denoted as 'Collective dose' for the society and its unit is person-Sievert. (p-Sv). The relevance of these quantities would be clear in the sequel.

For living systems the radiation exposure can occur in two different ways. In the first case, the source of radiation is external to the body. Radiation emanating from the source impinges on the body and deposits energy therein. This is called External Exposure and it ceases to occur with the removal of the source or when the source is well shielded. The other mode of exposure arises when a living being breathes air contaminated with radioactivity or ingests contaminated water or food materials. Part of the activity thus entering the body gets deposited in different organs depending on the chemical nature of the radioactive substance. It persists there over a period of time, of course in a diminishing measure, depending on its radioactive half-life and biological removal rate. Throughout this period the body gets exposed to the radiation and this is called Internal Exposure. In computing the radiation dose for internal exposure, one has to take into account the total energy deposition that is likely to occur over the entire period. This is known as the 'Committed' dose.

2.2. Radiation Effects

Biological effects of radiation are of two types, deterministic and probabilistic. Deterministic effects result from massive cell-killing due to acute radiation exposure that is associated with severe radiation accidents or medical treatment. These effects are characterized by their appearance within a few hours to few weeks after the exposure and they have a threshold. That is, the effects manifest only if the radiation dose received is above a certain minimum level. The deterministic effects are generally confined to the operating personnel and do not involve public. Hence they have not generated much public concern. The second class of effects, called probabilistic or stochastic effects, arise out of the 'mutagenic' action of ionising radiation. In a biological cell the 'Deoxyribonucleic acid (DNA)', a macromolecule residing inside the nucleus, is the repository of all the information required for the cell functioning and its replication. The information in DNA is written in the form of a long sequence of certain chemical species called nucleotides. Ionising radiation can alter this sequence, either directly or indirectly interacting with DNA and such an alteration is called mutation. If the mutation occurs in a germinal cell, it may be carried on to the progeny leading to genetic effects and if it is in a non-germinal cell, it may result in the loss of control over cell replication leading to cancer induction. The mutational effect is supposed to be cumulative over all the exposures for an individual, and over all the individuals for a community (hence the relevance of cumulative and collective doses mentioned earlier). Because of the high redundancy in the biological information and resilience of the biological systems, not every mutation will necessarily lead to detrimental effects. Hence it is dealt in terms of probabilities and risk coefficient/factors. Simply put, risk coefficient is the number of defects likely to be introduced into the community due to unit collective dose. **Based on Life Span Studies (LSS) of Hiroshima-Nagasaki survivors, the risk factor has been evaluated as 5 x 10^{-2} per Sievert for cancer induction and 1 x 10^{-2} per Sievert for genetic effect.** A very crucial assumption made here is that the detriment is linearly proportional to the total exposure and that there is no threshold for this effect to manifest. That is, unlike the deterministic effects which do not occur below a particular radiation exposure, however small the exposure is the risk of stochastic effects exists. It is linearly proportional to the exposure and it is cumulative. This is called 'Linear No Threshold (LNT)' model. Despite the existence of a large amount of experimental as well as epidemiological data on low level exposures contradicting this assumption, it is made only 'to be on the safe side'. Unfortunately, this 'to be on the safe side' assumption has resulted in undue scare in the minds of public.

3. Radiation and Nuclear power

3.1 Sources of radiation exposure in nuclear power generation

Naturally occurring heavy element uranium has two major isotopes, uranium-235 and uranium-238. When uranium is exposed to neutrons (a fundamental particle and constituent of the atom) some of the uranium-235 nuclei absorb neutrons and break up into two fragments. This process is called fission and the fragments, which are highly radioactive, are called fission products. The fissioning process also releases a very large quantity of energy, 2-3 neutrons and high energy radiation such as gamma rays. Nuclear reactor is a configuration including uranium where one of the 2-3 neutrons produced in each fission is used up to result in the next generation of fission and thus maintain a 'chain reaction' of fissions. It is the large energy produced during this chain reaction that is used to generate electricity. Obviously, as the energy is being produced, fission products also build up resulting to gigantic quantities of radioactivity accumulated in the power reactors. Radiation emitted by the built-up fission products as well as fields due to γ rays and neutrons produced during fission result in very high radiation fields inside the reactor 'Core'. While utilizing the energy released during fission for our benefit, it is necessary to make arrangements for protecting the operating personnel from these intense radiation fields. It is also necessary to ensure that the radioactivity due to fission products are well contained so that no harm occurs due to them either to the operating personnel or to the general public during normal as well as abnormal conditions. This forms the essential theme for nuclear safety.

Not withstanding all the safety provisions in the design, construction, commissioning and operation of nuclear power reactors, radiation exposures, however small they are, can not be totally ruled out during normal operation. Further, with all the safety provisions, it may be possible to bring down the accident probabilities to very low levels but one can not totally rule out accidents. As such, acceptance criteria for nuclear energy have to be essentially based on experience with respect to radiation exposures during normal and abnormal situations. Further, obtaining electricity from nuclear energy involves not only reactor operation but mining and milling of uranium ore, fuel fabrication and reprocessing etc. All these operations together are termed as Nuclear fuel cycle. Hence one has to consider the radiation exposures not only during the power plant operation but from the entire nuclear fuel cycle and that is discussed below.

3. 2 Normal Operations

Radiation exposures during normal operations are to be considered in two parts; i) exposures to occupational workers and ii) exposures to general public. Governing principle for control of exposure in both the cases is that the collective exposure should be kept as low as possible (ALARA) and in any case the individual dose should not exceed 20 mSv/yr for the occupational worker and 1 mSv/yr for the general public, the limits set by the International Commission on Radiological Protection (ICRP). Control on the collective exposure would be seen in the normalised collective dose for the station, expressed as person-Sieverts per Gigawatt year (p-Sv/GWa). The United Nations Scientific Committee on the Effect of Atomic Radiations (UNSCEAR) has been collecting and analysing all such data almost from the very beginning of nuclear technology and presenting it to the United Nations General Assembly in its periodic reports. Extracted from its 2008 report, trends in the average individual dose and the normalised collective dose from the entire nuclear fuel cycle during the period 1975 to 2002 for all the world reactors are given in Table 1,

Table1. Average Individual and normalised collective Radiation doses to the occupational workers and the public due to Nuclear Fuel Cycle

Period	1975 - 1979	1980 - 1984	1985 - 1989	1990- 1994	1995- 1997	1997- 2002
Average Individual dose (mSv/yr)	4.4	3.7	2.6	1.6	1.4	1.0
Normalised Collective dose to the workers (p-Sv/GWa)	20	18	12	9.8	1.0	1.0
Normalised Collective dose to the Public (p-Sv/GWa)	12	3.1	0.97	0.92	0.91	0.72

As can be seen from the Table, for the period 1997-2002 the average individual exposure for the occupational worker is 1 mSv/yr which is far below the ICRP limit of 20 mSv/yr. Normalised annual collective dose has been 1 p-Sv/GWa for the workers and 0.72 p-Sv/GWa for the public in 1997-2002. Furthermore, there is strong decreasing trend in the individual and collective exposures highlighting the emphasis laid on radiological safety in nuclear industry. **With this collective dose and with the presently accepted risk coefficients for radiation exposure as $5x10^{-2}$/Sv for cancer induction and $1x10^{-2}$/Sv for genetic effects mentioned earlier, the probable cancer incidences and genetic abnormalities amongst the occupational workers are negligibly small at about 0.1 and 0.02 respectively per GWa of electricity generation.**

3.3 Reactor Accidents

There have been three major accidents in nuclear power reactors- Three Mile Island (TMI) in 1979 in USA, Chernobyl in 1986 in former USSR and Fukushima - Daiichi, very recently in Japan. What follows is a brief description of these accidents, particularly their radiological aspects.

Three Mile Island

Three Mile Island Nuclear Generating Station (TMI) is located on the Three Mile Island in Pennsylvania, USA. It had two separate power reactors, known as TMI-1 and TMI-2. On March 28, 1979, there was a cooling system failure in TMI-2 that caused a partial melt-down of the reactor core. This resulted in the release of a significant amount of radioactivity in to the containment building but the containment held the radio-activity with very little release to the environment. Initially there was a lot of public anxiety and about 200 000 people voluntarily moved out of station surroundings but returned shortly afterwards. The accident caused concerns about the possibility of radiation-induced health effects, principally cancer, in the area surrounding the plant. Because of those concerns, the Pennsylvania Department of Health maintained, for 18 years, a registry of more than 30,000 people who lived within five miles of Three Mile Island at the time of the accident. The state's registry was discontinued in mid 1997, without any evidence of unusual health trends in the area. Indeed, more than a dozen major, independent health studies of the accident showed no evidence of any abnormal number of cancers around TMI years after the accident. The only detectable effect was psychological stress during and shortly after the accident. The studies found that the radiation releases during the accident were minimal, well below any levels that have been associated with health effects from radiation exposure.

Chernobyl

The largest ever nuclear reactor accident occurred at the Chernobyl nuclear power plant on 26 April 1986. The Chernobyl Power Complex, lying about 130 km north of Kiev, Ukraine, and about 20 km south of the border with Belarus, consisted of four nuclear reactors of the unique Russian design (called RBMK-1000). Two more reactors were under construction at the site at the time of the accident. The accident occurred during a low power engineering test of the Unit 4 reactor. Improper, unstable operation of the reactor allowed an uncontrollable power surge to occur, resulting in successive steam explosions that severely damaged the reactor building and completely destroyed the reactor. There was a gigantic release of radioactivity from the damaged reactor over a 10 day period, with varying release rates. The activity release contaminated large areas (approximately 150,000 km2) in Belarus, the Russian Federation and Ukraine resulting in the evacuation of about 300000people. Outside the former Soviet Union, there were many areas in Western Europe with a low deposition density of radioactivity. These regions represent an area of 45,000 km2.

The accident resulted in the death of 30 operators and firemen within three months. One person was killed immediately and a second died in hospital soon after as a result of injuries received. Another person is reported to have died from coronary thrombosis. Acute radiation syndrome (ARS) was originally diagnosed in 237 people on-site and involved with the clean-up operations. It was later confirmed only in 134 cases. Of these, apart from the 30 deaths mentioned earlier, nineteen persons died subsequently between 1987 and 2004 but their deaths cannot necessarily be attributed to radiation exposure. Nobody off-site suffered from acute radiation effects. However, a large proportion of childhood thyroid cancers diagnosed since the accident is likely to be due to intake of radioactive iodine fallout. There were in all about 6000 such cases, out of which there were only 15 fatalities since thyroid cancer is eminently curable. Apart from the above, there is no evidence of a major public health impact related to ionizing radiation due to the Chernobyl accident. In the 1986-analysis of the accident more than 4000 cases of solid cancer and leukemia were predicted with in 20 years. However, no increases in overall cancer incidence or mortality that could be associated with radiation exposure have been observed so far. The risk of leukemia, one of the most sensitive indicators of radiation exposure, has not been found to be elevated even in the accident recovery operation workers or in children. There is no evidence of any increase in other non-malignant disorders related to ionizing radiation. The gross difference between the prediction and observation of cancer incidence in the Chernobyl accident appears to be a direct consequence of ultra conservative assumptions such as LNT in our risk analysis.

In the words of Professor Zbigniew Jaworowski, an eminent Radiation Scientist from Poland and former Chairman of UNSCEAR, about Chernobyl accident, "This was the worst possible catastrophe of a badly constructed nuclear reactor, with a complete meltdown of the reactor core, followed by the ten -day's long completely free emission of radio nuclides into the atmosphere. Nothing worse could happen. It resulted in a comparatively small occupational death toll, amounting to about half of that of each weekend's traffic in Poland, and tens or hundreds of times lower than that of many other industrial catastrophes and it is unlikely that any fatalities were caused by radiation among the public. In the centuries to come, the Chernobyl catastrophe will be seen as a proof that nuclear power is a safe means of energy production".

Environmental damage was widespread immediately following the accident, affecting the fauna and vegetation in the 30-kilometer zone around Chernobyl (called Exclusion Zone). The extent of the damage led scientists and government officials to believe that the Chernobyl exclusion zone had been subjected to enough radioactive fallout to severely alter the ecological balance of the region for decades. However, many studies conducted over the past 20 years have shown that the initial assessment could not have been farther from the truth as wildlife abounds even in the most affected areas of Chernobyl. In the 20 years since the accident, the sum effect for the flora and fauna in the highly radioactive, restricted, zone has been overwhelmingly positive in favor of biodiversity and abundance of individuals. While exposure to high levels of radiation could have discernible, negative impacts on plant and animal life in the initial stages, the benefit of excluding humans from this highly contaminated ecosystem appears to far outweigh any negative cost associated with Chernobyl radiation and the region now is considered as a sanctuary for biodiversity.

Fukushima

The Fukushima I Nuclear Power Plant, also known as Fukushima Dai-ichi (dai-ichi means "number one") is located in the Fukushima Prefecture on the east coast of Japan. First commissioned in 1971, the plant consisted of six power reactors with a combined capacity of 4.7 GWe. On 11 March 2011, at 14:46 Japan Standard Time (JST), an earthquake of magnitude 9 occurred off the northeast coast of Japan. At the time of the quake, Reactor 4 had been de-fuelled while 5 and 6 were in shutdown condition for planned maintenance. The remaining reactors shut down automatically after the earthquake with emergency generators starting up to run the control electronics and water pumps needed to cool reactors. Within about an hour, a 15 m high tsunami wave of doomsday proportions flooded the entire plant including low-lying generators, electrical switchgear in reactor basements and external pumps intended for supplying cooling seawater. The connection to the electrical grid had been broken as the Tsunami had destroyed the power lines. All power for cooling was lost and reactors started to overheat due to the decay heat from the fission products created before shutdown. Over the following three weeks there was evidence of partial fuel meltdown in units 1, 2 and 3. Fuel over-heating also led to the interaction of the clad material Zircaloy with steam resulting in hydrogen production. There were visible explosions caused by hydrogen gas in units 1 and 3 and an explosion in unit 2 might have damaged the primary containment vessel.

Radioactivity got released from the Fukushima as a result of deliberate venting of containment vessels and deliberate discharge of coolant water into the sea to reduce the pressure in the containment. The total activity thus released has been estimated to be about 10 % of that of Chernobyl accident but a large part of the activity released found its way to the Pacific Ocean. There had been release of radioactivity to the atmosphere also, contaminating the surroundings and resulting in the evacuation of about 100000 persons. Trace amounts of radioactivity, of no radiological consequence, has been observed in several places within and outside Japan. An assessment of the 8300 workers and emergency personnel who were involved in responding to the incident has revealed that 88 personnel have received radiation doses between 100 and 150 mSv, 14 have received between 150 and 200 mSv, 3 have received between 200 and 250 mSv, and 6 have received about 350 mSv. Radiation exposure of the public due to the accident has been insignificant. Presently the damaged reactors are in a stable condition without any leakage of radioactivity. Extensive work is going on to asses the radiological effects of the accident and planning of resettlement of the evacuated people.

Considering the Chernobyl experience and noting that the total activity release was only about 10 % of that of Chernobyl, a large part of which has found its way to the Pacific Ocean, any adverse health effect either on the workers or population seems to be highly unlikely. It was reported that due to the tsunami event about 15000 persons died and 10000 missing but not even single one of them was due to radiation exposure. However, the psychological impact of the accident has been very high and as in the case of Chernobyl it appears that a large part of the public scare is due to ultra conservative assumptions in our risk estimates.

4. Risk Comparison

From the above account it is seen that not withstanding all the safety precautions taken in the generation of electricity from nuclear energy, accidents have taken place and fatalities have occurred. However, it must be recognized that no technological option of generating electricity, whether it is coal, oil or hydel based, is free from risks. The risk could be accident related or could be due to normal operations. In order to obtain an optimum choice or an optimum mix of options for the much needed electricity generation, it is necessary to make comparative analysis of the risks involved in the different options we have. A possible indicator for the health-related risk is the additional normalised fatalities (fatalities per unit power generated) in each technology. Based on the large data available, accident-related risk coefficients have been evolved for the different electricity generating options and they are given in Table 2. As can be seen in the table, the coal option has maximum risk and the nuclear option has the least.

Table 2. Worldwide Severe Accidents, Aggregate Fatalities and Normalized Fatalities for all Energy Options during 1969-2000

Energy Chain	No. of Accidents	Total Fatalities	Normalised Fatalities (per GWa)
Coal-global	1221	25107	0.876
- China excluded	177	7090	0.690
Oil	397	20283	0.436
Natural Gas	125	1978	0.093
Hydro	11	299	4.265
*Hydro 10 -2 10	10	38	0.561
Nuclear	1	65**	0.006

*** Excluding the Banqio / Shimantan dam burst (in China) which resulted in 26000 fatalities.**
**** Including late fatalities**

A major problem in evaluating the risk in the nuclear option is that it has tended to be largely subjective. Detrimental effects of radiation, carcinogenic or genetic, are delayed and only incremental over a large natural incidence. This has given rise to a problem of perception; the perception of the experts and the public, at least a section of them, has a large variance. This has heightened the concern in the minds of public. The real focus in the case of nuclear energy now should be on an intense and objective public awareness programme.

ಕೆಲವು ಪ್ರಮುಖ ಬೈಜಿಕ ಅಪಘಾತಗಳು: ಒಂದು ಪಕ್ಷಿನೋಟ

ಬೈಜಿಕ ವಿದ್ಯುತ್ ಸ್ಥಾವರಗಳು ತಾಂತ್ರಿಕತೆಯ ದೃಷ್ಟಿಯಿಂದ ಅತ್ಯಂತ ಸಂಕೀರ್ಣ ವ್ಯವಸ್ಥೆಗಳು. ಅಲ್ಲಿ ನಡೆಯುವ ಕೆಲವು ವಿದ್ಯಮಾನಗಳು ಕೇವಲ ಮಿಲಿ ಸೆಕಂಡ್‌ಗಳಲ್ಲಿ ಕೈ ಮೀರಿ ಹೋಗ ಬಹುದು. ಹಾಗಾಗಿ ಸುರಕ್ಷತೆಯ ಬಗ್ಗೆ ಎಷ್ಟೇ ನಿಗಾ ವಹಿಸಿದರೂ ಅನಿರೀಕ್ಷಿತ ಘಟನೆಗಳು ಸಂಭವಿಸುವ ಸಾಧ್ಯತೆ ಇದ್ದೇ ಇರುತ್ತದೆ; ಸಂಭವಿಸಿವೆ. ಅವುಗಳಲ್ಲಿ ಕೆಲವು ಪ್ರಮುಖ ವಾದವುಗಳನ್ನು ಪರಿಶೀಲಿಸೋಣ.

ಡಿಸೆಂಬರ್ ೧೨, ೧೯೫೨. ಕೆನಡಾದ ಚಾಕ್‌ರಿವರ್ ಬೈಜಿಕ ಕ್ರಿಯಾಕಾರಿಯಲ್ಲಿ ಕೆಲಸಗಾರನೊಬ್ಬ ಅಜಾಗರೂಕತೆಯಿಂದ ತಂಪು ಕಾರಿಯ ಕವಾಟವನ್ನು ಮುಚ್ಚಿಬಿಟ್ಟನು. ಆ ತಪ್ಪನ್ನು ಗಮನಿಸಿ ನಿಯಂತಣ ಸರಳುಗಳನ್ನು ಇಳಿಸು ವುದರೊಳಗೇ ತಾಪ ಏರಿ, ಇಂಧನ ಕರಗಿತು. ಕೂಡಲೇ ಅದು ನೀರಿನೊಂದಿಗೆ ಪ್ರತಿಕ್ರಿಯಿಸಿ ಜಲಜನಕ ಉತ್ಪತ್ತಿಯಾಗಿ ಸ್ಫೋಟಗೊಂಡಿತು. ಆದರೆ, ಇತರ ಸುರಕ್ಷಾ ಸಾಧನಗಳು ಕಾರ್ಯಶೀಲ ವಾಗಿದ್ದುದರಿಂದ ಪರಿಸರಕ್ಕೆ ವಿಕಿರಣ ಧಾತು ಬಿಡುಗಡೆಯಾಗಲಿಲ್ಲ. ಬೈಜಿಕ ಇತಿಹಾಸ ದಲ್ಲಿ ಇದು ಮೊದಲನೇ ಘಟನೆ ಎಂದು ದಾಖಲಾಗಿದೆ. ಅಂದಿನಿಂದ ಇಂದಿನ ವರೆಗೆ ವಿಶ್ವದಾದ್ಯಂತ ಬೈಜಿಕ ಘಟಕಗಳಲ್ಲಿ ನೂರಾರು ಘಟನೆಗಳು ಸಂಭವಿಸಿವೆ. ಆದರೆ ಸುರಕ್ಷತೆಯ ದೃಷ್ಟಿಯಿಂದ ಹೆಚ್ಚಿನವು ಕ್ಷುಲ್ಲಕ. ಮೂರು ಘಟನೆಗಳು ಮಾತ್ರ ಅಪಘಾತವೆಂದು ಪರಿಗಣಿಸಲ್ಪಡುತ್ತವೆ.

ಅದರಲ್ಲಿ ಮೊದಲನೇ ಅಪಘಾತ ೧೯೫೭ರಲ್ಲಿ ಬ್ರಿಟನ್ನಿನ ವಿಂಡ್‌ಸ್ಕೇಲ್ ಬೈಜಿಕ ಕ್ರಿಯಾಕಾರಿಯಲ್ಲಿ (Windscale reactor) ಸಂಭವಿಸಿತು. ರಿಯಾಕ್ಟರ್‌ನ ಗ್ರಾಫೈಟ್ ಮಂದಕದ ನಿರ್ವಹಣೆಯಲ್ಲಿ ಕೆಲಸಗಾರರು ರೂಢಿಯನ್ನು ಉಲ್ಲಂಘಿಸಿದುದರಿಂದ ಅದು ಉರಿದು, ಇಂಧನ ಕರಗಿ, ಸುಮಾರು ೨೦ ಚದುರ ಮೈಲಿ ಪ್ರದೇಶದಲ್ಲಿ ವಿಕಿರಣ ಹರಡಿತು. ಅದರಿಂದ ಮಾನವನಿಗೆ ಹಾನಿಯುಂಟಾಗದಿದ್ದರೂ, ಪರಿಸರಕ್ಕೆ ಧಕ್ಕೆಯಾಯಿತು. ಆ ಪ್ರದೇಶದಲ್ಲಿ ಉತ್ಪಾದಿಸಿದ ಹಾಲು, ಮಾಂಸ, ತರಕಾರಿ, ಹಣ್ಣುಗಳು ವಿಕಿರಣ ಧಾತುಗಳಿಂದ ಕಲುಷಿತವಾದವು. ಹಾಗಾಗಿ ಅವುಗಳನ್ನು ಬಹು ಕಾಲದವರೆಗೆ ತಿರಸ್ಕರಿಸಬೇಕಾಯಿತು.

ಮಾರ್ಚ್ ೨೮, ೧೯೭೯ರಂದು ಅಮೆರಿಕದ ತ್ರೀ ಮೈಲ್ ಐಲೆಂಡ್‌ನ (**Three Mile Island**) ಕ್ರಿಯಾ ಕಾರಿಯೊಂದರಲ್ಲಿ ಸಲಕರಣೆಗಳ ವೈಫಲ್ಯ, ಕೆಲಸಗಾರರ ತಪ್ಪು ಹಾಗೂ ಕೆಲವು ಅನಿರೀಕ್ಷಿತ ಘಟನೆಗಳಿಂದಾಗಿ ತಂಪುಕಾರಿಯಲ್ಲಿ ಲೋಪ ಉಂಟಾಯಿತು. ಇಂಧನದ ಸ್ವಲ್ಪ ಭಾಗ ಕರಗಿ, ಜಲಜನಕ ಉತ್ಪತ್ತಿಯಾಗಿ ಸ್ಫೋಟ ವಾಯಿತು. ಸ್ಫೋಟ ದುರ್ಬಲವಾಗಿದ್ದುದರಿಂದ ಕಟ್ಟಡಕ್ಕೆ ಯಾವ ಹಾನಿಯೂ ಆಗಲಿಲ್ಲ. ಆದರೆ, ತಂಪುಕಾರಿ ನೀರು ವಿಕಿರಣ ಧಾತುಗಳಿಂದ ಕಲುಷಿತಗೊಂಡಿತ್ತು. ಸುಮಾರು ೪೦,೦೦೦ ಗ್ಯಾಲನ್ ನೀರನ್ನು ಹತ್ತಿರದ ನದಿಗೆ ಬಿಡಬೇಕಾಯಿತು. ಅಲ್ಲದೇ ಅಧಿಕ ಮಟ್ಟದಲ್ಲಿ ಕಲುಷಿತಗೊಂಡಿದ್ದ ೨೫೦,೦೦೦ ಗ್ಯಾಲನ್ ನೀರನ್ನು ಸಂಗ್ರಹಿಸಿಡಬೇಕಾಯಿತು. ಆ ಅಪಘಾತದಲ್ಲಿ ಕೆಲಸಗಾರರಿಗಾಗಲೀ, ಸಾರ್ವಜನಿಕರಿಗಾಗಲೀ ಹೆಚ್ಚಿನ ವಿಕಿರಣ ತಾಡನೆ

ಎಂ.ಎಸ್.ಎಸ್.ಮೂರ್ತಿ

ಆಗದಿದ್ದರೂ ಅವರಲ್ಲಿ ತೀವ್ರ ಗಾಬರಿಗೆ ಎಡೆ ಮಾಡಿತು. ರಿಯಾಕ್ಟರ್‌ನಿಂದ ೫ ಮೈಲಿ ವ್ಯಾಸದಲ್ಲಿದ್ದ ಗರ್ಭಿಣಿಯರು ಹಾಗೂ ಎಳೆ ಮಕ್ಕಳನ್ನು ತಾತ್ಕಾಲಿಕವಾಗಿ ಸ್ಥಳಾಂತರಿಸ ಬೇಕಾಯಿತು. ಶಾಲಾ ಕಾಲೇಜುಗಳು ಮುಚ್ಚಿದವು. ಅಪಘಾತದಲ್ಲಿ ಪ್ರಾಣ ಹಾನಿಯಾಗದಿದ್ದರೂ, ಬೈಜಿಕ ಸ್ಥಾವರದಲ್ಲಿ ಅಪಘಾತ ಸಂಭವಿಸಿದರೆ ಎಂತಹ ಘೋರ ಪರಿಣಾಮ ಗಳಾಗಬಹುದು ಎಂಬುದರ ಬಗ್ಗೆ ಖಚಿತ ಚಿತ್ರ ದೊರಕಿತು.

ಅಂತಹ ಘೋರ ಪರಿಣಾಮಗಳು ಏಪ್ರಿಲ್ ೨೬, ೧೯೮೬ರಂದು ಅಂದಿನ ಸೋವಿಯತ್ ಒಕ್ಕೂಟದ ಚೆರ್ನೊಬಿಲ್ ಕ್ರಿಯಾಕಾರಿ (Chernobyl reactor) ಅಪಘಾತದಲ್ಲಿ ಪ್ರತ್ಯಕ್ಷವಾದವು. ಚೆರ್ನೊ ಬಿಲ್ ಕ್ಷೇತ್ರದಲ್ಲಿ ೧೦೦೦ ಮೆಗಾವಾಟ್ ವಿದ್ಯುತ್ ಉತ್ಪಾದಿಸುವ ನಾಲ್ಕು ಘಟಕಗಳಿದ್ದವು. ನಾಲ್ಕನೇ ಘಟಕದಲ್ಲಿ ಕೆಲವು ಪ್ರಯೋಗಗಳನ್ನು ನಡೆಸಲು ತಯಾರಿ ನಡೆಯುತ್ತಿತ್ತು. ಆದರೆ, ಆ ಸಂದರ್ಭದಲ್ಲಿ ನೌಕರರು ಸುರಕ್ಷತಾ ನಿಯಮಗಳನ್ನು ನಿರ್ಲಕ್ಷಿಸಿ, ಪ್ರಯೋಗದ ಅಂಗವಾಗಿ ಕೆಲವು ನಿಯಂತ್ರಣ ಸರಳುಗಳನ್ನು ಹೊರತೆಗೆದರು. ತಂಪುಕಾರಿ ಪಂಪುಗಳನ್ನು ನಿಷ್ಕ್ರಿಯಗೊಳಿಸಿದರು. ಮುಂಜಾನೆ ೧–೨೩ಕ್ಕೆ ರಿಯಾಕ್ಟರ್‌ನ ವಿದಳನ ಸಾಂದ್ರತೆ ಸುರಕ್ಷತಾ ಮಟ್ಟದಿಂದ ಸುಮಾರು ೧೦೦ ಪಟ್ಟು ಹೆಚ್ಚಿತು. ತಾಪ ಮಿತಿಮೀರಿ ಇಂಧನ ಕರಗಿತು. ಆ ಉಷ್ಣಕ್ಕೆ ಗ್ರಾಫೈಟ್ ಮಂದಕಾರಿ ದಹಿಸಲಾರಂಭಿಸಿ ಎರಡು ಬಾರಿ ಮಹಾಸ್ಫೋಟಗಳಾದವು. ೨೦೦೦ ಟನ್ ತೂಕದ ರಿಯಾಕ್ಟರ್ ಮುಚ್ಚಳ ಸಿಡಿದು, ಕಟ್ಟಡ ನಾಶವಾಯಿತು. ಇಂಧನ ಬಾಷ್ಪೀಕರಣಗೊಂಡು ವಿಕಿರಣ ಧಾತುಗಳು ಪರಿಸರಕ್ಕೆ ಸೇರಿದವು. ಮುಂದಿನ ೪೮ ಗಂಟೆಗಳಲ್ಲಿ ಹೊರಗಿನ ಬೆಂಕಿಯನ್ನು ನಿಯಂತ್ರಿಸಲು ಸಾಧ್ಯವಾದರೂ, ಒಂಬತ್ತು ದಿನಗಳ ತನಕ ಇಂಧನ ಉರಿಯುತ್ತಲೇ ಇದ್ದು ಪರಿಸರಕ್ಕೆ ವಿಕಿರಣ ದ್ರವ್ಯ ಬಿಡುಗಡೆ ಯಾಗುತ್ತಾ ಯೂರೋಪಿನಲ್ಲೆಲ್ಲಾ ಹರಡಿತು. ಕಾಲ ಕ್ರಮೇಣ ಅಮೆರಿಕ ಹಾಗೂ ಹಿಮಾಲಯ ತಪ್ಪಲನ್ನೂ ಮುಟ್ಟಿತು.

ಬೆಂಕಿ ನಿಯಂತ್ರಿಸಲು ಹೋರಾಡಿದವರಲ್ಲಿ ಸುಮಾರು ೨೦೦ ಮಂದಿ ತೀವ್ರ ವಿಕಿರಣ ರೋಗಕ್ಕೆ ತುತ್ತಾಗಿ ಸುಸ್ತು, ವಾಂತಿ, ಭೇದಿ, ರಕ್ತ ಹೀನತೆ ಗಳಿಂದ ಬಳಲಿದರು. ಅವರಲ್ಲಿ ೩೦ ಮಂದಿ, ಎಲ್ಲ ಚಿಕಿತ್ಸೆಗಳ ನಂತರವೂ ಸಾವಿಗೀಡಾದರು. ಸುಮಾರು ೩೩೬,೦೦೦ ನಿವಾಸಿಗಳನ್ನು ಕಲುಷಿತ ಪ್ರದೇಶದಿಂದ ಸ್ಥಳಾಂತರಿಸಬೇಕಾಯಿತು. ಸ್ಥಳಾಂತರಗೊಂಡವರಲ್ಲಿ ಸುಮಾರು ೧೮೦೦ ಮಂದಿಗೆ ಥೈರಾಯ್ಡ್ ಕ್ಯಾನ್ಸರ್ ಕಾಣಿಸಿಕೊಂಡಿದೆ.

ಅತಿ ಅಧಿಕವಾಗಿ ಕಲುಷಿತ ಗೊಂಡಿದ್ದ ಪ್ರಿಪ್ಯಾಟ್ ಎಂಬ ಊರು ಇನ್ನೂ ಹಾಳು ಬಿದ್ದಿದೆ. ಚೆರ್ನೊಬಿಲ್ ಅಪಘಾತ ಬೈಜಿಕ ವಿದ್ಯುತ್ ಇತಿಹಾಸದಲ್ಲಿ ಅತ್ಯಂತ ಘೋರವಾದ ಅಪಘಾತವೆಂದು ದಾಖಲಾಗಿದೆ.

ಬೈಜಿಕ ಘಟಕದಲ್ಲಿ ಅಪಘಾತವಾದರೆ ವಿಕಿರಣ ವಸ್ತುಗಳು ಬಿಡುಗಡೆಯಾಗಿ ಮಾನವನಿಗೂ ಪರಿಸರಕ್ಕೂ ಹಾನಿಯುಂಟಾಗಬಹುದೆಂದು ಈಗಾಲೇ ನೋಡಿದ್ದೇವೆ. ಇದರಿಂದಾಗಿ ಜನ ಸಾಮಾನ್ಯರಿಗೆ ಬೈಜಿಕ ಅಪಘಾತ ಗಳ ಬಗ್ಗೆ ಭಯವಿದೆ. ಆದರೆ ಬೈಜಿಕ ಘಟಕದಲ್ಲಿ ಸಂಭವಿಸುವ ಎಲ್ಲ ಘಟನೆಗಳೂ ಒಂದೇ ಮಟ್ಟದ ಪರಿಣಾಮ ಬೀರುವುದಿಲ್ಲ. ಕೆಲವು ಘಟನೆ ಗಳಲ್ಲಿ ಸುರಕ್ಷಾ ವ್ಯವಸ್ಥೆಗಳಿಗೆ ಯಾವ ಹಾನಿಯೂ ಆಗದಿರ ಬಹುದು. ಅದರಿಂದ ಹೆಚ್ಚಿನ ಪರಿಣಾಮ ವಾಗುವುದಿಲ್ಲ. ಕೆಲವು ಸಂದಭ ಗಳಲ್ಲಿ ಸ್ಥಳೀಯ ಸುರಕ್ಷತಾ ವ್ಯವಸ್ಥೆಗಳಲ್ಲಿ ಕೆಲವು ಭಗ್ನ ಗೊಂಡಿದ್ದು, ಪರಿಣಾಮವಾಗಿ ಸ್ವಲ್ಪಮಟ್ಟಿಗೆ ವಿಕಿರಣ ಬಿಡುಗಡೆಯಾಗಬಹುದು (ಉದಾಹರಣೆಗೆ ಟಿಎಮ್‌ಐ ದುರಂತ). ಮತ್ತೆ

(ಪುಟ 23ಕ್ಕೆ)

A.R.Sundararajan, after graduating from 8th batch of training school at Bhabha Atomic Research Centre, in 1965 started his career as Health Physicist in fuel reprocessing and waste management plants in Trombay. Later he moved to Kalpakkam where as Head, Health and Safety Division was responsible for organising surveillance for radiation protection at Indira Gandhi Centre for Atomic Research (IGCAR). He was instrumental in starting a strong research group on internal dosimetry, atmospheric studies, accident source term and aerosol research. He was Associate Director of Safety Research and Health Physics Group at IGCAR during 1997-98. Later he moved to Atomic Energy Regulatory Board (AERB) and was associated with more than 20 Safety Review Committees for various nuclear fuel cycle facilities. He was entrusted with the responsibility of setting up the Safety Research Institute (SRI) at Kalpakkam. He has to his credit 85 publications in the area of Radiation Protection. His areas of special interests include Safety of Fuel Reprocessing, Fast Reactor Safety and Environmental Safety of Nuclear facilities. He has participated in several IAEA Technical Committee and Advisory Group Meetings in the area of radiation protection, emergency preparedness and waste management. After his retirement in 2003 as Director Radiological Safety Division, AERB and Director, SRI he continues to serve in many committees of AERB. Currently he is the Chairman of Safety Review Committee for Application of Radiation in Industry, Medicine and Research (SARCAR) of AERB.

MANAGEMENT OF RADIOACTIVE WASTE

✍ **A.R. Sundararajan**

1. Introduction

Every industry generates certain amount of waste and nuclear industry is no exception. However nuclear waste differs from other wastes since it contains certain quantities of radioactive materials, some of which could remain hazardous for long periods of time. Though the nuclear industry has from its inception given utmost importance to safe and effective management of radioactive waste, there has been always large public concern regarding the risks from nuclear waste. In fact safety of nuclear waste is a major issue for the acceptability of the nuclear power programme. Development of safe and economically viable strategies for management of wastes is therefore an important component of any major nuclear power programme. The main objective of the management of radioactive waste is to ensure the protection of man and environment from short term and long term effects of radioactivity contained in the waste.

2. Philosophy of Waste Management

During the operation of the reactor radioactive waste may arise in a wide variety of physical and chemical forms. The waste may contain varying inventories of radionuclides of different half-lives. Taking these factors into account the wastes are classified into low or intermediate or high level wastes. The three basic approaches adopted in the management of wastes are

i) delay and decay (for wastes containing short lived radionuclides)

ii) dilute and disperse (for low level radioactive effluents)

iii) concentrate and contain (for intermediate and high level active wastes)

Generation of radioactive waste is kept to the minimum by judicious selection of design, process equipment and materials and appropriate operating procedures. Efforts are also constantly made for recycling and reuse of the useful material by selecting appropriate technology and decontamination.

3. Wastes from Reactor Operation

Major source of radioactive waste from the reactor systems is the coolant which gets contaminated with activation and fission products. The fuel matrix and the cladding are very good barriers to the release of fission product activity into the coolant. However due to certain possible defects in the fuel subassemblies and tramp uranium on the fuel, very small amount of radioactivity gets into the coolant system over a period of time. The principal fission product radionuclides in the coolant are cesium-137 and iodine-131. The corrosion products in the coolant system get activated in the reactor and the important radionuclides in this category are Fe-55, Ni-63 and Co-60. Though bulk of the radioactivity in the form of fission products is contained in the spent fuel, it is not considered as a waste since it also contains recoverable quantities of fissionable plutonium which can be used as fuel in the reactors after due processing. In Pressurised Heavy Water Reactors radionuclide tritium is formed in heavy water which is used both as moderator and coolant. The bulk of the wastes generated during the operation of the reactor belong to low level category and intermediate level category. High level waste is generated mostly during the reprocessing of the spent fuel.

4. Treatment of wastes

i) Liquid Wastes:

In a nuclear power plant liquid waste from different sources is collected and transported to a treatment facility through a permanent pipeline system. The type of treatment selected will depend on the chemical nature of the waste and the radiological characteristics of the radionuclides contained in the waste. Following are some of the typical treatment methods adopted in the nuclear power plant sites in the country.

a) Chemical treatment:

Certain chemicals like chlorides of barium or calcium, trisodium phosphate, sodium or copper sulphate, metal ferrocyanide, are mixed in appropriate quantities with the waste in treatment tanks at an optimum pH value. The chemicals get precipitated in the tank as sludges carrying bulk of the radioactivity. The supernatant with highly depleted radioactivity will be discharged to the environment with dilution if necessary after regulatory sampling and monitoring. The sludges will be further conditioned before disposal.

b) Ion exchange treatment:

This technique is often used for removal of specific radionuclides like cesium. Naturally occurring materials like vermiculite, bentonite and zeolites are quite efficient in removal of many radionuclides and therefore used extensively in waste treatment plants. Clinoptilolite removes effectively both cesium and strontium radionuclide. Synthetic ion exchange resins have higher capacity and faster kinetics for removal of radionuclides. They are also amenable for regeneration and reuse.

c) Reverse Osmosis:

This process involves the passage of solvent through a semipermeable membrane when a solution is pressurized in excess of its own osmotic pressure. Membranes used often for this purpose are aromatic polyamides and cellulose acetates. The membrane separates the waste into two components, permeate and reject. The permeate can be discharged to the environment after dilution if necessary. The reject can be further processed prior to disposal.

d) Evaporation:

For concentration of the liquid wastes both steam heating and natural process like solar heating are used. For handling large volumes of low level activity, solar evaporation is highly suitable particularly in sites like Rajasthan, Narora with high solar radiation. Steam evaporation is used in treatment of some intermediate level and all high level liquid waste.

In all the above liquid waste treatment processes there are two resultant streams. The low level active stream is discharged to the environment after appropriate monitoring. The concentration of radionuclides in effluents discharged to the environment is indeed very low and is of the same order as the concentration of naturally occurring radionuclides in water. The sludges from chemical treatment processes or concentrates from evaporator are conditioned and immobilized in a suitable matrix before disposal as solid wastes. The type of matrix chosen for immobilization of waste will have to meet certain safety criteria.

- Low leachability so that activity released from the matrix is minimal.
- High mechanical strength
- High radiation stability
- Amenability for volume reduction
- Low volatility of the constituents

Cement composites are extensively used as a good matrix in view of their low cost and easy process. Certain polymers have been found to be excellent matrix in view of their high chemical and radiation resistance in particular for immobilizing spent resins from ion exchangers. For immobilization of high active liquid wastes which are generated during the reprocessing of spent fuel, glass matrix is the universal choice. This process is called vitrification of radioactive wastes.

ii) Solid Wastes:

In a nuclear power plant solid waste is generated at different stages and in many different forms like contaminated cotton mops, tissue papers, plastic sheets, clothing, protective wares like gloves, shoes, contaminated parts of equipment etc. The other major source of solid waste is the immobilized wastes from liquid treatment plants. All the wastes are disposed in the site under the control of the operating agency. The waste material should be chemically inert, physically stable and should not be pyrophoric or explosive. The waste is disposed in engineered structures such as concrete trenches or tile holes depending on the physico-chemical and radiological characteristics of the waste. Such structures are located in what is called near surface disposal facility. Choice of a site for such a facility, design of engineered barriers and disposal operation undergo elaborate safety assessment and review procedures as laid down by the regulatory authority. Clearly the design of the disposal facility has to take into account many important site parameters like maximum earth quake potential, extreme precipitation, severe flood conditions etc. The objective of all this review is to ensure that any possible radioactive release from the waste matrix does not contaminate the soil and water. There are several barriers built around the disposal facility and also several boreholes around it from where water samples are drawn periodically to check the migration of radioactivity if any.

Before the disposal the waste material is segregated into compressible, combustible and non-combustible. In order to reduce the volume of the waste to be buried, compressible wastes are compacted to smaller volumes by using bailing press. Combustible wastes are burnt in a specially designed incinerator. The radioactive ash is conditioned, immobilised and buried. The incinerators have elaborate off-gas clean-up system.

iii) Gaseous Wastes:

The gaseous waste generated in a nuclear power plant can be classified into particulate, vapours and noble gases. The ventilation system in the plant areas is designed to ensure that the airactivity in the working environment is with in the safety limits. Typically the operating areas of the plant are kept under negative pressure compared to outside atmosphere. to restrict the direct release to the environment. The particulate activity like cesium and strontium are removed from the stream by high efficiency particulate air filters with removal efficiency as high as 99.97%. In PHWRs the tritium activity is associated with leakage of heavy water. The recovery system installed to recover precious heavy water removes associated tritium also. Molecular sieves are excellent absorbers for tritium. Iodine-131 in the off gas is removed by activated charcoal impregnated filters. The noble gases like radioactive krypton and xenon are subjected to delay and dispersion by tall stacks. The total activity released from the stack is continuously monitored to ensure that the releases are well with in the permissible limits specified by the regulatory body.

5. Concluding Remarks

Just like in any other industry wastes are generated during the operation of nuclear power plants. The wastes are unique in the sense that they are radioactive and one has to take into account their long term hazards in their treatment and disposal to ensure the safety of the present as well as future generations. It is worth noting that the volume of the waste generated in nuclear power plants is very small. For example a 1000 MWe nuclear power plant will generate in a year about 50 tonnes of wastes while a coal based plant of the same capacity will produce 7,50,000 tonnes of fly ash. Therefore the land required for disposal of the nuclear wastes is very small. Over the past four decades the Department of Atomic Energy has installed nuclear waste management plants at several sites, meeting the requirements of the national and international standards of design, construction and operations. □

ಕೆಲವು ಪ್ರಮುಖ ಬೈಜಿಕ ಅಪಘಾತಗಳು:

(ಪುಟ 20ರಿಂದ)

ಬೈಜಿಕ ಅಪಘಾತಗಳ ತೀವ್ರತೆಯನ್ನು ಸೂಚಿಸುವ ಮಾಪನ

ಕೆಲವು ಸನ್ನಿವೇಶಗಳಲ್ಲಿ ಅಪಘಾತ ತೀವ್ರವಾಗಿದ್ದು, ಅನೇಕ ಸುರಕ್ಷಾ ಮಜಲುಗಳು ನಿಷ್ಕ್ರಿಯಗೊಂಡು ಹೆಚ್ಚಿನ ಮಟ್ಟದಲ್ಲಿ ವಿಕಿರಣ ಬಿಡುಗಡೆಂಯಾಗಿ ಅಪಾರವಾದ ಹಾನಿ ಉಂಟಾಗಬಹುದು (ಚೆರ್ನೊಬಿಲ್ ದುರಂತ). ಹಾಗಿದ್ದರೆ ಬೈಜಿಕ ಘಟನೆಗಳ ತೀವ್ರತೆಯ ವಾಸ್ತವತೆಯನ್ನು ಜನ ಸಾಮಾನ್ಯರಿಗೆ ಅರಿವುಂಟು ಮಾಡಿಸುವುದು ಹೇಗೆ? ಅದಕ್ಕಾಗಿ ಅಂತರ ರಾಷ್ಟ್ರೀಯ ಪರಮಾಣು ಶಕ್ತಿ ಆಯೋಗವು, ಭೂಕಂಪನದ ತೀವ್ರತೆಯನ್ನು ಸೂಚಿಸುವ ರಿಕ್ಟರ್ ಮಾಪನ ದಂತೆ ಬೈಜಿಕ ಘಟನೆಗಳ ತೀವ್ರತೆಯನ್ನು ಸೂಚಿಸಲು International Nuclear Events Scale- INES ಎಂಬ ಮಾಪನವನ್ನು ಜಾರಿಗೊಳಿಸಿದೆ.

ಅದರ ಪ್ರಕಾರ ಬೈಜಿಕ ಘಟಕಗಳಲ್ಲಿ ಸಂಭವಿಸುವ ಘಟನೆಗಳನ್ನು ಸೊನ್ನೆಯಿಂದ ಏಳರವರೆಗೆ ಸಂಖ್ಯಿಸಲಾಗಿದೆ. ಸೊನ್ನೆ ಎಂದರೆ ಘಟಕದ ಕಾರ್ಯದಲ್ಲಿ ರೂಢಿಯಿಂದ ಸ್ವಲ್ಪ ಮಟ್ಟಿಗೆ ವಿಚಲನೆಯಾಯಿತು. ಆದರೆ ಅದು ಸುರಕ್ಷೆಯ ದೃಷ್ಟಿಯಿಂದ ಗಮನಾರ್ಹವಲ್ಲ. ಏಳನೇ ಮಟ್ಟದ ದುರಂತವೆಂದರೆ ಘಟಕದ ಎಲ್ಲ ಸುರಕ್ಷಾ ವ್ಯವಸ್ಥೆಗಳೂ ಭಗ್ನಗೊಂಡು ಪರಿ ಸರಕ್ಕೆ ಅತಿದೊಡ್ಡ ಪ್ರಮಾಣ ದಲ್ಲಿ ವಿಕಿರಣ ಬಿಡುಗಡೆ ಯಾಗಿ ಪ್ರಾಣಹಾನಿ ಹಾಗೂ ಆಸ್ತಿ ಹಾನಿ ಉಂಟಾಗುವುದು. ಇತರ ಎಲ್ಲ ಘಟನೆಗಳನ್ನೂ ಈ ಎರಡರ ನಡುವೆ ಕಲ್ಪಿಸಿಕೊಳ್ಳಬಹುದು. ಇದುವರೆಗೆ ಸಂಭವಿಸಿದ ಅಪಘಾತಗಳನ್ನು ಅವಲೋಕಿಸಿದಾಗ, ಚೆರ್ನೊಬಿಲ್ ಅಪಘಾತ ಏಳನೇ ದರ್ಜೆಯದೆಂದು ಪರಿಗಣಿಸಬಹುದು. ಆದರೆ TMI ಮತ್ತು Windscale ಅಪಘಾತ ಗಳು ಐದನೇ ಶ್ರೇಣಿಗೆ ಸೇರುತ್ತವೆ. ಮೊದಲೇ ಹೇಳಿದಂತೆ ರೀಯಾಕ್ಟರ್ ರಚನೆಯ ಪ್ರತಿ ಹಂತದಲ್ಲಿಯೂ ಸುರಕ್ಷಾ ವ್ಯವಸ್ಥೆಯು ದ್ವಿಪ್ರತಿಯಲ್ಲಿರುವುದರಿಂದ ಒಂದು ವಿಫಲ ವಾದರೆ ಮತ್ತೊಂದು ಕಾರ್ಯ ನಿರ್ವಹಿ ಸುತ್ತದೆ. ಹಾಗಾಗಿ ಬಹುತೇಕ ಘಟನೆಗಳು **INES** ಸೂಚಿಯ ಎರಡನೇ ಶ್ರೇಣಿಯವು ಅಥವಾ ಕೆಳಗಿನವು ಎಂಬುದು ಗಮನಾರ್ಹ.

ಭಾರತದ ಬೈಜಿಕ ಘಟಕಗಳಲ್ಲಿ ಸಣ್ಣಸಣ್ಣ ಘಟನೆಗಳು ಸಂಭವಿಸಿದ್ದರೂ ಅವುಗಳಿಂದ ಪ್ರಾಣಹಾನಿಯಾಗಲೀ, ಆಸ್ತಿಹಾನಿಯಾಗಲೀ ಅಥವಾ ಪರಿಸರಕ್ಕೆ ನಿಗದಿತ ಮಟ್ಟಕ್ಕಿಂತ ಹೆಚ್ಚು ವಿಕಿರಣ ದ್ರವ್ಯ ಬಿಡುಗಡೆ ಯಾಗುವುದಾಗಲೀ ಆಗಿಲ್ಲವೆಂದು ಅಧಿಕಾರಿಗಳು ಆಶ್ವಾಸನೆ ಕೊಡುತ್ತಾರೆ. ಹಾಗಾಗಿ ಅವುಗಳನ್ನು ಐಎನ್‌ಇಎಸ್ ಶ್ರೇಣಿ ಎರಡನೇ ಹಂತಕ್ಕಿಂತ ಕೆಳದರ್ಜೆಯ ಘಟನೆಗಳೆಂದು ಪರಿಗಣಿಸ ಬಹುದು. □

ಕಲಿತ ಪಾಠಗಳು

ಈ ಎಲ್ಲ ಅಪಘಾತಗಳ ಬಗ್ಗೆಯೂ ವಿಜ್ಞಾನಿಗಳು ಕೂಲಂಕಷವಾಗಿ ಅಧ್ಯಯನ ನಡೆಸಿದ್ದಾರೆ. ಈ ಅಧ್ಯಯನ ಗಳಿಂದ ಬೈಜಿಕ ಸ್ಥಾವರಗಳ ಬಗ್ಗೆ ಇದುವರೆಗೂ ತಿಳಿಯದ ಯಾವುದೇ ಹೊಸ ವಿಷಯ ಬೆಳಕಿಗೆ ಬಂದಿಲ್ಲ. ಆದರೆ, ಅಪಘಾತಗಳಿಗೆ ಮೂರು ಪ್ರಮುಖ ಕಾರಣಗಳನ್ನು ಗುರುತಿಸಲಾಗಿದೆ:

೧) ತಾಂತ್ರಿಕ ಸಮಸ್ಯೆಗಳು,

೨) ಉಪಕರಣಗಳ ವೈಫಲ್ಯ, ಮತ್ತು

೩) ಕೆಲಸಗಾರರಿಂದಾದ ತಪ್ಪುಗಳು. ಹಾಗಾಗಿ ಈ ಮೂರು ಕ್ಷೇತ್ರ ಗಳಲ್ಲಿಯೂ ಸುರಕ್ಷತೆ ಯನ್ನು ತೀವ್ರಗೊಳಿಸುವ ಪ್ರಯತ್ನಗಳು ನಡೆದಿವೆ.

ಚೆರ್ನೊಬಿಲ್ ರೀಆಕ್ಟರ್ ಇಂಧನ ದಲ್ಲಿ ಯುರೇನಿಯಮ್–೨೩೫ ಅಂಶ ವನ್ನು ಪುಷ್ಟೀಕರಿಸಲಾಗಿತ್ತು. ಅದರಲ್ಲಿ ಬಳಸಿದ ಗ್ರಾಫೈಟ್ ಮಂದಕ ಬೆಂಕಿಹತ್ತುವ ಗುಣ ವುಳ್ಳದ್ದು. ಅಂತಹ ಸಂಯೋಜನೆ ಯಲ್ಲಿ ಇಂಧನ ತಾಪ ಮತ್ತು ವಿದಳನ ಸಾಂದ್ರತೆ ಒಂದನ್ನೊಂದು ಅವಲಂಬಿಸಿ ಏರುತ್ತಾ ಕ್ಷಣಾರ್ಧದಲ್ಲಿ ಕೈಮೀರಿ ಹೋಗಿಬಿಡುತ್ತದೆ. ಚೆರ್ನೊಬಿಲ್ ದುರಂತಕ್ಕೆ ಇದೂ ಒಂದು ಕಾರಣವೆಂದು ತಿಳಿದು ಬಂದಿದೆ. ಭಾರತದ ಎಲ್ಲ ಬೈಜಿಕ ಸ್ಥಾವರ ಗಳಲ್ಲಿಯೂ (ತಾರಾಪುರ್‌ನ ಎರಡು ಘಟಕಗಳನ್ನು ಹಾಗೂ ಕೂಡಂ ಕುಳಮ್‌ನ ಘಟಕಗಳನ್ನು ಹೊರತು ಪಡಿಸಿ) ನೈಸರ್ಗಿಕ ಯುರೇನಿ ಯಮ್–ಭಾರಜಲ ಸಂಯೋಜನೆ ಇರುವುದರಿಂದ ಸಹಜ ಸುರಕ್ಷತೆಯ ಲಾಭ ಪಡೆದಿವೆ.

ಚೆರ್ನೊಬಿಲ್ ಘಟಕದಲ್ಲಿ ಒಂದೇ ಪದರದ ಪ್ರತಿಬಂಧಕ ಕವಚ ವಿತ್ತು. ಆ ದುರಂತ ಸಂಭವಿಸಿದ ನಂತರ ಭಾರತದಲ್ಲಿ ಕ್ರಿಯಾಶೀಲ ವಾದ ಬೈಜಿಕ ಘಟಕಗಳಲ್ಲಿ ಎರಡು ಪದರಗಳ ಪ್ರತಿಬಂಧಕ ಆವರಣಗಳನ್ನು ಅಳವಡಿಸ ಲಾಯಿತು.

ಕೆಲವು ವರ್ಷಗಳ ಹಿಂದೆ ನರೋರ ಘಟಕದಲ್ಲಿ ಬೆಂಕಿ ತಗುಲಿತು. ರೀಆಕ್ಟರ್ ನಿಯಂತ್ರಣ ಕೊಠಡಿಗೆ ವಿದ್ಯುತ್ ಸರಬರಾಜು ಮಾಡುತ್ತಿದ್ದ ಎಲ್ಲ ಕೇಬಲ್‌ಗಳೂ ಒಂದರೊ ಡನೊಂದು ಹೆಣೆದು ಕೊಂಡಿದ್ದುದರಿಂದ ಎಲ್ಲವೂ ಬೆಂಕಿಯಲ್ಲಿ ನಾಶವಾಗಿ ಘಟಕಕ್ಕೆ ವಿದ್ಯುತ್ ಕಡಿತವಾಯಿತು. ಅಂದಿನಿಂದ ಬೈಜಿಕ ಸ್ಥಾವರ ನಿರ್ಮಾಣದಲ್ಲಿ ಪರ್ಯಾಯ ವ್ಯವಸ್ಥೆಗಳನ್ನು ಪರಸ್ಪರ ಬೇರ್ಪಡಿಸುವ ವ್ಯವಸ್ಥೆ ಜಾರಿಗೆ ಬಂದಿತು. ಹಾಗಾಗಿ ಯಾವುದೇ ಕಾರಣದಿಂದ ಒಂದಕ್ಕೆ ಧಕ್ಕೆಯಾದರೆ ಮತ್ತೊಂದರ ಕಾರ್ಯ ಸಿದ್ಧತೆಯಲ್ಲಿ ಲೋಪಉಂಟಾಗದು. ಸ್ಥಾವರಕ್ಕೆ ನಿರಂತರ ವಿದ್ಯುತ್ ಸರಬರಾಜು ಮಾಡಲು ನಾಲ್ಕು ಸ್ವತಂತ್ರ ವ್ಯವಸ್ಥೆಗಳಿವೆ. ಅಷ್ಟೇ ಅಲ್ಲ. ತುರ್ತು ಸಮಯದಲ್ಲಿ ಬಳಸಲು ಎರಡು ಡೀಸೆಲ್ ಜನರೇಟರ್‌ಗಳೂ, ಒಂದು ಬೃಹತ್ ಬ್ಯಾಟರಿ ಬ್ಯಾಂಕ್ ಕೂಡ ಇವೆ.

TMI ದುರಂತದ ಒಂದು ಹಂತದಲ್ಲಿ ನಿಯಂತ್ರಣ ಕೊಠಡಿಯಲ್ಲಿನ ನೂರಾರು ಅಪಾಯ ಸೂಚಕ ಗಂಟೆಗಳು ಒಂದೇ ಕಾಲದಲ್ಲಿ ಶಬ್ದ ಮಾಡುತ್ತಿದ್ದವು. ಅದರಿಂದ ಕೆಲಸಗಾರರು ತಬ್ಬಿಬ್ಬಾಗಿ ಯಾವುದಕ್ಕೆ ಪ್ರಾಮುಖ್ಯತೆ ಕೊಡಬೇಕೆಂದು ಅವರಿಗೆ ತೋಚಲೇ ಇಲ್ಲ. ಇಂದು ಘಟಕದ ನಿಯಂತ್ರಣ ಬಹುಮಟ್ಟಿಗೆ ಕಂಪ್ಯೂಟರ್ ಆಧಾರಿತವಾಗಿದ್ದು, ತುರ್ತು ಪರಿಸ್ಥಿತಿಯಲ್ಲಿ ತಂತಾನೇ ನಿರ್ಧಾರ ತೆಗೆದುಕೊಳ್ಳುವ ಸಾಮರ್ಥ್ಯ ಹೊಂದಿರುತ್ತವೆ. ಅಲ್ಲದೇ ತುರ್ತು ಪರಿಸ್ಥಿತಿಯಲ್ಲಿ ಯಾವ ರೀತಿಯ

✍ ಎಂ.ಎಸ್.ಎಸ್. ಮೂರ್ತಿ

ಕ್ರಮಗಳನ್ನು ತೆಗೆದುಕೊಳ್ಳ ಬೇಕೆಂಬುದರ ಬಗ್ಗೆ ಕೆಲಸಗಾರರಿಗೆ ವಿಪುಲ ತರಪೇತಿ ನೀಡಲಾಗುತ್ತದೆ.

ಇದಲ್ಲದೇ ಅಂತರರಾಷ್ಟ್ರೀಯ ಪರಿಣಿತರು ಎಲ್ಲ ರಾಷ್ಟ್ರಗಳ ಬೈಜಿಕ ಘಟಕಗಳ ಸುರಕ್ಷತೆ ಯನ್ನೂ ಪರಿಶೀಲಿಸಿ ಸಲಹೆ ನೀಡುವ ವ್ಯವಸ್ಥೆಯೂ ಇದೆ. ಇದರಿಂದ ಅನುಭವ ವಿನಿಮಯವಾಗಿ ಸುರಕ್ಷತೆಯ ಗುಣಮಟ್ಟ ಇನ್ನಷ್ಟು ಹೆಚ್ಚಲು ಸಾಧ್ಯವಾಗುತ್ತದೆ.

ಈ ರೀತಿಯ ಸಮಗ್ರ ಸುರಕ್ಷತಾ ವ್ಯವಸ್ಥೆಯಿಂದಾಗಿ ಇಂದಿನ ಬೈಜಿಕ ಘಟಕಗಳಲ್ಲಿ ಅಪಘಾತ ಸಂಭವಿಸಿ ಪರಿಸರಕ್ಕೆ ಹಾನಿ ಯಾಗುವ ಸಾಧ್ಯತೆ ಹತ್ತು ಲಕ್ಷ ರೀಯಾಕ್ಟರ್–ವರ್ಷಗಳಲ್ಲಿ (Reactor-years) ಒಂದಕ್ಕಿಂತಲೂ ಕಡಿಮೆ ಎಂದು ತಜ್ಞರು ಲೆಕ್ಕ ಹಾಕಿದ್ದಾರೆ. ಹಾಗಾಗಿ ಬೈಜಿಕ ವಿದ್ಯುತ್ ಘಟಕಗಳು ಕಲ್ಲಿದ್ದಲು, ನೈಸರ್ಗಿಕ ಅನಿಲ, ಜಲ ಇತ್ಯಾದಿ ಇತರ ವಿಧವಾದ ವಿದ್ಯುತ್ ಘಟಕಗಳಿಗಿಂತಲೂ ಬಹುಪಾಲು ಸುರಕ್ಷವೆಂದು ಅಂಕಿಅಂಶಗಳಿಂದ ಅವರು ತೋರಿಸಿದ್ದಾರೆ. ಇವುಗಳಲ್ಲಿ ಉಂಟಾಗಿರುವ ಅಪಘಾತಗಳ ಸಂಖ್ಯೆಯನ್ನು ಕೋಷ್ಟಕದಲ್ಲಿ ತೋರಿಸಿದೆ. ಉದಾಹರಣೆಗೆ, ೧೯೭೦ ರಿಂದ ೧೯೯೨.

ವಿವಿಧ ಇಂಧನ ಮೂಲಗಳಿಂದ ವಿದ್ಯುತ್ ಉತ್ಪಾದನೆ ಯಲ್ಲಿ ೧೯೭೦ ರಿಂದ ೧೯೯೨ ರ ನಡುವೆ ಸಂಭವಿಸಿದ ಅಪಘಾತಗಳಲ್ಲಿ ಮೃತರಾದವರ ಸಂಖ್ಯೆ.

ಇಂಧನ	ಒಟ್ಟು ಮೃತರ ಸಂಖ್ಯೆ	ಸರಾಸರಿ ಒಂದು Trillion waat-year ಉತ್ಪಾದನೆಗೆ
ಕಲ್ಲಿದ್ದಲು	6400	342
ನೈಸರ್ಗಿಕ ಅನಿಲ	1200	85
ಜಲ	4000	883
ಬೈಜಿಕ	31	8

Ref: Sustainable Development and Nuclear power, 1977; Severe accidents in the Energy Sector.

ದರವರೆಗೆ ಕಲ್ಲಿದ್ದಲು, ಜಲ, ಅನಿಲ, ಮತ್ತು ಬೈಜಿಕ ಇತ್ಯಾದಿ ವಿವಿಧ ಇಂಧನ ಮೂಲಗಳಿಂದ ವಿದ್ಯುತ್ ಉತ್ಪಾದಿಸುವಾಗ ಉಂಟಾದ ಅಪಘಾತಗಳಲ್ಲಿ ಮೃತ ರಾದವರ ಸಂಖ್ಯೆಯನ್ನು ತುಲನೆ ಮಾಡಬಹುದು. ಐವತ್ತೇಳು ವರ್ಷಗಳ ಬೈಜಿಕ ವಿದ್ಯುತ್ ಅನುಭವದಲ್ಲಿ ಕೇವಲ ಎರಡು ತೀವ್ರ ಮಟ್ಟದ ಅಪಘಾತಗಳು ಸಂಭವಿಸಿ, ಒಂದರಲ್ಲಿ ಮಾತ್ರ ೩೧ ಮಂದಿ ಮೃತರಾಗಿದ್ದಾರೆ. ಆದರೆ ಇತರ ರೀತಿಯ ವಿದ್ಯುತ್ ಘಟಕಗಳಲ್ಲಿ ಸಾವಿನ ಸಂಖ್ಯೆ ಸಹಸ್ರಾರು. ಆದರೆ, ಇವೆಲ್ಲದರಲ್ಲೂ ಒಂದೇ ಪ್ರಮಾಣದಲ್ಲಿ ವಿದ್ಯುತ್ ಉತ್ಪಾದಿಸದೇ ಇರುವುದರಿಂದ (ಉದಾಹರಣೆಗೆ, ಕಲ್ಲಿದ್ದಲಿನಿಂದ ಉತ್ಪತ್ತಿಯಾದ ವಿದ್ಯುತ್ ಪ್ರಮಾಣ ಬೈಜಿಕ ವಿದ್ಯುತ್ ಪ್ರಮಾಣಕ್ಕಿಂತಲೂ ಬಹುಪಟ್ಟು ಜಾಸ್ತಿ ಆ ಅಂಕಿಅಂಶಗಳನ್ನು ನೇರ ಹೋಲಿಸಿ ಯಾವುದರಲ್ಲಿ ಹೆಚ್ಚಿನ ಅಪಘಾತದ ಸಾಧ್ಯತೆ ಇದೆ ಎಂಬುದನ್ನು ಹೇಳಲಾಗುವುದಿಲ್ಲ. ಆದರೆ, ಸರಾಸರಿ ಲೆಕ್ಕಾಚಾರದ ಮೇಲೆ ಅವುಗಳನ್ನು ತುಲನೆ ಮಾಡಬಹುದು. ಕೋಷ್ಟಕದ ಮೂರನೇ ಕಾಲಮಿನಲ್ಲಿ ಒಂದು Terrawatt-year ವಿದ್ಯುತ್ ಉತ್ಪಾದನೆಯಲ್ಲಿ ಸರಾಸರಿ ಎಷ್ಟು ಅಪಘಾತ ಸಾವು ಸಂಭವಿಸಿದೆ ಎಂದು ಲೆಕ್ಕಹಾಕಿ ತೋರಿಸಿದೆ. ಎಲ್ಲಕ್ಕಿಂತಲೂ ಬೈಜಿಕ ವಿದ್ಯುತ್ ಉತ್ಪಾದನೆ ಬಹುಪಟ್ಟು ಸುರಕ್ಷ ಎಂಬುದು ಇದರಿಂದ ಸ್ಪಷ್ಟವಾಗುತ್ತದೆ.

ಅಲ್ಲದೆ ಕಲ್ಲಿದ್ದಲು ಉರಿಸುವುದರಿಂದ ಉತ್ಪತ್ತಿಯಾಗುವ ಅನಿಲ ಗಳಿಂದ ಮಾನವನಿಗೂ ಹಾಗೂ ಪರಿಸರಕ್ಕೂ ಅನೇಕ ವಿಧವಾದ ಪರೋಕ್ಷ ಹಾನಿಗಳೂ ಉಂಟಾಗುತ್ತವೆ. ಹೃದಯ ಆಘಾತ, ಉಬ್ಬಸ, ಮುಂತಾದ ರೋಗ ಗಳೂ, ಬಿಸಿಪ್ರಳಯ ಮುಂತಾದ ಪರಿಸರ ಪರಿಣಾಮಗಳಿಗೆ ಇಂಗಾಲ ಆಧಾರಿತ ಇಂಧನ ಬಳಕೆಯೇ ಒಂದು ಮುಖ್ಯ ಕಾರಣವೆಂದು ತಿಳಿದು ಬಂದಿದೆ. ಅಷ್ಟೇ ಅಲ್ಲ.

ಕಲ್ಲಿದ್ದಲು ಉರಿಸುವುದರಿಂದ ಪರಿಸರಕ್ಕೆ ವಿಕಿರಣ ಧಾತುಗಳೂ ಸೇರ್ಪಡೆ ಯಾಗುತ್ತವೆ ಎಂಬುದು ಅನೇಕರಿಗೆ ತಿಳಿದಿಲ್ಲ. ಕಲ್ಲಿದ್ದಲಿನಲ್ಲಿ ಯುರೇನಿಯುವ್, ರೇಡಿಯುವ್, ಥೋರಿಯಮ್ ಮುಂತಾದ ನೈಸರ್ಗಿಕ ವಿಕಿರಣ ಧಾತು ಗಳು ಸ್ವಲ್ಪ ಪ್ರಮಾಣದಲ್ಲಿ ಸೇರಿರುತ್ತವೆ. ಕಲ್ಲಿದ್ದಲನ್ನು ಉರಿಸಿದಾಗ ಉತ್ಪತ್ತಿಯಾಗುವ ಬೂದಿಯಲ್ಲಿ (Fly ash) ಅವೆಲ್ಲ ಸಾಂದ್ರೀಕೃತಗೊಂಡು ಪರಿಸರ ವನ್ನು ಸೇರಬಹುದು. ಅದೇ ರೀತಿ ನೈಸರ್ಗಿಕ ಅನಿಲವನ್ನು ಉರಿಸುವುದರಿಂದ ಅದರಲ್ಲಿ ಅಡಗಿರುವ ರೆಡಾನ್ ಎಂಬ ವಿಕಿರಣ ಅನಿಲ ಪರಿಸರವನ್ನು ಸೇರುತ್ತದೆ. ಹೀಗೆ ಬಿಡುಗಡೆಯಾದ ವಿಕಿರಣ ನೈಸರ್ಗಿಕ ವಿಕಿರಣಕ್ಕಿಂತ ಕಡಿಮೆ ಇದ್ದರೂ ಅದು ಅಷ್ಟೇ ಶಕ್ತಿಯ ಬೈಜಿಕ ವಿದ್ಯುತ್ ಆಗರ ದಿಂದ ಪರಿಸರವನ್ನು ಸೇರುವ ವಿಕಿರಣ ಧಾತುಗಳಿಗಿಂತಲೂ ಮಿಗಿಲಾಗಿರುತ್ತದೆಂಬುದು ಅನೇಕ ಸಮೀಕ್ಷೆಗಳಿಂದ ತಿಳಿದು ಬಂದಿದೆ. □

ಜಾಲತಾಣದ ಉದ್ಘಾಟನೆ

ವಿದೇಶಗಳಿಗೂ ಹೋಗಿ ನೆಲೆಸಬೇಕಾಗಿ ಬಂದ ಸುಮಾರು ಮೂರ್ನಾಲ್ಕು ಪೀಳಿಗೆ ಸದಸ್ಯರುಗಳಿಗೆ ಈಗ ತಮ್ಮ ಆತ್ಮೀಯ ಅಸೋಸಿಯೇಶನ್ ನೊಂದಿಗೆ ಮನ ಬಂದಾಗ, ಕುಳಿತಲ್ಲೇ ಸ್ಪಂಧಿಸುವ ಸುವರ್ಣಾವಕಾಶ ಇದಾಗಿದೆ.

ಅಸೋಸಿಯೇಶನ್‌ನ ಆರಂಭ'ದ ದಿನಗಳಿಂದಲೂ ನಡೆದ ಪ್ರಮುಖ ಘಟನೆಗಳ ವಿವರಗಳು, ಛಾಯಾಚಿತ್ರಗಳು, ಭೇಟಿ ನೀಡಿದ ವಿಶೇಷ ಅತಿಥಿಗಳು ಮುಂತಾದ ಎಲ್ಲಾ ಹಳೆಯ, ಹೊಸ ಸುದ್ದಿಸಾರಗಳ ಜೊತೆಗೆ, ಸುಮಾರು ಹಿಂದಿನ ಎಲ್ಲಾ ವರ್ಷಗಳ ನೇಸರು ತಿಂಗಳೋಲೆಯ ಎಲ್ಲಾ ಬರಹಗಳು ಈಗ ಬೆರಳ ತುದಿಯಲ್ಲಿ ಕ್ಷಣದಲ್ಲಿ ಕೈಗೆಟುಕುವಂತಾಗಿದೆ. ಉಚಿತವಾಗಿ, ಸರ್ವರಿಗೂ ಲಭ್ಯವಿರುವ ಈ ಜಾಲತಾಣದಲ್ಲಿ ತಮ್ಮ ಅನಿಸಿಕೆ, ಸಲಹೆಗಳಲ್ಲಿ ನೇರವಾಗಿ ಅಸೋಸಿಯೇಶನಗೆ ಕಳುಹಿಸುವ ಸಂಪರ್ಕ ವ್ಯವಸ್ಥೆಯನ್ನು ಸಹ ಕಲ್ಪಿಸಲಾಗಿದೆ.

ಇದೀಗ ತಾನೆ ಕಣ್ತೆರದ ಈ ಜಾಲತಾಣವನ್ನು ಒಂದು ಸಕ್ಷಮ ಸಂಪರ್ಕಶಕ್ತಿಯಾಗಿ ಹಿರಿಯ ಕಿರಿಯ ಎಲ್ಲಾ ಸದಸ್ಯರುಗಳು ತಾವು ಬಳಸುವದರೊಂದಿಗೆ ತಮ್ಮ ದೂರ ದೂರದ ಆಸಕ್ತ ಗೆಳೆಯ, ಬಂಧುಗಳಿಗೂ ಈ ತಾಣವನ್ನು ಪರಿಚಯಿಸಿ ಸಹಕಾರ ನೀಡಬೇಕಾಗಿ ವಿನಂತಿ.

ಜಾಲ ತಾಣ ವಿಳಾಸ :

www : **mysoreassociation.in**

–ಡಾ. ದೇವಾನಂದ್

ಪರಿಸರಪ್ರೇಮಿ ಬೈಜಿಕ ವಿದ್ಯುತ್

ವಿಶ್ವದಲ್ಲಿ ಬೈಜಿಕ ವಿದ್ಯುತ್ ಬೆಳವಣಿಗೆಯನ್ನು ಐತಿಹಾಸಿಕ ವಾಗಿ ನೋಡಿದಾಗ ಒಂದು ಸ್ವಾರಸ್ಯಕರ ಸಂಗತಿ ಗಮನಕ್ಕೆ ಬರುತ್ತದೆ. ಅದರ ಬೆಳವಣಿಗೆ, ಆರಂಭದ ದಶಕಗಳಲ್ಲಿ ಕಂಡಷ್ಟು ವೇಗದಲ್ಲಿ ೧೯೮೬ರಿಂದ ಈಚೆಗೆ ಮುಂದುವರಿದಿಲ್ಲ. ೧೯೬೦ರಲ್ಲಿ ವಿಶ್ವದಲ್ಲಿ ಉತ್ಪತ್ತಿಯಾದ ಒಟ್ಟು ವಿದ್ಯುತ್ತಿನಲ್ಲಿ ಶೇಕಡ ೧ ಮಾತ್ರ ಬೈಜಿಕ ವಿದ್ಯುತ್ತಾಗಿತ್ತು. ಅದು ೧೯೮೬ ರ ವೇಳೆಗೆ ಶೇಕಡ ೧೬ಕ್ಕೆ ಏರಿತು. ಇಂದು ಕೂಡ ಅಷ್ಟೇ ಇದೆ.

ಆಗುತ್ತಿರುವ ಬೆಳವಣಿಗೆಯೂ ಬಹುಮಟ್ಟಿಗೆ ಏಷ್ಯ ಖಂಡದ ರಾಷ್ಟ್ರಗಳಲ್ಲಿ ಮಾತ್ರ. ಅಂತರರಾಷ್ಟ್ರೀಯ ಪರಮಾಣು ಶಕ್ತಿ ಆಯೋಗದ ಪ್ರಕಾರ ಅಕ್ಟೋಬರ್ ೨೦೦೭ ರಲ್ಲಿ ಹೊಸದಾಗಿ ನಿರ್ಮಿಸಲಾಗುತ್ತಿ ರುವ ೩೦ ರೀಆಕ್ಟರ್‌ಗಳಲ್ಲಿ ೧೮ ಏಷ್ಯ ಖಂಡದಲ್ಲಿವೆ. ಇಂದು ಚೈನಾದಲ್ಲಿ ಬೈಜಿಕ ವಿದ್ಯುತ್ ಒಟ್ಟಾರೆ ವಿದ್ಯುತ್ತಿನ ಕೇವಲ ಶೇಖಡ ೨ ರಷ್ಟು ಇದೆ. ಅದನ್ನು ೨೦೨೦ರವೇಳೆಗೆ ಐದು ಪಟ್ಟು ಹೆಚ್ಚಿಸುವ ಯೋಜನೆ ಇದೆ. ಅದೇರೀತಿ ಜಪಾನಿನಲ್ಲಿ ೫೫ ರೀಆಕ್ಟರ್‌ಗಳು ಶೇಖಡ ೩೦ ವಿದ್ಯುತ್ ಒದಗಿಸುತ್ತಿದ್ದು, ಮುಂದಿನ ದಶಕದಲ್ಲಿ ಅದು ಶೇಖಡ ೪೦ ಆಗಲಿದೆ.

Scientific American ವಿಜ್ಞಾನ ಪತ್ರಿಕೆಯ ಪ್ರಕಾರ ೨೦೦೦ದಿಂದ ಈಚೆಗೆ ಸುಮಾರು ೨೦,೦೦೦ ಮೆಗಾವಾಟ್ ವಿದ್ಯುತ್ ಉತ್ಪಾದಿಸುವ ಬೈಜಿಕ ಸ್ಥಾವರಗಳು ಏಷ್ಯ ಖಂಡ ರಾಷ್ಟ್ರಗಳಲ್ಲಿ (ಚೀನ, ಜಪಾನ್, ಭಾರತ, ಕೊರಿಯ, ಫಿಲಿಪಿನ್ಸ್, ಇತ್ಯಾದಿ) ನಿನಿರ್ಮಿತವಾಗಿವೆ. ಭಾರತದಲ್ಲಿ ಪ್ರಸ್ತುತ ದಲ್ಲಿ ೪೧೨೦ ಮೆಗವಾಟ್ ಉತ್ಪಾದನೆಯ ಸಾಮರ್ಥ್ಯವಿದ್ದು (ಕೋಷ್ಠಕ ೧ ನೋಡಿ) ಅದನ್ನು ೨೦೩೦ರ ವೇಳೆಗೆ ೫೦,೦೦೦ ಮೆಗವಾಟ್‌ಗೆ ಏರಿಸುವ ಯೋಜನೆ ಇದೆ.

ಪಶ್ಚಿಮ ರಾಷ್ಟಗಳಲ್ಲಿ ಇಂದು ಬೈಜಿಕ ವಿದ್ಯುತ್ತಿಗೆ ಆದ್ಯತೆ ಕಡಿಮೆ ಆದಂತೆ ಕಾಣುತ್ತದೆ. ಅದಕ್ಕೆ ಎರಡು ಪ್ರಮುಖ ಕಾರಣಗಳನ್ನು ಗುರುತಿಸಬಹುದು. ಮೊದಲನೆಯದಾಗಿ ೧೯೭೯ ಮತ್ತು ೧೯೮೬ ರಲ್ಲಿ ಅಮೆರಿಕದ ತ್ರೀ ಮೈಲ್ ಐಲೆಂಡ್ ಹಾಗೂ ಅಂದಿನ ಸೋವಿಯತ್ ಯೂನಿಯನ್‌ನ ಚೆರ್ನೋಬಿಲ್‌ನಲ್ಲಿ ಸಂಭವಿಸಿದ ಅಪಘಾತಗಳಿಂದಾಗಿ ಬೈಜಿಕ ಸ್ಥಾವರಗಳ ಸುರಕ್ಷತೆಯ ಬಗ್ಗೆ ಅಲ್ಲಿನ ಜನರಲ್ಲಿ ಉದ್ಭವಿಸಿರುವ ಆತಂಕ. ಎರಡನೆಯದಾಗಿ, ಮುಂದುವರಿದ ರಾಷ್ಟ್ರಗಳಲ್ಲಿ ತಲಾ ವಿದ್ಯುತ್ ಬಳಕೆ ಈಗಾಗಲೇ ಸಾಕಷ್ಟು ಉನ್ನತ ಮಟ್ಟದಲ್ಲಿರುವುದರಿಂದ, ಯೋಜನಾ ತಂತ್ರಜ್ಞರ ದೃಷ್ಟಿಯಲ್ಲಿ ಸಧ್ಯಕ್ಕೆ ಹೊಸ ವಿದ್ಯುತ್ ಸ್ಥಾವರಗಳ ಅವಶ್ಯಕತೆ ಇಲ್ಲ. ಬದಲಾಗಿ ಉತ್ಪಾದನೆಯಲ್ಲಿ ಕೆಲವು ಸಣ್ಣಪುಟ್ಟ ಸುಧಾರಣೆಗಳನ್ನು (ಉದಾಹರಣೆಗೆ ಉಷ್ಣವಿದ್ಯುತ್ ಸ್ಥಾವರಗಳ ದಕ್ಷತೆಯನ್ನು ಹೆಚ್ಚಿಸುವುದು, ವಿದ್ಯುತ್ ಸಾಗಣೆಯಲ್ಲಿ ಉಂಟಾಗುವ ನಷ್ಟವನ್ನು ಕಡಿಮೆ ಮಾಡುವುದು, ಇತ್ಯಾದಿ) ಕಾರ್ಯರೂಪಕ್ಕೆ ತರುವುದರಿಂದ ಪ್ರಸ್ತುತದ ಬೇಡಿಕೆಗಳನ್ನು ನಿಭಾಯಿಸಲು ಸಾಧ್ಯವಾಗಿದೆ. ಅಲ್ಲದೆ, ಅಮೆರಿಕ ಮುಂತಾದ ರಾಷ್ಟ್ರಗಳಲ್ಲಿ ಕಲ್ಲಿದ್ದಲು, ತೈಲ, ನೈಸರ್ಗಿಕ ಅನಿಲ ಮುಂತಾದ ಪಳೆಯುಳಿಕೆ ಇಂಧನಗಳು ಸಾಕಷ್ಟು ಲಭ್ಯವಿವೆ.

✍ ಎಂ.ಎಸ್.ಎಸ್.ಮೂರ್ತಿ

ಆದರೆ ಅಭಿವೃದ್ಧಿಶೀಲ ರಾಷ್ಟ್ರಗಳ ಕಥೆಯೇ ಬೇರೆ. ಅಲ್ಲಿ ಊರ್ಜ ಬೇಡಿಕೆ ನಾಗಾಲೋಟದಿಂದ ಏರುತ್ತಿದೆ. ಅದನ್ನು ನಿಭಾಯಿಸಲು ಅವಶ್ಯವಾದ ಪಳೆಯುಳಿಕೆ ಇಂಧನ ನಿಕ್ಷೇಪಗಳು ಸಾಕಷ್ಟು ಇಲ್ಲ. ಇರುವ ನಿಕ್ಷೇಪಗಳೂ ಕೂಡ ಬಹು ಬೇಗ ಖಾಲಿಯಾಗುತ್ತಿವೆ. ಜತೆಗೆ ಇಂಧನ ಅಮದು ವಿಪರೀತ ದುಬಾರಿಯಾಗುತ್ತಿದೆ. ಈ ಎಲ್ಲ ಕಾರಣಗಳಿಂದಾಗಿ ಈ ರಾಷ್ಟ್ರಗಳಲ್ಲಿ ಪರ್ಯಾಯ ಊರ್ಜಯೋಜನೆಗೆ, ಅದೂ ಬೈಜಿಕ ವಿದ್ಯುತ್ ಯೋಜನೆಗೆ ಹೆಚ್ಚಿನ ಆಸ್ತೆ ಕೊಡಲಾಗುತ್ತಿದೆ. ಹಾಗಾಗಿ ಈಚಿನ ದಶಕಗಳಲ್ಲಿ ಬೈಜಿಕ ವಿದ್ಯುತ್ ಬೆಳವಣಿಗೆ ಬಹುಮಟ್ಟಿಗೆ ಏಷ್ಯ ಖಂಡದ ರಾಷ್ಟ್ರಗಳಲ್ಲಿ ಮಾತ್ರ ಕಂಡು ಬರುತ್ತದೆ.

ಆದರೆ ಇತ್ತೀಚಿನ ಘಟನೆಗಳಿಂದಾಗಿ ಪಶ್ಚಿಮ ರಾಷ್ಟ್ರಗಳಲ್ಲಿ ಪಳೆಯುಳಿಕೆ ಇಂಧನಕ್ಕೆ ಪರ್ಯಾಯವಾಗಿ ಇತರ ಇಂಧನಗಳ ಬಗ್ಗೆ ಆಸಕ್ತಿ ಉಂಟಾಗುತ್ತಿದೆ. ಅಂತಹ ಘಟನೆ ಗಳಲ್ಲಿ ಮುಖ್ಯವಾದದ್ದು ಭೂಮಿಯ ವಾತಾವರಣದ ಉಷ್ಣಾಂಶದಲ್ಲಿ ಆಗುತ್ತಿರುವ ಏರಿಕೆ ಅಥವ 'ಬಿಸಿ ಪ್ರಳಯ'.

ಈಚಿನ ದಿನಗಳಲ್ಲಿ ಭೂ ತಾಪ, ಅಂದರೆ ಭೂಮಿಯ ಸರಾಸರಿ ತಾಪ ಮಾನದಲ್ಲಿ ಕಂಡುಬರುತ್ತಿರುವ ಏರಿಕೆ ಎಲ್ಲೆಡೆ ಬಿಸಿಬಿಸಿ ಸುದ್ದಿ ಮಾಡುತ್ತಿದೆ. ಇಂದು ಭೂ ತಾಪ ಅಳೆಯಲು ಅನೇಕ ವೀಕ್ಷಣಾಲಯಗಳಿವೆ. ಆದರೆ ಶತ ಮಾನಗಳ ಹಿಂದೆ ಭೂತಾಪ ಎಷ್ಟಿದ್ದಿತು ಎಂದು ತಿಳಿಯುವುದು ಹೇಗೆ? ಅದಕ್ಕಾಗಿ ವಿಜ್ಞಾನಿಗಳು ಕೆಲವು ಚಾರಿತ್ರಿಕ ದಾಖಲೆಗಳು, ಮರಗಳ ಕಾಂಡದಲ್ಲಿರುವ ಉಂಗುರಗಳು, ಪುರಾತನ ಹಿಮ ಗಡ್ಡೆಗಳು ಇವುಗಳ ವಿಶ್ಲೇಷಣೆಗಳಿಂದ ಅದರ ಬಗ್ಗೆ ಲೆಕ್ಕಹಾಕುತ್ತಾರೆ. ಈ ರೀತಿಯ ಲೆಕ್ಕಾಚಾರಗಳ ಆಧಾರದ ಮೇಲೆ ೨೦ನೇ ಶತ ಮಾನದ ಆರಂಭದಿಂದ ಭೂಮಿಯ

ವಾರ್ಷಿಕ ಸರಾಸರಿ ತಾಪ ಏರುತ್ತಿದೆ ಎಂದು ತಿಳಿದು ಬಂದಿದೆ. ಇದು ಔದ್ಯೋಗಿಕ ಕ್ರಾಂತಿಯ ಆರಂಭದೊಂದಿಗೆ ತಾಳೆಯಾಗುತ್ತದೆ. ಅಲ್ಲದೆ, ೧೯೬೦ ರಿಂದ ಈಚೆಗೆ ಏರಿಕೆ ಗಣನೀಯವಾಗಿದೆ. ಈ ಕಾಲಾವಧಿಯಲ್ಲಿ ಭೂಮಿಯ ವಾರ್ಷಿಕ ಸರಾಸರಿ ತಾಪ ಸುಮಾರು ೦.೫೬ ಡಿಗ್ರಿ ಸೆಲ್ಸಿಯಸ್ ಹೆಚ್ಚಳವಾಗಿರಬಹುದು ಎಂದು ತಜ್ಞರ ಅಭಿಪ್ರಾಯ. ಭಾರತದಲ್ಲಿ ಕೂಡ ಹವಾಮಾನ ಇಲಾಖೆ ಈ ಹಿಂದೆ ಪ್ರಕಟಿಸಿರುವ ಅಂಕಿ-ಅಂಶಗಳ ಪ್ರಕಾರ ೧೯೦೧ರಿಂದ ೨೦೦೮ರ ನಡುವಿನ ಅವಧಿಯಲ್ಲಿ ವಾರ್ಷಿಕ ಸರಾಸರಿ ಭೂ ತಾಪ ೦.೫೨ ಡಿಗ್ರಿ ಹೆಚ್ಚಾಗಿದೆ.

ನಮ್ಮ ದೈನಂದಿನ ಅನುಭವಗಳೊಂದಿಗೆ ಹೋಲಿಸಿದಾಗ ಈ ಹೆಚ್ಚಳ ಮಹತ್ವದ್ದಲ್ಲ ಎನಿಸಬಹುದು. ಆದರೆ, ನಿಸರ್ಗದ ದೃಷ್ಟಿಯಲ್ಲಿ ಹಾಗಲ್ಲ. ಈ ಏರಿಕೆಯಿಂದಲೇ ಇಂದು ನಾವು ಹಿಮಗಡ್ಡೆಗಳು ಕರಗುವುದು, ಸಮುದ್ರ ಮಟ್ಟದಲ್ಲಿ ಏರಿಕೆ, ಪ್ರವಾಹ, ಅಕಾಲಿಕ ಮಳೆ, ಬರ, ಇತ್ಯಾದಿ ಹವಾಮಾನ ವೈಪರೀತ್ಯಗಳನ್ನು ನೋಡುತ್ತಿದ್ದೇವೆ.

ಭೂ ತಾಪ ಇದೇ ರೀತಿ ಮುಂದುವರಿಯುತ್ತಾ ಹೋದರೆ ಸಮುದ್ರ ಉಕ್ಕಿ, ತಗ್ಗು ಪ್ರದೇಶಗಳಲ್ಲಿ ಜಲಪ್ರಳಯುವಾಗಬಹುದು. ಅನಂತರದ ದಶಕಗಳಲ್ಲಿ ಮಳೆ, ನೀರಿನ ಕೊರತೆಯಿಂದಾಗಿ ಬರ, ಕ್ಷಾಮ, ರೋಗ ರುಜಿನಗಳು ಹರಡಿ ಮಾನವ ಹಾಗೂ ಇತರ ಪ್ರಾಣಿ ಸಂಕುಲದ ಅಸ್ತಿತ್ವಕ್ಕೇ ಧಕ್ಕೆಯಾಗಬಹುದೆಂದು ತಜ್ಞರು ಆತಂಕ ವ್ಯಕ್ತಪಡಿಸಿದ್ದಾರೆ.

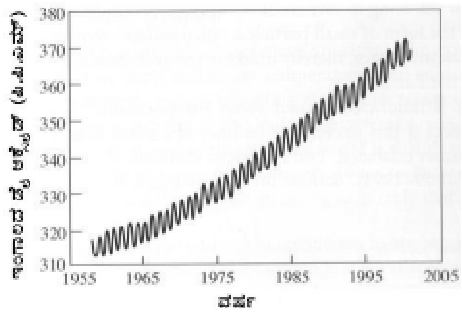
ಈ ಏರಿಕೆಗೆ ಮುಖ್ಯ ಕಾರಣವೆಂದರೆ ಮಾನವನ ಕೆಲವು ಚಟವಟಿಕೆಗಳು (ಕಲ್ಲಿದ್ದಲು ಉರಿಸಿ ವಿದ್ಯುತ್ ಉತ್ಪಾದನೆ, ವಾಹನಗಳು ಉಗುಳುವ ಹೊಗೆ, ಇತ್ಯಾದಿ) ಎಂದು ಮನವರಿಕೆಯಾಗಿದೆ. ಇವುಗಳಿಂದ ಬಿಡುಗಡೆಯಾಗುವ ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್, ಮೀಥೇನ್, ನೈಟ್ರೋಜೆನ್ ಮತ್ತು ಗಂಧಕದ ಆಕ್ಸೈಡ್‌ಗಳು, ಹೈಡ್ರೋಫ್ಲೂರೋ ಕಾರ್ಬನ್‌ಗಳು ಮುಂತಾದ ಹಸಿರು ಮನೆ ಅನಿಲಗಳು ಭೂಮಿಯ ಮೇಲೆ ಒಂದು ಹೊದಿಕೆಯಂತೆ ಹರಡಿಕೊಳ್ಳುತ್ತವೆ. ಈ ಹೊದಿಕೆಯು ಭೂಮಿಯಿಂದ ಪ್ರತಿಫಲಿತವಾದ ಸೂರ್ಯತಾಪವನ್ನು ಹೊರಗೆ ಹೋಗದಂತೆ ತಡೆದು ಭೂಮಿಗೇ ವಾಪಸ್ಸು ತಳ್ಳುವುದರಿಂದ ಭೂ ತಾಪ ಕ್ರಮೇಣ ಏರುತ್ತಿದೆ ಎಂಬುದು ವಿಜ್ಞಾನಿಗಳ ಅಭಿಮತ.

ಹಸಿರು ಮನೆ ಅನಿಲಗಳು ಯಾವ ಪ್ರಮಾಣದಲ್ಲಿದ್ದರೂ ಅಪಾಯಕರ ವೆಂದೇನಿಲ್ಲ. ಸಸ್ಯಗಳು ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್‌ನ್ನು ಹೀರಿಕೊಂಡು ಸೂರ್ಯನ ಬೆಳಕಿನ ಸಹಾಯದಿಂದ ಕಾರ್ಬೋಹೈಡ್ರೈಟ್‌ನ್ನು ಉತ್ಪಾದಿಸುತ್ತವೆ. ಮನುಷ್ಯ ಮತ್ತು ಇತರ ಪ್ರಾಣಿಗಳಿಗೆ ಲಭ್ಯವಿರುವ ವಿವಿಧ ಆಹಾರಗಳ ಮೂಲವೇ ಈ ಕಾರ್ಬೋ ಹೈಡ್ರೈಟ್. ಅಲ್ಲದೇ ಹಸಿರು ಮನೆ ಅನಿಲದ ಹೊದಿಕೆ ಇಲ್ಲದಿದ್ದರೆ, ಭೂಮಿಯ ಮೇಲೆ ಬಿದ್ದ ಸೂರ್ಯನ ಶಾಖವೆಲ್ಲಾ ಪ್ರತಿಫಲನಗೊಂಡು ಜೀವಿಗಳು ಬದುಕಲಾರದಷ್ಟು ಭೂಮಿ ತಣ್ಣಗಾಗುತ್ತಿತ್ತು. ಅಂದರೆ ಒಂದು ನಿಗದಿತ ಪ್ರಮಾಣ ದಲ್ಲಿ ಹಸಿರುಮನೆ ಅನಿಲಗಳೂ ಮಾನವನ ಪರಿಸರಕ್ಕೆ ಅವಶ್ಯಕ. ಆದರೆ, ಮಿತಿಮೀರಿದರೆ ಉಪಯುಕ್ತ ಸನ್ನಿವೇಶವೂ ಪ್ರತಿಕೂಲವಾಗ ಬಹುದೆಂಬುದಕ್ಕೆ ಇದೊಂದು ಉತ್ತಮ ನಿದರ್ಶನ.

ಈಗ್ಗೆ ಎರಡು ಶತಮಾನಗಳ ಹಿಂದೆ ಆರಂಭವಾದ ಔದ್ಯೋಗಿಕ ಕ್ರಾಂತಿಗೆ ಮುನ್ನ ವಾತಾವರಣಕ್ಕೆ ಅವಶ್ಯಕವಾದ ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್ ಹಾಗೂ ಇತರ ಹಸಿರುಮನೆ ಅನಿಲಗಳನ್ನು ಪ್ರಕೃತಿಯೇ ಒದಗಿಸುತ್ತಿತ್ತು. ಮನು ಷ್ಯರು ಹಾಗೂ ಪ್ರಾಣಿಗಳು ಶ್ವಾಸೋ ಚ್ಛಾಸ ಕ್ರಿಯೆಯಲ್ಲಿ ಆಮ್ಲಜನಕವನ್ನು ಹೀರಿಕೊಂಡು ಇಂಗಾಲದ ಡೈಆಕ್ಸೈ ಡ್‌ನ್ನು ಹೊರಬಿಡುತ್ತವೆ. ಅದೇ ರೀತಿ ಕೊಳೆತ ಸಸ್ಯಗಳು, ಸತ್ತ ಪ್ರಾಣಿಗಳು, ಜ್ವಾಲಾಮುಖಿ, ಕಾಡುಗಿಚ್ಚು ಇತ್ಯಾದಿ ಪ್ರಕೃತಿದತ್ತವಾದ ಕ್ರಿಯೆಗಳಿಂದ ಸೀಮಿತ ಪ್ರಮಾಣದಲ್ಲಿ ಇತರ ಅನಿಲಗಳೂ ವಾತಾವರಣಕ್ಕೆ ಬಿಡುಗಡೆ ಯಾಗುತ್ತಿದ್ದವು. ಭೂಮಿಯ ಧ್ರುವ ಪ್ರದೇಶಗಳಲ್ಲಿನ ಮಂಜುಗೆಡ್ಡೆ ನಿಕ್ಷೇಪ ಗಳಲ್ಲಿ ವಿವಿಧ ಆಳಗಳಿಗೆ ಬೈರಿಗೆ ಕೊರೆದು ಮಂಜುಗೆಡ್ಡೆ ತೆಗೆದು ಅವುಗಳಲ್ಲಿ ಸಂಯೋಜಿತವಾಗಿರುವ ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್‌ನ್ನು ವಿಜ್ಞಾನಿ ಗಳು ಅಳೆದಿದ್ದಾರೆ. ನಿಸರ್ಗದಲ್ಲಿ ಹಿಮಗಡ್ಡೆ ಸೃಷ್ಟಿಯಾದಾಗ ಅದರೊಂ ದಿಗೆ ಸ್ವಲ್ಪ ಗಾಳಿ ಕೂಡ ಸಂಯೋಜಿತವಾಗುತ್ತದೆ. ಆದ್ದರಿಂದ ಪುರಾತನ ಹಿಮ ರಾಶಿಗಳಲ್ಲಿ ಬೈರಿಗೆ ಕೊರೆದು ಅದರಿಂದ ಬಿಡುಗಡೆಯಾಗುವ ಗಾಳಿಯನ್ನು ವಿಶ್ಲೇಷಿಸುವುದರಿಂದ ಗತ ಕಾಲದ ವಾತಾವರಣದಲ್ಲಿ ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್ ಅಂಶ ಎಷ್ಟು ಇದ್ದಿರಬಹುದು ಎಂದು ಲೆಕ್ಕಹಾಕುವುದು ಸಾಧ್ಯ. ಈ ಅಧ್ಯನಗಳ ಆಧಾರದ ಮೇಲೆ ಕಳೆದ ಕೆಲವು ಶತಮಾನಗಳಿಂದ ವಾತಾವರಣದಲ್ಲಿ ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್‌ನ ಅಂಶ ಹೇಗೆ ಏರುತ್ತಿದೆ ಎಂಬುದರ ಬಗ್ಗೆ ಆಶ್ಚರ್ಯಕರ ಮಾಹಿತಿಗಳು ಒದಗಿವೆ.

ಔದ್ಯೋಗಿಕ ಕ್ರಾಂತಿಗೆ ಮುನ್ನ ಅನೇಕ ಶತಮಾನಗಳ ಕಾಲ ವಾತಾವರಣದಲ್ಲಿ ಸುಮಾರು ೨೮೦ ಪಿಪಿಎಮ್ (ದಶಲಕ್ಷದಲ್ಲಿ ಒಂದು ಭಾಗ) ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್ ಇತ್ತು. ಔದ್ಯೋಗಿಕ ಕ್ರಾಂತಿ ಆರಂಭವಾದನಂತರ, ನೈಸರ್ಗಿಕ ಮೂಲದ ಜತೆಗೆ ಮಾನವನ ವಿವಿಧ ಚಟುವಟಿಕೆಗಳೂ ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್ ಬಿಡುಗಡೆಗೆ ಕಾರಣವಾಗಿವೆ. ಇವುಗಳಲ್ಲಿ ಪ್ರಮುಖವಾದದ್ದು ವಿದ್ಯುತ್ ಉತ್ಪಾದನೆಗಾಗಿ ಕಲ್ಲಿದ್ದಲನ್ನು ಸುಡುವುದು. ಇದುವರೆಗೆ ಭೂಗರ್ಭದಲ್ಲಿ ಕಲ್ಲಿದ್ದಲು ಹೇರಳವಾಗಿ ದೊರಕುತ್ತಿದ್ದುದರಿಂದ ಅದನ್ನು ಉರಿಸಿ ಕಡಿಮೆ ವೆಚ್ಚದಲ್ಲಿ ವಿದ್ಯುತ್ ಉತ್ಪಾದಿಸಲಾಗುತ್ತಿತ್ತು. ಹಾಗಾಗಿ ಕಳೆದ ಎರಡು ಶತಮಾನ ಗಳಲ್ಲಿ ಅನಿಯಂತ್ರಿತವಾಗಿ ಅದರ ಬಳಕೆಯಾಗುತ್ತಿದೆ. ಅದರ ಪರಿಣಾಮವೇ ಇಂದಿನ ಹವಾಮಾನ ವೈಪರೀತ್ಯಕ್ಕೆ ಬಹುಮಟ್ಟಿಗೆ ಕಾರಣವಾಗಿದೆ.

ಪ್ರತಿ ಟನ್ ಕಲ್ಲಿದ್ದಲು ಸುಟ್ಟಾಗಲೂ ೩.೭ ಟನ್ ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್ ಬಿಡುಗಡೆಯಾಗುತ್ತದೆ. ವಿಶ್ವಸಂಸ್ಥೆಯ ಒಂದು ಸಮೀಕ್ಷೆಯ ಪ್ರಕಾರ ಪ್ರತಿವರ್ಷ ೭ ಬಿಲಿಯನ್ ಟನ್ ಕಲ್ಲಿದ್ದಲು ಬಳಕೆಯಾಗುತ್ತಿದ್ದು ಸುಮಾರು ೨೫ ಬಿಲಿಯನ್ ಟನ್ ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್ ವಾತಾವರಣವನ್ನು ಸೇರುತ್ತಿದೆ. ಹಾಗಾಗಿ ವಾತಾವರಣದಲ್ಲಿ ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್ ಪ್ರಮಾಣ ಔದ್ಯೋಗಿಕ ಕ್ರಾಂತಿಯ ಪೂರ್ವದಲ್ಲಿದ್ದ ೨೮೦ ಪಿಪಿಎಮ್‌ನಿಂದ ಈಗ ೪೦೦ ಪಿಪಿಎಮ್‌ಗೆ ಏರಿದೆ. ಇದೇ ರೀತಿ ಮುಂದುವರಿದರೆ ೨೦೫೦ರ ವೇಳೆಗೆ ಅದು ೫೦೦ ಪಿಪಿಎಮ್ ಮೀರಬಹುದೆಂದು ಅಂದಾಜು ಮಾಡಲಾಗಿದೆ. ಸಂಯುಕ್ತ ಸಂಸ್ಥೆಯ Intergovernmental Panel on Climate Change (IPCC) ಹಾಗೂ



ಭೂಮಿಯ ವಾತಾವರಣದಲ್ಲಿ ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್ ಅಂಶ

ಅಮೆರಿಕದ The National Research Council ವರದಿಗಳ ಪ್ರಕಾರ ಭೂತಾಪವು ೧೯೦೦ರಿಂದ ಈಚೆಗೆ ಅತಿ ಶೀಘ್ರವಾಗಿ ಏರುತ್ತಿದೆ ಎಂದು ತಿಳಿದು ಬಂದಿದೆ.

ವಿಪರ್ಯಾಸವೆಂದರೆ, ವಿಶ್ವ ಸಂಸ್ಥೆಯ ಲೆಕ್ಕಾಚಾರದ ಪ್ರಕಾರ ೨೦೫೦ರ ವೇಳೆಗೆ ವಿಶ್ವದ ವಿದ್ಯುತ್ ಬೇಡಿಕೆ ಇಂದಿಗಿಂತಲೂ ಶೇಕಡ ೧೬೦ ರಷ್ಟು ಹೆಚ್ಚುವ ನಿರೀಕ್ಷೆ ಇದೆ. ಈ ಹೆಚ್ಚಳದ ಬಹುಭಾಗ ಅಭಿವೃದ್ಧಿಶೀಲ ರಾಷ್ಟ್ರ ಗಳಿಂದ ಬರಲಿದೆ.

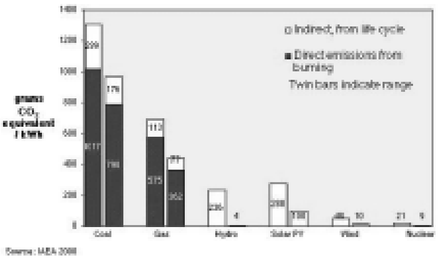
ಈ ಮಟ್ಟದ ಬೇಡಿಕೆಯನ್ನು ಪೂರೈಸುವುದು ಹೇಗೆ? ಅದರ ಜತೆಗೆ ಭೂತಾಪವನ್ನೂ ನಿಯಂತ್ರಿಸಬೇಕಾದರೆ ಕಲ್ಲಿದ್ದಲನ್ನು ಇಂಧನವಾಗಿ ಉರಿಸುವುದನ್ನು ಕಡಿಮೆ ಮಾಡಬೇಕು. ಆದ್ದರಿಂದ ಊರ್ಜತಜ್ಞರು ಇಂಗಾಲ ರಹಿತ ಊರ್ಜ ಮೂಲಗಳಕಡೆಗೆ ಗಮನ ಹರಿಸುತ್ತಿದ್ದಾರೆ. ಅದರಲ್ಲಿ ಬೈಜಿಕ ಊರ್ಜವೂ ಒಂದು.

ಬೈಜಿಕ ಇಂಧನದ ಆಯ್ಕೆಗೆ ಮುಖ್ಯ ಕಾರಣ

ಅದರಿಂದ ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್ ಹಾಗೂ ಇತರ ಹಸಿರು ಮನೆ ಅನಿಲಗಳು ಹೆಚ್ಚಿನ ಪ್ರಮಾಣದಲ್ಲಿ ಬಿಡುಗಡೆಯಾಗುವುದಿಲ್ಲ ಎಂಬುದು. ಬೈಜಿಕ ಇಂಧನ ಚಕ್ರದಲ್ಲಿ – ಗಣಿಗಾರಿಕೆಯಿಂದ ಹಿಡಿದು ತ್ಯಾಜ್ಯ ನಿರ್ವಹಣೆಯವರೆಗೆ ಒಂದು ಯೂನಿಟ್ ಕಿಲೊವಾಟ್ ವಿದ್ಯುತ್ ಉತ್ಪಾದನೆಯಲ್ಲಿ ಒಂದು ಗಂಟೆಗೆ ೯ ರಿಂದ ೨೧ ಗ್ರಾಮ್ ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್ ಉತ್ಪತ್ತಿಯಾಗುತ್ತದೆ. ಅಷ್ಟೇ ವಿದ್ಯುತ್ತನ್ನು ಕಲ್ಲಿದ್ದಲು ಉರಿಸಿ ಉತ್ಪಾದಿಸಿದರೆ ೧ ಕಿಲೋಗ್ರಾಮ್ ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್ ಬಿಡುಗಡೆ ಯಾಗುತ್ತದೆ. ಹಾಗಾಗಿ ಇಂದು ವಿಶ್ವದಾದ್ಯಂತ ಕಾರ್ಯ ನಿರ್ವಹಿ ಸುತ್ತಿರುವ ಬೈಜಿಕ ವಿದ್ಯುತ್ ಸ್ಥಾವರಗಳಿಂದಾಗಿ (ಸುಮಾರು ೩೮೪ ಗಿಗಾವಾಟ್ ವಿದ್ಯುತ್) ಸುಮಾರು ಎರಡು ಬಿಲಿಯನ್ ಟನ್ ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್ ಬಿಡುಗಡೆ ಯಾಗು ವುದನ್ನು ತಪ್ಪಿಸಿದಂತಾಗಿದೆ. ಅಮೆರಿಕದ MIT ಸಂಸ್ಥೆಯು ೨೦೦೩ ರಲ್ಲಿ "the Future of Nuclear Power" ಎಂಬ ಅಧ್ಯಯನ ಸಮಿತಿ ಯನ್ನು ಸ್ಥಾಪಿಸಿತು. ಅದರ ಪ್ರಕಾರ ಭೂತಾಪದ ಏರಿಕೆಯನ್ನು ತಡೆಗಟ್ಟ ಬೇಕಾದರೆ ೨೦೫೦ರ ವೇಳೆಗೆ ಸುಮಾರು ಒಂದು ಮಿಲಿಯನ್ ಮೆಗಾ ವ್ಯಾಟ್‌ನಷ್ಟು ವಿದ್ಯುಚ್ಛಕ್ತಿ ಬೈಜಿಕ ಸ್ಥಾವರಗಳಿಂದ ಬರಬೇಕು. ಅದರಿಂದ ಪ್ರತಿವರ್ಷ ೨ ರಿಂದ ೬ ಬಿಲಿಯನ್ ಟನ್ ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್ ಬಿಡುಗಡೆಯಾಗುವುದನ್ನು ತಪ್ಪಿಸಬಹುದು. ಅದರಲ್ಲಿ ಸುಮಾರು ಮೂರನೆ ಒಂದು ಭಾಗ ಅಮೆರಿಕದಲ್ಲಿ ಉತ್ಪತ್ತಿ ಯಾಗಬೇಕು. ಆ ಗುರಿಯನ್ನು ತಲಪಬೇಕಾದರೆ ಅಲ್ಲಿ ನೂರಾರು ಹೊಸ ಬೈಜಿಕ ಸ್ಥಾವರಗಳ ನಿರ್ಮಾಣವಾಗಬೇಕು.

ಪ್ರಸ್ತುತದಲ್ಲಿ ಬೈಜಿಕ ವಿದ್ಯುತ್ ಕಲ್ಲಿದ್ದಲಿನಿಂದ ಉತ್ಪತ್ತಿಯಾದ ವಿದ್ಯುತ್ತಿಗಿಂತಲೂ ಸ್ವಲ್ಪ ದುಬಾರಿ ಎಂಬುದು ನಿಜ. ಆದರೆ ಕಲ್ಲಿದ್ದಲು ಬಳಕೆಯನ್ನು ಕಡಿಮೆ ಮಾಡುವ ಉದ್ದೇಶದಿಂದ ಅದನ್ನು ಬಳಸುವವರಿಗೆ ಇಂಗಾಲ ತೆರಿಗೆ ಹೇರುವ ಯೋಜನೆ ಇದೆ. ಅಲ್ಲದೇ ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್‌ನ್ನು ಪರಿಸರಕ್ಕೆ ಬಿಡದಂತೆ ತಡೆಹಿಡಿಯುವ ಕೆಲವು ತಾಂತ್ರಿಕ ಯೋಜನೆಗಳನ್ನೂ ಕಡ್ಡಾಯ ಮಾಡಲಾಗುವುದು. ಈ ಎಲ್ಲ ಬೆಳವಣಿಗೆಗಳಿಂದ ಕಲ್ಲಿದ್ದಲು ವಿದ್ಯುತ್ತಿನ ಬೆಲೆ ಏರುವುದು ಅನಿವಾರ್ಯ. ಅಲ್ಲದೇ ಬೈಜಿಕ ವಿದ್ಯುತ್ತನ್ನು ಪ್ರೋತ್ಸಾಹಿಸಲು ಕೆಲವು ರಾಷ್ಟ್ರಗಳು ತೆರಿಗೆ ರಿಯಾಯತಿ ಯನ್ನೂ ಘೋಷಿಸಿವೆ.

ಇಂತಹ ಒಂದು ಬೃಹತ್ ಯೋಜನೆಯನ್ನು ಕಾರ್ಯಗತಗೊಳಿಸಲು ಅಮೆರಿಕ ಸರ್ಕಾರವು ೧೯೯೭ರಲ್ಲೇ Generation IV International Forum (GIF) ಎಂಬ ಆಯೋಗವನ್ನು ಸ್ಥಾಪಿಸಿತ್ತು. ಅದರ ಮುಖ್ಯ ಉದ್ದೇಶ ೨೧ನೇ ಶತಮಾನದಲ್ಲಿ



ವಿದ್ಯುತ್ ಉತ್ಪಾದನೆಗೆ ಬಳಸುವ ವಿವಿಧ ಇಂಧನಗಳಿಂದ ಬಿಡುಗಡೆಯಾಗುವ ಇಂಗಾಲದ ಡೈಆಕ್ಸೈಡ್ ಅಂಶ (ಪ್ರತಿ ಕಿಲೋವಾಟ್ ವಿದ್ಯುತ್ತಿಗೆ)

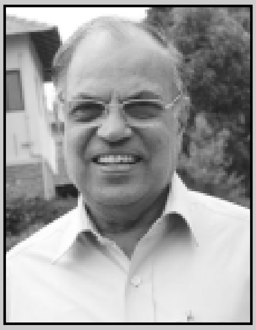
ವಿದ್ಯುತ್ ಉತ್ಪಾದನೆ ಯೋಜನೆಯಲ್ಲಿ ಬೈಜಿಕ ಸ್ಥಾವರ ಗಳಿಗೆ ಸೂಕ್ತ ಆಸ್ಥೆ ನೀಡುವುದು. ಅದಕ್ಕಾಗಿ ಅಂತರರಾಷ್ಟ್ರೀಯ ಮಟ್ಟದಲ್ಲಿ ಸುರಕ್ಷವಾದ ಹಾಗೂ ಮಿತ ವ್ಯಯವಾದ ಹೊಸ ರೀತಿಯ ಬೈಜಿಕ ಇಂಧನ ಚಕ್ರ ಹಾಗೂ ಕ್ರಿಯಾಕಾರಿಗಳ ಅಧ್ಯಯನ ನಡೆಸಿ, ೨೦೩೦ರ ವೇಳೆಗೆ ಪ್ರಶಸ್ತವಾದುದನ್ನು ಕ್ರಿಯಾಶೀಲಗೊಳಿಸುವುದು. ಅವುಗಳಲ್ಲಿ ವಿಕಿರಣ ತ್ಯಾಜ್ಯವನ್ನು ಸಮರ್ಪಕವಾಗಿ ನಿಭಾಯಿಸ್‌ಸುವ ಕ್ರಮಗಳನ್ನೂ ಅಳವಡಿಸಲಾಗುವುದು. ಕೆಲವು ಕ್ರಿಯಾಕಾರಿಗಳಲ್ಲಿ ಜಲಜಕವನ್ನು ಉಪಉತ್ಪಾದನೆಯಾಗಿ ತಯಾರಿಸಿ ಅದನ್ನೂ ಇಂಧನವಾಗಿ ಬಳಸುವ ಯೋಜನೆಯೂ ಇದೆ.ಇವೆಲ್ಲವೂ ಸಾಧ್ಯವಾಗಬೇಕಾದರೆ

ಬೈಜಿಕ ವಿದ್ಯುತ್ ಉತ್ಪಾದನೆಯಲ್ಲಿ ಸುರಕ್ಷತೆ ಹಾಗೂ ಮಿತ ವ್ಯಯಕ್ಕೆ ಆದ್ಯತೆ ನೀಡಬೇಕಾಗುತ್ತದೆ. ಅಂತರ ರಾಷ್ಟ್ರೀಯ ಪರಮಾಣು ಶಕ್ತಿ ಆಯೋಗವು ಅದಕ್ಕಾಗಿ International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) ಎಂಬ ಯೋಜನೆಯನ್ನೂ ೨೦೦೦ದಲ್ಲಿ ಆರಂಭಿಸಿದೆ. ಇದರಲ್ಲಿ ಅಭಿವೃದ್ಧಿಪಥದಲ್ಲಿರುವ ರಾಷ್ಟ್ರಗಳ ಅವಶ್ಯಕತೆಗೇ ಆದ್ಯತೆ ನೀಡಲಾಗಿದೆ. ಭಾರತವೂ ಈ ಯೋಜನೆಯಲ್ಲಿ ಸದಸ್ಯತ್ವ ಪಡೆದಿದೆ.

ಅದರ ನೇತೃತ್ವದಲ್ಲಿ ಬೈಜಿಕ ಸ್ಥಾವರಗಳಲ್ಲಿ ಸುರಕ್ಷತೆಯನ್ನು ಹೆಚ್ಚಿಸಲು ವಿಶ್ವದಾದ್ಯಂತ ಪ್ರಯೋಗಗಳು ನಡೆಯುತ್ತಿವೆ. ಉದಾಹರಣೆಗೆ, ಯೂರೋಪಿ ನಲ್ಲಿ Passive reactor system, ಜಪಾನಿನಲ್ಲಿ Pebble bed reactor ಮುಂತಾದ ಹೊಸಹೊಸ ವಿನ್ಯಾಸಗಳು ಅಧ್ಯಯನದಲ್ಲಿವೆ. Passive reactor systemನ ವಿಶಿಷ್ಟತೆ ಏನೆಂದರೆ ಅಪಘಾತ ಸಂಭವಿಸುವ ಪರಿಸ್ಥಿತಿ ಉತ್ಪತ್ತಿಯಾದರೆ, ಕ್ರಿಯಾ ಕಾರಿ ತಂತಾನೇ ಸ್ಥಗಿತಗೊಂಡು ಬಿಡುತ್ತದೆ. ಹಾಗಾಗಿ ಚಾಲಕರ ಬೇಜವಾಬ್ದಾರಿಯಿಂದಾಗಿ ಪರಿಸ್ಥಿತಿ ಕೈಮೀರಿ ಹೋಗುವ ಸಾಧ್ಯತೆ ಇರುವುದಿಲ್ಲ. ಭಾರತದಲ್ಲಿ ಕೂಡ ಮುಂದುವರಿದ ಭಾರಜಲ ರೀಯಾಕ್ಟರ್ (Advanced heavy water reactor) ಎಂಬ ಹೊಸ ವಿನ್ಯಾಸ ಪರಿಶೀಲನೆಯಲ್ಲಿದೆ. ಈ ದಿಕ್ಕಿನಲ್ಲಿ ಮತ್ತೊಂದು ಪ್ರಮುಖ ಬೆಳವಣಿಗೆ ಎಂದರೆ ವೇಗೋತ್ಕರ್ಷ ಚಾಲಿತ ರೀಯಾಕ್ಟರ್ (Accelerater driven reactor). ಸಾಂಪ್ರದಾಯಕ ರೀಯಾಕ್ಟರ್‌ನಲ್ಲಿ ವಿದಳನ ಸರಪಳಿ ಕ್ರಿಯೆಯನ್ನು ನಿರ್ವ ಹಿಸಲು ಅದರಲ್ಲಿ ಉತ್ಪತ್ತಿಯಾಗುವ ನ್ಯೂಟ್ರಾನ್‌ಗಳನ್ನೇ ಬಳಸಲಾಗು ವುದಷ್ಟೆ? ಈ ಹೊಸ ಮಾದರಿಯ ರೀಯಾಕ್ಟರ್‌ನಲ್ಲಿ ವೇಗೋತ್ಕ ರ್ಷದಲ್ಲಿ ಉತ್ಪತ್ತಿಯಾಗುವ ನ್ಯೂಟ್ರಾನ್‌ಗಳನ್ನು ಉಪಯೋಗಿಸ ಲಾಗುತ್ತದೆ. ಸುರಕ್ಷತೆಯ ದೃಷ್ಟಿಯಿಂದ ಇದರಲ್ಲಿ ಎರಡು ಅನುಕೂಲಗಳುಂಟು. ಒಂದು ಕ್ರಾಂತಿರಾಶಿ ಗಿಂತಲೂ ಕಡಿಮೆ ಪ್ರಮಣದಲ್ಲಿ ಇಂಧನವನ್ನು ಬಳಸ ಬಹುದು. ಹಾಗಾಗಿ ಇಂಧನದಲ್ಲಿ ವಿದಳನಸಾಂದ್ರತೆ ಅತಿಯಾಗಿ ಅಪಘಾತಕ್ಕೆ ನಾಂದಿಯಾಗುವ ಸಾಧ್ಯತೆಯೇ ಇರುವುದಿಲ್ಲ. ಎರಡನೆಯದಾಗಿ ಯಾವ ಕ್ಷಣದಲ್ಲಿಯಾದರೂ ವೇಗೋತ್ಕರ್ಷವನ್ನು ಸ್ಥಗಿತಗೊಳಿಸುವುದರಿಂದ ರೀಆಕ್ಟರ್‌ನ್ನು ನಿಷ್ಕ್ರಿಯಗೊಳಿಸಬಹುದು. ಅಲ್ಲದೇ ವಿದಳನ ಕ್ರಿಯೆಯಲ್ಲಿ ಉತ್ಪತ್ತಿಯಾಗುವ ದೀರ್ಘ ಅರ್ಧಾಯು ವಿಕಿರಣ ಧಾತುಗಳನ್ನು, ರೀಆಕ್ಟರಿನಲ್ಲೇ ನ್ಯೂಟ್ರಾನ್ ತಾಡನೆಗೆ ಒಡ್ಡಿ ಅವನ್ನು ಅಲ್ಪಾಯು ವಿಕಿರಣ ಧಾತುಗಳಾಗಿ ಪರಿವರ್ತನೆ ಮಾಡಬಹುದು. ಇದರಿಂದ ಬೈಜಿಕ ಘಟಕಗಳ ಮತ್ತೊಂದು ಸಮಸ್ಯೆಯಾದ ತ್ಯಾಜ್ಯ ವಸ್ತು ನಿರ್ವಹಣೆಯೂ ಸುಧಾರಿತ ವಾಗುತ್ತದೆ. ಆದರೆ ಈ ರೀತಿಯ ಹೊಸ ರೀಆಕ್ಟರ್‌ನ ಅಭಿವೃದ್ಧಿಯಲ್ಲಿರುವ ಪ್ರಮುಖ ಸಮಸ್ಯೆ ಎಂದರೆ, ಸಾಕಷ್ಟು ಶಕ್ತಿಶಾಲಿಯಾದ ವೇಗೋತ್ಕರ್ಷಕದ ಅವಶ್ಯಕತೆ. ಆ ಸಮಸ್ಯೆಯ ಪರಿಹಾರಕ್ಕಾಗಿ ಭಾರತ ವೂ ಸೇರಿದಂತೆ ಅನೇಕ ರಾಷ್ಟ್ರಗಳಲ್ಲಿ ಪ್ರಯೋಗಗಳು ನಡೆಯುತ್ತಿವೆ. ಹಾಗಾಗಿ, ಭವಿಷ್ಯದ ಬೈಜಿಕ ವಿದ್ಯುತ್ ಸ್ಥಾವರಗಳಲ್ಲಿ ಇಂದಿಗಿಂತಾ ಹೆಚ್ಚಿನ ಮಟ್ಟದ ಸುರಕ್ಷತೆ ಸಾಧ್ಯ.

ಅಲ್ಲದೆ, ಚೆರ್ನೋಬಿಲ್ ದುರಂತದ ನಂತರ ಬೈಜಿಕ ಕ್ರಿಯಾಕಾರಿಗಳಲ್ಲಿ ಗರಿಷ್ಠ ಮಟ್ಟದ ಸುರಕ್ಷತೆಯನ್ನು ಖಚಿತಪಡಿಸಿಕೊಳ್ಳಲು ಭಾರತವೂ ಸೇರಿದಂತೆ ೧೧೫ ರಾಷ್ಟ್ರಗಳು World Association of Nuclear Opeaators (WANO) ಎಂಬ ಸಂಸ್ಥೆಯನ್ನು ಸ್ಥಾಪಿಸಿವೆ. ಈ ಅಂತರರಾಷ್ಟ್ರೀಯ ಜಾಲವು ಪ್ರತಿ ರಾಷ್ಟ್ರದ ಬೈಜಿಕ ಕ್ರಿಯಾಕಾರಿಗಳ ವಿನ್ಯಾಸ, ಸುರಕ್ಷತೆ, ಮಿತವ್ಯಯ ಇವುಗಳನ್ನು ಪರಿಶೀಲಿಸಿ ಸೂಕ್ತ ಸಲಹೆ ನೀಡುತ್ತದೆ.

ಭವಿಷ್ಯದಲ್ಲಿ ಜಪಾನ್, ಚೈನ, ಉತ್ತರ ಅಮೆರಿಕ, ರಷ್ಯ, ದಕ್ಷಿಣ ಕೊರಿಯ ಮುಂತಾದ ಅನೇಕ ರಾಷ್ಟ್ರಗಳು ಬೈಜಿಕ ವಿದ್ಯುತ್ ಉತ್ಪಾದನೆಯ ಬಗ್ಗೆ ಭಾರತ ಕ್ಕಿಂತಲೂ ಮಿಗಿಲಾದ ಯೋಜನೆಗಳನ್ನು ಹಮ್ಮಿಕೊಂಡಿವೆ (ಕೋಷ್ಟಕ ೧ ನೋಡಿ). ಈ ಎಲ್ಲ ಲೆಕ್ಕಾಚಾರಗಳಿಂದ ಮುಂದಿನ ದಶಕಗಳಲ್ಲಿ ಪರಿಸರಪ್ರೇಮಿ ಬೈಜಿಕ ವಿದ್ಯುತ್ ಉತ್ಪಾದನೆಗೆ ಚೇತನ ದೊರಕುವ ಸಂಭವವಿದೆ. □



Dr.M.A.R.Iyengar, obtained his Master's degree in Inorganic Chemistry from Osmania University Hyderabad and joined the Health physics Division of AEET,Trombay (presently BARC), in 1961. He received his Ph.D degree from Bombay University, for his research thesis on the Marine Radioecological Aspects of the Kalpakkam coastal environment. Earlier between 1966-72, he also headed the Health Physics Unit at UCIL, Jaduguda, Singhbhum Dist, Jharkhand, and has contributed significantly in understanding the environmental impact aspects from uranium mining and milling operations. As Head, Environmental Survey Laboratory, Kalpakkam site (1973-99), which a hosts a major nuclear complex, he has carried out a number of field studies, R&D investigations in the Kalpakkam environment, including development of sensitive radiochemical techniques for environmental analyses.

Dr.M.A.R. Iyengar has been the Chief Scientific Investigator from India on the IAEA project on "Radium Distribution and Movement Aspects in the Environment ", and has contributed a monograph on the subject brought out by IAEA. He has represented India in a number of International meetings/ Conferences at Indonesia, Japan, France, Germany and USA. He was also deputed to Juelich, Germany as Visiting Scientist, during 1981-82. He has more than 100 research publications to his credit.

In his post-retirement phase, Dr.Iyengar is actively associated in finding solutions to the pollution problems relating to community water supplies, and has successfully developed an innovative technology for water purification, which is currently being commercially marketed by a leading Company.

Nuclear Energy – The Environmental Aspects

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INTRODUCTION

Energy in the form of electricity is a key input in the economic development and promotion of quality of life in contemporary human societies. Among the various sources of energy, nuclear power accounts for an average of 14% of the global electricity generation. Some countries like France, produce nearly 75% of its entire electricity requirements from Nuclear Power Plants (NPP's), while Japan and South Korea derive substantial electricity from nuclear energy (~31%). In India presently with 19 operating units of NPP's, around 2.9 % of national power grid, is contributed by nuclear power. However in a scenario of fast depletion of coal resources in the coming decades and the looming threat of the greenhouse effects on a global scale accompanying fossil fuel combustion, a shift to a more environmentally viable alternative route to energy generation assumes considerable significance. In this context nuclear energy appears to fit into the role very effectively, as nuclear electricity generation is singularly free from emission of greenhouse gases (CO_2, NO_x) and Sulphur dioxide, and devoid of massive problems of fly ash disposal in the environment, as in case of thermal power stations. However nuclear power plants do generate considerable radioactive wastes, which because of their significant in-built hazard potential, both to the operating personnel and neighborhood community, need careful handling and treatment, followed by approved safe disposal methods. However thanks to the advanced technology pioneered within, the nuclear industry in India, possesses some of the state of the art waste treatment technologies,-comparable with the best practices elsewhere-, and thus has largely been successful in safe handling and disposal of the radioactive waste effluents, ensuring safety of the environment and public. Apart from this, all radioactive effluent releases to the environment come under strict regulatory norms, for compliance purposes. Additionally, an extensive Environmental Monitoring Programme-in both preoperational and operational phases -is operated continuously in the public domain around all nuclear power plants and allied facilities, to objectively oversee environmental safety compliance aspects and evaluate any potential public exposure to radiation from the facilities.

Nuclear Energy and Environment

Generation of electricity by any means whether by coal, gas or oil or through hydel or nuclear energy is accompanied by certain amount of occupational and environmental risks. However several studies on comparative risk assessment of various energy options have clearly indicated that nuclear energy is no more hazardous than any other form of energy production. Radioactive releases into the environment, although generally on a limited scale, can occur during the operation of the various stages of the nuclear cycle. The characteristics of such releases, the behaviour of radionuclides released into the environment and the environmental monitoring programme to ensure public safety and the findings of a case study at MAPS, Kalpakkam are discussed here.

Environmental Radiation Pathways to Human Exposure

Radionuclides released to the environment from the nuclear facilities such as nuclear power plants eventually could reach man through various pathways. Radioactive materials released during the operation of various nuclear facilities could be in solid or liquid or gaseous form. However the radioactive effluents undergo appropriate treatment before release to the environment (Fig. 1). Gaseous activity released into the atmosphere gets dispersed via natural processes before deposition on the ground, depending on the site atmospheric conditions and the height of release. Similarly the radioactive liquid effluents released into the ambient waters, say a lake, or river or sea undergoes dilution in the water body. However the solid radioactive waste materials produced in nuclear facilities are normally contained within the site, by storage in specially engineered underground facilities, such as trenches and tile holes. The multibarrier systems designed for such facilities like, waste form, canister, steel liners, concrete covers, back filling materials etc., retard any possible migration of the radionuclides from the storage locations to surrounding environment.

Subsequent to the regulated release of the radioactive wastes into the biosphere, the radionuclides get distributed through different environmental pathways in different matrices such as water, vegetables, crops, milk, meat, fish, salt, etc. Fig. 2 shows some of the pathways in the environment through which man has a radiation exposure potential from radioactivity discharges to the environment.

a. Air Route

The gaseous radioactive effluents from nuclear power plants and fuel cycle facilities after appropriate off gas cleaning processes are released through tall stacks into the atmosphere. Following release, the concentration of a radionuclide in air at the ground level, is a function of the downward distance from the stack and the release height. More importantly however, the ground concentration of a radionuclide will be dependant on the specific site meteorological conditions during the release like, wind speed, wind direction, atmospheric stability conditions, terrain features etc.

The major pathways of exposure to an individual from the atmospheric release of radionuclides are

- Plume / cloud dose
- Immersion dose
- Inhalation dose

i. Plume / cloud dose

Radionuclides released into the atmosphere continuously at the stack level, will travel in downwind direction and undergoing steady dispersion, forming a standing plume. In case of an instantaneous or sporadic release, it will form a puff which will travel in the downwind direction and disperse instantly. Gamma emitting radionuclides if present in the plume will cause exposure at the ground level, even if the plume or cloud does not descend on the ground. This contribution to public exposure is termed as cloud gamma or plume dose. However alpha and beta emitters, if present in the plume will not contribute to the dose as the ranges of their radiations are short.

ii. Immersion Dose

A subject at the ground will be completely immersed in the radioactive cloud when the plume touches the ground. This will give the immersion dose. The beta radiation of the radionuclides contributes significantly to the dose through this route.

iii. Inhalation Dose

The radionuclides present in the air at the ground level will also lead to internal exposure through the inhalation route. A part of the inhaled nuclides will be retained in the body and a part will be exhaled. The deposition of the radionuclides in different parts of the lung will depend on the size of the aerosols. The fate of the deposited radionuclides will depend on the physio-chemical characteristics of the aerosols. The dose received by the individual will depend on the energy and the half life of the radionuclide and its residence time in the body. This dose is referred to as inhalation dose.

b. Terrestrial Route

During plume transit following release, the radioactive particulates will be removed by impaction of the plume by the surface/terrain over which the plume travels. The particle will also deposit on the surface due to gravitational settling -dry deposition, or by washout by water droplets in case of rain -wet deposition (Fig. 3).The radionuclides thus deposited on the ground can cause exposure to an individual via several pathways. They are as follows:

- External dose from deposited activity

The beta and gamma radiations from the radionuclides deposited on the ground contribute to external dose to a resident individual on the ground. The dose is typically calculated at a distance of one meter above the ground.

- Ingestion dose from intake of contaminated food

The radionuclide deposited on the soil is taken up by the plants through the roots and gets distributed in different parts of the plant. However some of the radioactivity released could directly be deposited on the leaf matrices, which could be partially taken up by the plant and partially blown off or washed down to the soil matrix, due to prevailing atmospheric conditions. The uptake fraction by the plant depends largely on the chemical characteristics of the radionuclide and the plant species. The consumption of the contaminated plant products like rice, wheat, fruits, vegetables, leaves etc., and such other dietary materials etc can lead to individual radiation exposures.

- Ingestion dose from intake of contaminated water
- Ingestion dose from contaminated milk from grass-cow-milk route

Radionuclides deposited on the grass are consumed by grazing animals. Following metbolisation a fraction of the ingested activity is secreted in the milk, which is an important component of human diet, particularly for growing children. This is an important route especially for Iodine-131 radionuclide, which gets released in substantial quantities following reactor accidents, and the infants among the affected population in the vicinity, could receive significant thyroid exposures from contaminated milk, as most of the ingested iodine ends up in thyroid.

- Inhalation dose from re-suspended particles from the surface

The deposited activity on the ground can get airborne once again due to the action of the wind or personnel/vehicular traffic. Such airborne activity contributes to the inhalation dose.

c. Water Route

Nuclear power plants and other fuel cycle facilities generate radioactive liquid wastes which after appropriate treatment and monitoring could be released to large water bodies like river or sea. Radionuclides released to the atmosphere also could deposit on a nearby water body and thus could constitute a source of radiation exposure of the community. Human radiation exposures could occur from various uses of water, such as, drinking, cooking, irrigation, fishing, swimming, water sports, and harvesting and consumption of aquatic organisms, etc.

One of the important pathways of exposure from water, following activity discharge is, through the ingestion of water and food like fish, crab and other benthic organisms. The aquatic plants and animals inhabiting surface waters generally tend to accumulate the radionuclides dispersed in water. Some of these species have the unique property of concentrating considerable activity levels of certain specific nuclides in their system. In fact it is this property which is made use of to identify certain critical nuclides and critical pathways of exposures. The concentration of a radionuclide in aquatic species is defined by concentration factor or bio-accumulation factor which is the ratio of the concentration of the radionuclide per unit mass in the species to the concentration of the radionuclide in the water. These concentration factors are nuclide specific and species specific, which could again be at variance for the same species in a fresh water or marine environment. Determination of these factors is an important component of the environmental monitoring programme for a given site.

Some examples of the concentration factors are given in the following Table.1.

Table.1.
Concentration Factor in Aquatic Foods [(Bq/kg)/(Bq/l)]

Element	Fresh Water Fish	Fish	Marine Molluscs
Sr	60	1	10
Cs	2000	50	10
Pu	4	1	1000
Co	300	100	1000

Environmental Monitoring Activities in DAE

India is among the very few countries which have demonstrated a proven capability to operate the entire Nuclear Fuel Cycle, and this includes the expertise in all aspects of health and safety operations of operating personnel, environment and public. The chief objective of the health and safety programme is to protect the operating personnel and members of the public from the harmful effects of radiation, adhering to the well laid down health and safety procedures in accordance with the international standards and regulations.

The primary objectives of the environmental protection policy followed at the sites of various nuclear facilities including PHWR's coming under the Department of Atomic Energy (DAE), are:

- The operations in a nuclear power plant shall not interfere in any manner with the proper utilization of the environmental resources outside its control.
- No deleterious effects of either acute or chronic nature shall accrue from nuclear operations and disturb the ecological balance of life forms including man in the environment under study.
- Radioactive and non-radioactive pollutants released to the environment shall be at such concentration levels and quantities that the resultant accumulation of radioactivity and other toxins in any component of environment will not pose a detriment to the ecosystem including the resident neighbourhood human community.

Environmental Survey Laboratories

In concordance with the above objectives, the Bhabha Atomic Research Centre has set up a chain of Environmental Survey Laboratories, (ESL's) throughout the country which is exclusively devoted to environmental surveillance, management and control at the site of each nuclear facility. These Laboratories are set up at each site, well before the commissioning of the nuclear facility, for carrying out baseline environmental surveillance for natural and fallout radioactivity levels in the environment. Presently as many as eleven ESL's are functioning in various parts of the country providing an extensive, year-round, environmental surveillance coverage for the utilities carrying out nuclear fuel cycle operations, including the Nuclear Power Plants at, Tarapur, Maharashtra, (1964), Ranapratap Sagar, Rajasthan (1972), Kalpakkam Tamilnadu (1974), Narora, U.P (1988), Kakrapur, Gujarat (1993), Kaiga, Karnataka(1996) and Kudankulam, Tamilnadu.

As a case study example, the environmental surveillance programme in operation at MAPS, the activities and findings of ESL, Kalpakkam are discussed below.

Case Study of MAPS, Kalpakkam

Kalpakkam hosts a major nuclear complex whose activities are centered around Madras Atomic Power Station (MAPS), India Gandhi Centre for Atomic Research (IGCAR), Kalpakkam Reprocessing Plant (KARP), with a host of service and R & D units supporting the overall activities. In accordance with the well considered policy adopted by the Department, Kalpakkam site has received extensive environmental surveillance, right from the inception stage of the site facility i.e., the pre-operational phase from 1974, which is being pursued steadily to this day, during the present operational phase.

As discussed above, the environmental health and safety objectives of the nuclear utilities are realized by putting in place an effective waste management system leading to an efficient control on environmental releases of radioactive and non-radioactive wastes conforming to stringent environmental standards, based on the recommendations of international bodies like, International Commission on Radiological Protection (ICRP) and International Atomic Energy Agency (IAEA)).

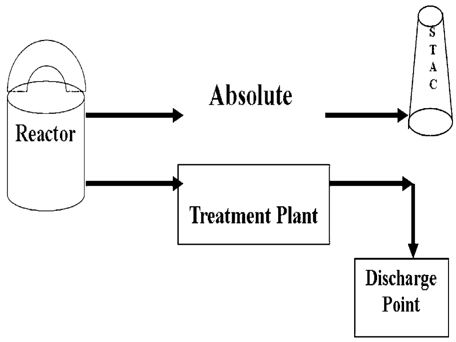
The primary objectives of the Environmental Survey Laboratory (ESL), Kalpakkam are as follows:

a) To establish baseline status for natural and fallout radioactivity in the site environment, before commissioning and operation of the Plant.
b) Environmental investigations on the behaviour of the discharged effluents, including the beneficial influence or otherwise of the local water movement and dilution availability etc., based on site micro-meteorological, hydrological data,
c) To obtain information on population distribution, professional activities, local dietary habits, identifying critical nuclides, critical pathways and population group,
d) Based on the above, deriving permissible limits for discharges of radioactive effluents.
e) Predicting environmental radiation doses from plant effluent releases with the application of appropriate environmental and dosimetric models.
f) Continuous dedicated environ mental surveillance in the 32 km surrounding zone by sampling and radioactivity analyses of various environmental matrices and assessment of the radiological exposures of the site population, during the operational phase, to oversee compliance with the regulatory limits.

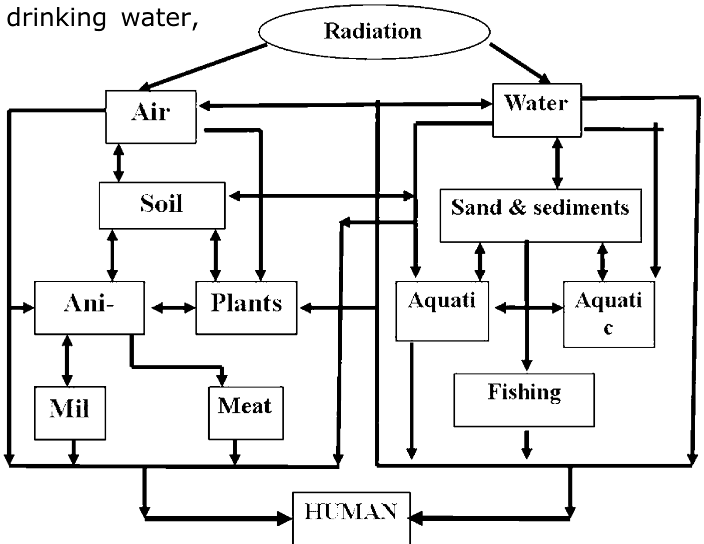
Right from 1974 till 1983, the environmental survey laboratory has carried out extensive Pre-Operational baseline radiological surveys in the environment, collecting valuable scientific data on radiation and radioactivity levels due to natural radiation and nuclear weapon related fallout activities. This survey also brought out interestingly, the occurrence of slightly enhanced natural radiation background in the Kalpakkam beach sands due to the occurrence of monazite, a radioactive mineral of Thorium. Also the survey enabled to detect the increased fallout activity levels at times, due to the Chinese weapon tests being held thousands of km away from the Indian mainland, thanks to the in-house development and standardization of very sensitive analytical techniques aiding the cause of environmental measurements. In particular, the ability of the pasture grazing animals like goats, whose thyroids have the potential to concentrate I-131 from the bomb fallout deposited in the environment in a significant way, was demonstrated. In fact, the pre-operational measurements of goat thyroids at Kalpakkam have successfully detected all the atmospheric nuclear tests conducted by China during the period (1976-1980), and later the fallout from Chernobyl accident, via the I-131 and goat-thyroid route. (Fig.3)

The atmospheric, terrestrial and aquatic samples which are systematically monitored under the programme belong to more than 25 types including air, soil, grass, milk, vegetables, cereals, drinking water, sea water, fishes, prawns and other seafood items, and whole diet of the population. These samples are subjected to radioactivity investigations, at ESL for reactor produced fission products (Cs-137, Sr-90, I-131 etc) and activation products (H-3, Co-60, Zn-65 etc) using advanced radiochemical procedures and employing state of the art nuclear counting and spectrometric instruments. Some of the environmental organisms have also been identified as index organisms, which play the role of highly sensitive environmental indicators e.g. goat thyroids for I-131, oysters for Zn-65, marine barnacles for Sr-90, and marine silt for Cs-137 etc.,.

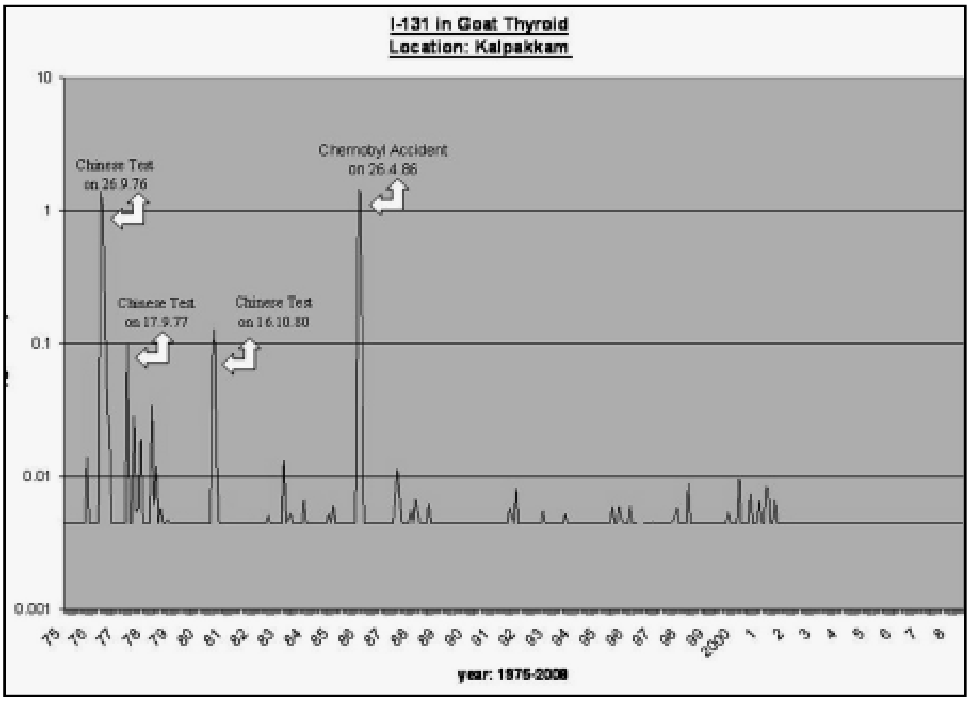
The environmental surveillance programme continues to be operated vigorously during the operational phase of MAPS from 1983 till date. The survey results have brought out clearly, that the level of environmental radioactivity



due to operational releases from MAPS, IACAR and other Units at site are at significantly low levels, due to a pragmatic combination of a sound waste management programme, constant up gradation of Reactor O & M practices and good adherence to regulatory aspects of waste discharges to the environment etc. Further, the environmental surveillance program carried out over nearly three decades,



has conclusively demonstrated that the annual dose at utility's immediate fence post (1.6km zone) has been less than 5% of ICRP dose limit (100 mrem/ year or 1 mSievert/year), which is mainly contributed by external exposure-i.e plume dose due to Argon-



the country, devoted to the maximum well being of man and his environment, while pursuing safe and viable power generation objectives. The environmental survey programme being carried out by ESL's (Units of Health, Safety & Environment. Group, BARC), throughout the country have demonstrated in good measure, the confidence placed on nuclear energy as a source of safe power, in meeting the growing energy demands in the nation's developmental efforts.

Fig.1 Schematic of Effluent Discharges from Nuclear Power Plant

Figure 2. Environmental Pathways to Human Exposure

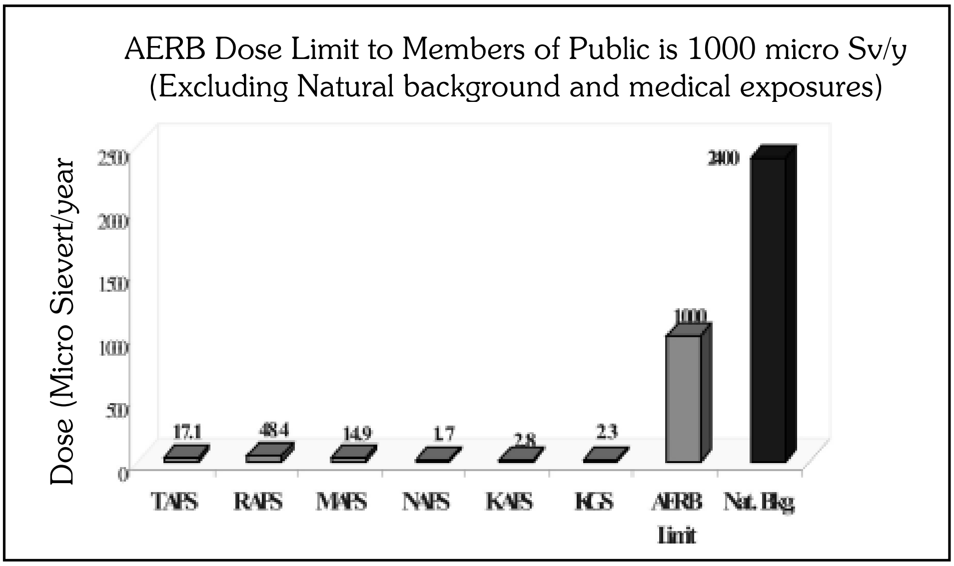
Figure 3. I-131 in goat thyroids at Kalpakkam.

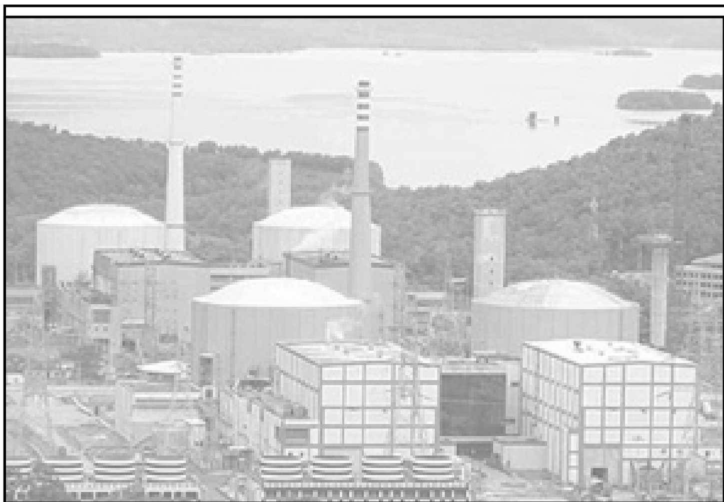
Figure 4. Environmental doses around NPP's in India

41,(T1/2:1.8 hrs), an activation product. At farther distances in the environment, these doses are even far less. For instance, the estimated dose in the 4.8 km zone which generally represents the public domain works out to be less than 1% of ICRP dose limit given above; thus demonstrating a very low and negligible impact of MAPS operations on the environment and public. The exposure levels in the environment of MAPS, Kalpakkam, together with other NPP"s at different sites, for the last few years, along with the natural background exposure levels and the permissible limits are given in Fig.4. A close look at the summarized presentation shows that the public radiation exposures from the operation of NPP'S are of a very low order and well below the permissible safety limits.

Conclusion

In conclusion it may be stated that the operations of MAPS reactors at Kalpakkam and NPP's in other regions of the country over the years, have resulted in least or negligible impact on the environment and public as convincingly demonstrated by the monitoring programme of a network of ESL's. This has been possible due the integrated efforts in evolving a conscious and purposeful safety philosophy by the nuclear industry in





Kaiga Power Plant

Safety Regulation of Nuclear Power Plants

✍ A.R. Sundararajan

1. Introduction

When Atomic Energy Act of 1962 was formulated to provide the development, control and use of atomic energy, considerable attention was given to nuclear and radiation safety aspects. This act has enabled framing of following rules related to radiation safety of all installations in the country handling radioactive materials or radiation generating equipment, which include the nuclear power plants.

1. Radiation Protection Rules, 1971, revised in 2004
2. Atomic Energy (working of Mines, Minerals and Handling of Prescribed Substances) Rules, 1984.
3. Atomic Energy (Safe Disposal of Radioactive Wastes) Rules, 1987

The Atomic Energy Regulatory Board (AERB) was constituted in 1983 by the Government of India with a mandate to carry out certain regulatory and safety functions under the Atomic Energy Act, 1962. AERB consists of a Chairman and four members appointed by Government of India. With respect to DAE installations, AERB has the following major functions and responsibilities.

i) Develop Safety Codes, Guides, Standards and Manuals for siting, design, construction, commissioning, operation and decommissioning of different types of facilities including nuclear power plants.

ii) Review of the safety aspects of DAE projects/ plants and issue authorisation/ licences for siting, construction, commissioning, operation and decommissioning of the plants.

iii) Ensure compliance of safety codes, standards etc. by Licensees.

2. Authorization Process for DAE Nuclear Installations

The regulatory authorisation process followed for a typical nuclear power plant is described here. The major stages of the authorisation process for nuclear power plants are siting, construction, commissioning (at different stages) and power operation (at different stages). Authorisation at each stage is preceded by a detailed review of all safety aspects of the proposal. In general, the safety review process is carried out at three different levels. In the first level the project is reviewed by Site Evaluation Committee (SEC), Project Design Safety Committee (PDSC) and Civil Engineering Safety Committee (CESC). The recommendations of these committees are reviewed at the next level of scrutiny through an Advisory Committee for Project Safety Review (ACPSR). These advisory committees are composed of experts not only from DAE and AERB but also from other governmental agencies and reputed academic institutions.

ACPSR after, its own assessment makes recommendations to AERB which is the statutory authorising agency. The Board can delegate its powers to Chairman, AERB for issue of authorisation for certain project activities. However, all important authorisation stages such as siting, construction, commissioning, first approach to criticality of reactors and first power generation stage are reviewed by the board. AERB while issuing the authorisation for a specific activity may stipulate the requirements and conditions governing the performance of the activity and where appropriate, specifies a time limit for the validity of the authorisation.

2.1 Siting

The main objective of the review before issue of authorisation for siting is to ensure that the applicant will be able to construct and operate nuclear power plants safely and to provide protection of the workers and the members of public against radiological impact resulting from releases of radionuclides during normal operations of the plant as well as under accidental conditions.

In evaluating the suitability of a site for locating a nuclear power plant, the following major aspects are considered:

i) Effect of external events (nature and man induced) on the plant
ii) Effect of plant on environment and population and
iii) Implementation of emergency procedures in the public domain

Sites for nuclear power plants shall be examined with respect to the frequency and the severity of external events and phenomena, natural and man made, that could affect the safety of the plant. All those events having significant radiological risk should be considered and their design bases determined. The radiological risks associated with external events should not exceed the range of radiological risks associated with the accidents of internal origin. For an external event, design basis should ensure that structures, systems and components important to safety in relation to that event will maintain their integrity and will not suffer loss of function during or after the design basis event.

While considering the natural events, it is important to collect the historical records of the occurrences and severity of the important natural phenomena for the region. The data collected shall be carefully analyzed for reliability, accuracy and completeness.

For each site, the potential radiological impact on people in the region during operational states and accident conditions shall be assessed. Consideration should be given to possible radiological consequences in the event of locating in the same site, other fuel cycle facilities like fuel fabrication, fuel reprocessing and waste management plants. Low population density in the region will help in achieving reduced population dose. It shall be ensured that effective implementation of emergency counter measures in case of an accident will be possible.

2.2 Construction

Like in siting, a three tier regulatory review is carried out for grant of authorisation of construction. The applicant is required to submit a Preliminary Safety Analysis Report (PSAR), a quality assurance program and a construction schedule along with the application for authorisation of construction. First tier review of the application for permission to construct the plant is conducted by Civil Engineering Safety Review Committee, constituted by AERB. Some of the important aspects of the project that are reviewed by this committee include the following:

- Geotechnical investigation data and foundation parameter
- Design basis ground motion
- Plant layout and surface drainage
- Engineering of site against natural and man made hazards
- Construction methodology

The second tier review is by ACPSR and the third tier review is by AERB before the issue of authorisation.

2.3 Commissioning

Commissioning is the process by which plant components and systems are made operational and verified to be in accordance with design specifications. The commissioning should also demonstrate that the plant could be operated in safe manner through integrated testing of the plant system. For grant of authorization for commissioning, the plant is required to submit a PSAR, Quality Assurance program documents. In addition the plant should also submit a list of all tests, related activities in their sequence, results expected, acceptance criteria and their relevance to the proposed operational limits and conditions if any. First tier review of the application for issue of authorization for commissioning is carried out by the Project Design Safety Committee. The second and third level reviews are carried out by ACPSR and AERB respectively, before the grant of authorization for commissioning. For Indian nuclear power plants, the authorization for commissioning is given in several interim stages and AERB Safety Guides are available that cover all aspects of commissioning procedures for nuclear power plants.

2.4 Operations

For comprehensive review of safety status and enforcement of safety regulations during the operational phase of nuclear power plants, a three-tier review structure has been put in place by AERB. At the plant level, a plant operation review committee reviews all operations and maintenance activities in the plant with potentials for safety problems. This committee reviews all unusual occurrences, deviations from Technical Specifications, modifications in the plant and changes in plant procedures.

Next higher-level review committee is the unit level safety committee. The reports from the plant operation review committee and the health physics unit at the plant provide the input for unit level safety review committee, which in turn reports to Safety Review Committee for Operating Plants (SARCOP) of AERB. Chairman, SARCOP is an AERB official and an ex-officio member of the Board of AERB. Unit level safety committees are constituted by Chairman SARCOP and have in their membership experts from AERB. Apart from the report from unit level safety committee, SARCOP receives as inputs for its review, periodic reports from AERB's Regulatory Inspection and Enforcement group and Quarterly reports of Health Physics units. In order to cater to the regulatory surveillance requirements of large number of operating plants, SARCOP meets very often and some of the meetings are held at the plant sites. SARCOP is empowered to impose restrictions or suspension of operation of the facility under intimation to DAE. Recommencement of operation after suspension following serious violations of safety norms or serious incidents will be permitted only after detailed review and approval by the regulatory board.

Other regulatory requirements to be complied with during the operational stage of nuclear plants include :

- licensing of operating personnel at various levels through committees constituted by SARCOP
- issue of authorization for disposal of radioactive wastes
- maintenance of emergency preparedness
- compliance with requirements of Atomic Energy Factory Rules

2.4 Decommissioning

Though decommissioning of nuclear power plants is not a problem of immediate concern in DAE, recognizing the importance of this activity, AERB has issued a Safety Manual on Decommissioning of Nuclear Facilities. The manual provides the regulatory framework of safety within which the decommissioning of an operating nuclear facility can be carried out at the end of its service life. It provides information on decommissioning, acceptance criteria and their bases, health physics considerations, waste management aspects, quality assurance practices and documentation requirements. It also includes an outline of design provisions to be made to facilitate decommissioning and recommends an organizational structure for the decommissioning activities.

3. Concluding Remarks

Atomic Energy Regulatory Board has been mandated to review, enforce standards and authorize from safety angle, siting, design, construction, commissioning, operation and decommissioning of nuclear installations. AERB over the years has put in place a sound regulatory framework and mechanism which permit the Department of Atomic Energy to construct and operate the nuclear power plants and associated fuel cycle facilities without undue risk to the operating personnel and members of the public.

The experience gained from the regulatory activities in the past several years has indicated that AERB, to carry out its function even more effectively, is required to augment the technical infrastructure and build up a wide knowledge base. To fulfill this need, AERB has set up a Safety Research Institute (SRI) at Kalpakkam to carry out safety-related research and analysis in certain areas of relevance to regulatory decision making. AERB is striving hard to expand its access to regulatory research work to support the independent evaluations of safety of nuclear power plants.

AERB places high importance on interaction with International Atomic Energy Agency (IAEA) and regulatory bodies of other countries as this helps in better understanding of the issues related to regulation of safety. AERB has signed memorandum of understanding with regulatory organizations of many advanced countries like USA, France, Russia etc. India is also a signatory to the International Convention on Nuclear Safety.

In the aftermath of major nuclear accidents like the ones at Chernobyl and Fukushima, AERB had appointed apex committees and working groups to review and study these events and ensured implementation of their recommendations on appropriate safety measures in our own nuclear power plants.

The effective functioning of the regulatory system in place in the country has been vindicated by the excellent safety record of the nuclear industry in the past five decades. However there has been a lot of criticism about the independence of AERB in the current organizational set up where AERB reports to the Atomic Energy Commission. To address this concern Government of India has proposed to establish an independent Nuclear Safety Regulatory Authority through an appropriate legislation. The proposed bill will provide for the establishment of a Council of Nuclear Safety (CNS), under the Prime Minister's chairmanship, to oversee and review the policies relating to radiation/ nuclear safety. □

Nuclear power cannot provide a solution to the climate change crisis. Concerns about global warming and climate change have been exploited by the nuclear industry to promote atomic energy by dubbing it "clean", "carbon-free" and environment-friendly. However, a number of studies have revealed that nuclear power is not a solution to climate change; rather, it becomes a dangerous quick-fix which will create more problems and aggravate them for the coming generations.

§ Nuclear power has a large carbon footprint—carbon-intensive processes are involved from mining to milling, enrichment, transportation, to reactor construction, heavy water production and spent fuel reprocessing, all the way to decommissioning reactors.

§ An assessment by the Massachusetts Institute of Technology and other studies estimate that we would need to build a minimum of 1,000 reactors worldwide for nuclear power to have any effect on global warming. This is wildly unrealistic, given the current decline in nuclear energy generation.

§ Even a massive, four-fold expansion of nuclear power by 2050 would provide only marginal reductions of 4 percent in greenhouse gas emissions, when we need global emissions to peak at 2015 and to be reduced by 80 to 90 percent by 2050. Thus, nuclear power can only make an expensive, late and marginal contribution to climate change mitigation.[i]

§ Uranium stocks, like those of any other mineral, are limited. Both the extraction cost of uranium and the carbon-intensity of the extraction process will rise rapidly after a few decades. This would make nuclear power's carbon footprint unacceptably large. [ii]

✍ P K Sundaram

§ Electricity is only a small part of our total energy consumption and nuclear energy is a much smaller sub-part of it. Carbon dioxide emissions are a cumulative effect of our entire energy consumption, including industrial processes, agriculture and other forms of direct combustion of fossil fuels. Nuclear energy just cannot replace all these processes.

§ There are plenty of credible and scientific studies by pioneer institutions and experts who have developed convincing models of a comprehensive "carbon-free, nuclear-free" energy policy [iii] with a proper mix of energy conservation, efficiency, R&D on renewable sources and larger social-political changes ensuring greater community and public use of resources which can help us in mitigating climate change effectively. [iv] □

(Kindly send your opinions/ views on the articles to Nesaru)

ವಿಜ್ಞಾನ ಮತ್ತು ಪ್ರಕೃತಿ/ಪರಿಸರ ಕುರಿತು

ವಿಜ್ಞಾನ ಮತ್ತು ತಂತ್ರಜ್ಞಾನದ ಬೆಳವಣಿಗೆ, ಪ್ರಭಾವ ಮತ್ತು ಪರಿಣಾಮಗಳು ಭೂಮಿಯ ಇಡೀ ಪ್ರಕೃತಿ/ ಪರಿಸರ ಮತ್ತು ಮಾನವ ಸಮಾಜಕ್ಕೆ ಸಂಬಂಧಿಸಿವೆ. ಈ ಹಿನ್ನೆಲೆಯಲ್ಲಿ ವಿಜ್ಞಾನದ ಸಾಮಾನ್ಯ ವಿದ್ಯಾರ್ಥಿಯಲ್ಲದ ನನಗೂ ವೈಜ್ಞಾನಿಕ ಸಂಶೋಧನೆ ಮತ್ತು ಬೆಳವಣಿಗೆಯ ದಿಕ್ಕು ದಿಸೆಗಳನ್ನು ಕುರಿತು ಆಲೋಚಿಸುವ ಹಕ್ಕು, ಅಧಿಕಾರ, ಜವಾಬ್ದಾರಿ ಇದೆ ಎಂದು ನಂಬಿದ್ದೇನೆ. ಆರಂಭದ ಹೆಜ್ಜೆಯಲ್ಲೆ ವೈಜ್ಞಾನಿಕ ಮನೋಭಾವ ತನ್ನ ಪ್ರಯೋಗ ಸಾಧ್ಯ ವಿಧಾನದ ಮೂಲಕ ಹೊಸ ಸತ್ಯಗಳ ಸ್ಥಾಪನೆ ಮಾಡಿ ಯೂರೋಪಿಯನ್ ಮತಧರ್ಮ ಭೂಮಿ ಮತ್ತು ವಿಶ್ವ ವ್ಯವಸ್ಥೆಯ ಬಗ್ಗೆ ಹೊಂದಿದ್ದ ಮತ್ತು ರೂಢಿಸಿದ್ದ ನಂಬಿಕೆಯನ್ನು ಸಡಿಲಗೊಳಿಸಿ ತಲೆ ಎತ್ತಿ ನಿಂತಿತು. ಅದೀಗ ಅದೆಷ್ಟೋ ಬೆಳಕಿನ ವರ್ಷಗಳ ದೂರದಲ್ಲಿರುವ ಮತ್ತೊಂದು ಗೆಲಕ್ಸಿಯಲ್ಲಿರುವ ಇನ್ನೊಂದು ಸಜೀವ ಭೂಮಿಯನ್ನು ಪತ್ತೆ ಮಾಡಿರುವ ವೈಜ್ಞಾನಿಕ ಸಾಧನೆಯ ಸಂದರ್ಭದಲ್ಲಿದೆ. ಇಂಥ ಅತ್ಯುನ್ನತ ಸಾಧನೆಯ ಈ ವಿಜ್ಞಾನ ಯುಗದಲ್ಲಿ ನಾವು ಜೀವಿಸುತ್ತಿರುವ ಭೂಮಿಯ ಸಜೀವತೆಯ ಸ್ಥಿತಿಗತಿಯುಲ್ಲುಂಟಾದ ಬದಲಾವಣೆಯ ಸ್ಥೂಲಾವಲೋಕನವನ್ನು ಪ್ರಕೃತಿ–ಮಾನವ ಸಂಬಂಧದಲ್ಲಿ ಮಾಡಬೇಕಾದ ಅಗತ್ಯತೆ ಉಂಟಾಗಿದೆ.

"ಪ್ರಕೃತಿಯಲ್ಲಿ ಅಡಗಿರುವ ರಹಸ್ಯಗಳನ್ನು ಬಯಲು ಮಾಡುತ್ತ ಅವುಗಳ ಸದುಪಯೋಗ ಮಾಡಿಕೊಂಡು ಬಂದಿರುವುದರಿಂದಲೇ ಶಿಲಾಯುಗದ ಪ್ರಾಣಿಯಂತಿದ್ದ ಮಾನವ ಸುಗುಣ ಸಂಪನ್ನನಾಗಿ ಸ್ವಾರಸ್ಯಮಯ ಜೀವನ ಸಾಗಿಸುವಲ್ಲಿ ಸಫಲನಾಗಿದ್ದಾನೆ. ಈ ರಹಸ್ಯಗಳನ್ನು ಪ್ರಾಯೋಗಿಕವಾಗಿ ಸಮರ್ಥಿಸಿ ಅವುಗಳನ್ನು ಮಾನವ ಕಲ್ಯಾಣಕ್ಕೆ ಉಪಯೋಗಿಸಿಕೊಳ್ಳಲು ಕಂಡುಹಿಡಿದ ಮಾರ್ಗೋಪಾಯಗಳನ್ನು ವೈಜ್ಞಾನಿಕ ಹೊಸ ಹೊಸ ತಂತ್ರಜ್ಞಾನಗಳೆಂದು ಗುರುತಿಸಿಕೊಂಡಿದ್ದೇವೆ." ಇದು ವಿಜ್ಞಾನದ ವಿದ್ಯಾರ್ಥಿ ತಳೆದಿರುವ ಅಚಲ ನಂಬಿಕೆಯಾಗಿದೆ. ಈ ಮಾತನ್ನು ಪರಿಶೀಲಿಸಿದರೆ, ವಿಜ್ಞಾನ ಮತ್ತು ತಂತ್ರಜ್ಞಾನ ಪ್ರಕೃತಿಯ ರಹಸ್ಯವನ್ನು ಮಾನವ ಕೇಂದ್ರಿತವನ್ನಾಗಿ ದುಡಿಸಿಕೊಂಡಿದೆ; ಪ್ರಕೃತಿಯ ಭಾಗವಾಗಿದ್ದ ಮಾನವನನ್ನು ಅದರ ಯಜಮಾನನನ್ನಾಗಿ ಮಾಡಿ ಅವನ ಹಿಡಿತಕ್ಕೆ ಒಳಪಡಿಸಿದೆ; ಇದರಿಂದ ಶ್ರಮ ಸಂಸ್ಕೃತಿಯ ಜೀವಿಯಾಗಿದ್ದ ಮಾನವನನ್ನು ಶ್ರಮರಹಿತ ಸಂಸ್ಕೃತಿಯ ಜೀವಿಯನ್ನಾಗಿ ಬದಲಾಯಿಸಿದೆ, ಅದನ್ನೆ ನಾಗರಿಕತೆ ಎಂದೂ ಮಾನವ ಚರಿತ್ರೆಯ ಸಕಾರಾತ್ಮಕ ಗುಣವೆಂದೂ ನಂಬಿಸಿರುವುದು ತಿಳಿದು ಬರುತ್ತದೆ, ಅಲ್ಲವೆ?

ಪ್ರಕೃತಿಯ ಅಗಾಧ ರಹಸ್ಯದ ಮೂಲವನ್ನು ಬಯಲು ಮಾಡುವ ಕಾರ್ಯದಲ್ಲಿ ತೊಡಗಿದ್ದೇನೆಂದು ನಂಬಿರುವುದೇ ಪ್ರಕೃತಿಯ ಭಾಗವಾಗಿರುವ ಮಾನವನ ಅಪಾರ ಬೌದ್ಧಿಕ ಅಹಂಕಾರದ ಪ್ರದರ್ಶನ ಮಾತ್ರವಾಗಿದೆ. ಇದು ಕುರುಡ ಆನೆಯ ಒಂದೊಂದೆ ಅಂಗವನ್ನು ಮುಟ್ಟಿ ಅದನ್ನೆ ಆನೆಯೆಂದು ಭ್ರಮಿಸುವ ಕತೆಯಂತಿದೆ. ರಾಜಕೀಯ ಪ್ರಾಣಿಯಾದ ಮಾನವ ತನ್ನ ಸ್ವಭಾವದಂತೆ ಪ್ರಕೃತಿಯಲ್ಲಿ ಅಡಗಿರುವ ಅಗಾಧ ಅರಿವಿನ ಶೋಧವನ್ನು ತನ್ನ ಸ್ವಲಾಭಕ್ಕಾಗಿ ಮಾಡುತ್ತಿದ್ದಾನೆ, ಆದರೂ ಅಸಾಧ್ಯವಾದ ಹೊಸ ಜ್ಞಾನಕ್ಷೇತ್ರದ ಸೃಷ್ಟಿಕರ್ತನಂತೆ ಬಿಂಬಿಸಿಕೊಳ್ಳುತ್ತಿದ್ದಾನೆ. ಹಾಗಾಗಿಯೇ ಅರಿವಿನ ಶೋಧ ಮಾನವನ ಬೌದ್ಧಿಕ ಜಗತ್ತಿನ ಇತಿಮಿತಿಯನ್ನೂ ಅದು ಇಡೀ

ಡಾ. ಶ್ರೀಧರ ಪಿಸ್ಸೆ, ಕಮಲಾಪುರ

ಪರಿಸರದ ಮೇಲೆ ಬೀರುವ ದುಷ್ಟ ಪ್ರಭಾವ ಮತ್ತು ಪರಿಣಾಮಗಳನ್ನೂ ತನ್ನ ಸೆರಗಲ್ಲೆ ಕಟ್ಟಿಕೊಂಡಿರುವುದು ನಮಗೆ ಅನುಭವಕ್ಕೆ ಬರುತ್ತಿದೆ. ಮಾನವ ಕಲ್ಯಾಣಕ್ಕಾಗಿ ಇಡೀ ಪ್ರಕೃತಿಯನ್ನು ದುಡಿಸಿಕೊಳ್ಳುವ ಕಲ್ಪನೆಯೆ ಪರಿಸರದ ಅಪವ್ಯಾಖ್ಯಾನದಿಂದ ಹುಟ್ಟಿದುದಾಗಿದೆ. ಪರಿಸರವನ್ನು ಮಾನವ ಕೇಂದ್ರಿತವನ್ನಾಗಿ ನೋಡುವ ನೋಟದಲ್ಲೆ ಪ್ರಕೃತಿ ಮತ್ತು ಪರಿಸರದಲ್ಲಿ ಅಡಕವಾಗಿರುವ ಸಮತೋಲನ ತತ್ವ ವಿರೋಧಿ ನಿಲುವಿದೆ. ಇದು ಯುರೋಪಿನಲ್ಲಿ ಪುನರುತ್ಥಾನದೊಂದಿಗೆ ಮೊಳಕೆಯೊಡೆದ ಆಕ್ರಮಣಕಾರಿ ಪ್ರವೃತ್ತಿ ವೈಜ್ಞಾನಿಕ ಬೆಳವಣಿಗೆಯಲ್ಲೂ ನೆಲೆ ಕಂಡುಕೊಂಡ ಪರಿಣಾಮ ವಾಗಿದೆ. ವಿಜ್ಞಾನ ಮತ್ತು ತಂತ್ರಜ್ಞಾನದ ಮಾರ್ಗೋಪಾಯದ ಮೂಲಕ ಪ್ರಕೃತಿಯನ್ನು ಮಾನವನ ಅನುಕೂಲಕ್ಕೆ ತಕ್ಕಂತೆ ಮಣಿಸಿದ ವಿಜಯೋತ್ಸಾಹ ಇಂದು ಅನುಭೋಗಿಸುತ್ತಿರುವ ವೈಜ್ಞಾನಿಕ ಸಾಫಲ್ಯತೆಯ ತುತ್ತತುದಿಯಲ್ಲಿ ಮಲಿನತೆಯೂ ತೀವ್ರತರವಾಗಿ ಹರಡಿ ಇಡೀ ಪರಿಸರ ಜೀವ ವಿರೋಧಿ ಸ್ವರೂಪ ಪಡೆಯಲು ಕಾರಣ ವಾಗಿದೆ. ಇಷ್ಟೆಲ್ಲ ವೈಜ್ಞಾನಿಕ, ನವನಾಗರಿಕತೆಗಳ ಸಾಧನೆಯ ನಂತರವೂ ಮಾನವ ತನ್ನ ಇರುವಿಕೆಗಾಗಿ ಹೋರಾಟ ಮಾಡುವ ಶಿಲಾಯುಗದ ಸ್ಥಿತಿಯಲ್ಲೇ ಇದ್ದಾನೆ ಎಂಬುದು ಕಪೋಲಕಲ್ಪಿತ ಸ್ಥಿತಿಯಾಗಿ ಉಳಿದಿಲ್ಲ. ಮಾನವ ಪ್ರವೃತ್ತಿಯಾದ ರಾಜಕೀಯ ಪ್ರಜ್ಞೆ ಮತ್ತು ಬೌದ್ಧಿಕ ಅಹಂಕಾರ ಅವನ ಅವಿವೇಕತನದ ಮಟ್ಟವನ್ನು ಮಾತ್ರ ಗುರುತಿಸುವ ಸಾಧನವಾಗಿದೆ ಎಂಬುದನ್ನು ವೈಜ್ಞಾನಿಕ ಸಾಧನೆಯ ಅಡ್ಡ ಪರಿಣಾಮಗಳು ಸೂಚಿಸುತ್ತಿವೆ. ಈ ಮಾತನ್ನು ಸಮರ್ಥಿಸಲು ಸಾಕಷ್ಟು ನಿದರ್ಶನಗಳು ಇಡೀ ಜಗತ್ತಿನ ಕಣ್ಣ ಮುಂದಿವೆ. ಸಾಮಾನ್ಯರ ನೆನಪಿಗೂ ಬರಬಹುದಾದ ಉದಾಹರಣೆಯೆಂದರೆ, ಹಿರೋಶಿಮಾ–ನಾಗಸಾಕಿ ದುರಂತ, ಚೆರ್ನೊಬಿಲ್ ದುರಂತ, ಭೂಪಾಲ್ ದುರಂತ, ಮಾತ್ರವಲ್ಲದೆ ಭೂಮಿಯ ಮೇಲಿನ ಸಕಲ ಜೀವಗಳ ಮೂಲಧಾತುಗಳಾದ ಅನ್ನ, ನೀರು, ವಾಯು, ಆಕಾಶ ಕ್ರಮೇಣ ವಿಷವಾಗಿ ಬದಲಾಗುತ್ತಿರುವ, ಅಗಾಧ ಪ್ರಮಾಣದಲ್ಲಿ ಜರುಗುತ್ತಿರುವ ಪರಿಸರ ಮಾಲಿನ್ಯ.

ಕ್ರಮಬದ್ಧ ಅಧ್ಯಯನ ವಿಧಾನದಿಂದ ಜ್ಞಾನ ಕ್ಷೇತ್ರಗಳು ಅಪಾರವಾಗಿ ವಿಕಾಸವಾಗಲು ಕಾರಣವಾಗಿರುವ ವೈಜ್ಞಾನಿಕ ಮನೋಭಾವ ತನ್ನ ತರ್ಕಶುದ್ಧತೆಯಿಂದ ಮತ್ತು ಹೊಸ ಅವಿಷ್ಕರದತ್ತ ನಿರಂತರವಾಗಿ ದಿಟ್ಟಿ ನೆಟ್ಟ ಪ್ರಯೋಗಶೀಲತೆಯಿಂದ ತನ್ನ ವ್ಯಾಪ್ತಿಯ ಮಿತಿಯನ್ನು ಗುರುತಿಸಿಕೊಳ್ಳುವಲ್ಲಿ ಸೋತಿದ್ದು ಕಾರಣವಿದ್ದಿರಬಹುದು ಎಂದು ನನ್ನ ಊಹೆ. ಇದನ್ನು ಹೀಗೂ ಹೇಳಬಹುದೇನೋ. ವಸ್ತುವಿನ ಭೌತಿಕ ಮೂಲಘಟಕ ಒಡೆಯಲು ಮಾಡಿದ ಪ್ರಯತ್ನ ಅಥವಾ ಮೂಲ ಘಟಕ ರಾಸಾಯನಿಕ ರೂಪವಾಗಿದ್ದಲ್ಲಿ ಅದನ್ನು ಕೃತಕವಾಗಿ ಸೃಷ್ಟಿಸುವ ಪ್ರಯತ್ನ ಅಥವಾ ಜೈವಿಕ ಕ್ರಿಯೆಯನ್ನು ಭೌತಿಕ ವಸ್ತುವಿನಂತೆ ಮತ್ತು ರಾಸಾಯನಿಕ ಕ್ರಿಯೆಯಂತೆ ಮರುಸೃಷ್ಟಿಸುವ ಪ್ರಯತ್ನಗಳು ಕಾರಣವಾಗಿರಬಹುದು.

ಮೊದಲ ಪ್ರಯತ್ನದಲ್ಲಿ ಅಣುಬಾಂಬು ನಿರ್ಮಾಣವಾದದ್ದೆ ಅಲ್ಲದೆ ಅದರ ಉಪಯೋಗ ಮಾನವ ಕಲ್ಯಾಣ ಎಂಬ ಆದರ್ಶ ಬೊಂಬೆಯನ್ನು ಸಮಾಧಾನ ಪಡಿಸಲು ತೋರಿಸಲಾಗುತ್ತದೆ ಯಾದರೂ ಮಾನವನ ವಿನಾಶಕ್ಕೆ ಹೆಚ್ಚು ಬಳಕೆಯಾಗಿದೆ. ಭೂ ಪ್ರಕೃತಿಯ ವಿನಾಶಕ್ಕೂ ಕಾರಣವಾಗಬಲ್ಲಷ್ಟು ಶಕ್ತವಾಗಿರುವ ಅಣುಶಕ್ತಿಯನ್ನು ಮಾನವ ತನ್ನ ಕುಲದ ಸ್ವನಾಶಕ್ಕೆ ಬಳಸದಿರಲಿ ಎಂದು ಸದಾ ಪ್ರಾರ್ಥಿಸಬೇಕಾದ ಸ್ಥಿತಿ ತಲುಪಿದ್ದೇವೆ. ಇದು ಒಂದು ಹಂತವಾದರೆ ಅಣುಶಕ್ತಿಯನ್ನು ಪ್ರಗತಿಯ ಉದ್ದೇಶಕ್ಕಾಗಿ ಬಳಕೆ ಮಾಡುವ ಸಂದರ್ಭದಲ್ಲಿ ಉಂಟಾದ ಅಚಾತುರ್ಯದ ಚಣಗಳಲ್ಲಿ ಸುತ್ತಲ ಪ್ರದೇಶದ ಜನಜೀವನ ನರಕಮಯವಾಗಿರುವುದು ಅದಕ್ಕಿಂತಲೂ ದಾರುಣವಾದುದಾಗಿದೆ.

ಈ ಹಂತದ ನಂತರದಲ್ಲಿ ಕೃತಕ ನೂಲು (ಸಿಂಥೆಟಿಕ್) ತಯಾರಿಕೆಯ ಮೂಲಕ ಇಡೀ ಜಗತ್ತು ಪ್ಲಾಸ್ಟಿಕ್ ಯುಗವಾಗಿ ಪರಿವರ್ತನೆ ಹೊಂದಿತು.

ಮಣ್ಣಿನಲ್ಲಿ ಕರಗುವ ಸಾವಯವ ಗುಣ ಕಳೆದುಕೊಂಡಿರುವ ಸಿಂಥೆಟಿಕ್‌ನಿಂದ ಮಾನವನ ಕಲ್ಯಾಣವನ್ನು ಕೇಂದ್ರೀಕರಿಸಿರುವಂತೆ ತೋರುವ ವಿಜ್ಞಾನ ಮತ್ತು ತಂತ್ರಜ್ಞಾನದ ಬೆಳವಣಿಗೆ ಇಡೀ ಪರಿಸರಕ್ಕೆ ಸವಾಲಾಗಿ ಪರಿಣಮಿಸಿದೆ. ಬಿಸಿಲಿನ ಝಳದಿಂದ ಕಾಪಾಡಿ ನೆರಳು ನೀಡುವ ಛತ್ರಿಯಂತಿದ್ದು ಇಡೀ ಭೂಮಿಯನ್ನು ಸೂರ್ಯನ ಕ್ಷ ಕಿರಣಗಳಿಂದ ಸಂರಕ್ಷಣೆ ಒದಗಿಸಿರುವ ಓಜೋನ್ ವಲಯದಲ್ಲಿ ಪ್ಲಾಸಿಕ್ ಸುಡುವಿಕೆ ತೂತು ಬೀಳುವಂತೆ ಮಾಡಿದೆ. ಪ್ರಕೃತಿಯ ಕೂಸಾಗಿರುವ ಮಾನವನಿಗೀಗ ವಿಜ್ಞಾನದ ಮೂಲಕ ಪರಿಸರಕ್ಕೆದುರಾಗಿರುವ ಕುತ್ತು ಸಕಲ ಜೀವ ಸಂಕುಲಗಳಿಗೆ ಮುಖಾಮುಖಿಯಾಗಿರುವ ಅಪತ್ತಾಗಿ ಮನವರಿಕೆಯಾಗುತ್ತಿದೆ. ಈ ಹಿನ್ನೆಲೆಯಲ್ಲಿ ಪ್ಲಾಸ್ಟಿಕ್‌ನ ಬಳಕೆ ತ್ಯಜಿಸಿ ಪ್ಲಾಸಿಕ್ ಯುಗದ ಪೂರ್ವಕ್ಕೆ ಮರಳಲು ತಹತಹಿಸಲಾಗುತ್ತಿದೆ. ಆದರೆ ಅದು ಅಷ್ಟು ಸುಲಭ ಸಾಧ್ಯವಾದ ಕಾರ್ಯವೆಂದೇನೂ ತೋರುವುದಿಲ್ಲ.

ಹಸಿರು ಕ್ರಾಂತಿಗೆ ಕಾರಣವಾದ ಕೃತಕ ರಾಸಾಯನಿಕ ಗೊಬ್ಬರಗಳ ತಯಾರಿಕೆ ಕೃಷಿಕ್ಷೇತ್ರದಲ್ಲಿ ದೊಡ್ಡ ಭ್ರಮೆಯನ್ನು ಸೃಷ್ಟಿಸಿದುದು ಅದರ ಅನುಸರಣೆಯಲ್ಲಿರುವ ರೈತರು ಆತ್ಮಹತ್ಯೆಗೆ ಮೊರೆ ಹೋಗುತ್ತಿರುವ ಸದ್ಯದ ಸ್ಥಿತಿಯಲ್ಲಿ ಅರ್ಥವಾಗುತ್ತಿದೆ. ಆ ನಂತರದ ಹಂತದಲ್ಲಿ ಬೆಳಕಿಗೆ ಬಂದ ಜೈವಿಕ ತಂತ್ರಜ್ಞಾನ, ಪ್ರಕೃತಿಯ ಸಂತಾನ ಪ್ರಕ್ರಿಯೆಯನ್ನು ಕೃತಕವಾಗಿ ಮರುಸೃಷ್ಟಿಸುವ ಜ್ಞಾನಶಾಖೆಯಾಗಿದೆ. ರಾಸಾಯನಿಕ ಗೊಬ್ಬರಗಳು ಭೂಮಿಯ ಫಲವಂತಿಕೆಯನ್ನು ಬಂಜರು ಭೂಮಿಯನ್ನಾಗಿ ಪರಿವರ್ತಿಸುವಲ್ಲಿ ಯಶಸ್ವಿಯಾಗಿವೆ, ಮತ್ತು ಮೂರನೆಯ ಜಗತ್ತಿನ ಆರ್ಥಿಕ ಬೆನ್ನೆಲುಬಾದ ಕೃಷಿಯನ್ನು ಬಹುರಾಷ್ಟ್ರೀಯ ಕಂಪನಿ ಮತ್ತದರ ಒಡೆಯ ದೇಶಗಳ ಹಿಡಿತಕ್ಕೆ ಸಿಗುವಂತೆ ಮಾಡುವಲ್ಲಿಯೂ ಯಶ ಪಡೆದಿವೆ.

ಜೈವಿಕ ತಂತ್ರಜ್ಞಾನದ ಮೂಲಕ ಇಡೀ ಸಸ್ಯ ಮತ್ತು ಪ್ರಾಣಿ ಸಂಕುಲಗಳೆಲ್ಲ ಸ್ವಾರ್ಥ ಮಾನವನ ದಾಳಗಳಾಗಿ ವಿನಾಶದ ಅಂಚಿಗೆ ತಳ್ಳಲಾಗುತ್ತದೆ. ವಿಶೇಷವೆಂದರೆ ಇದರಿಂದ ಮಾನವನೂ ಹೊರತಾಗದೆ ಹೋಗುವುದು ದೊಡ್ಡ ದುರಂತ. ಮಾನವ ಕೇಂದ್ರಿತವಾದ ವಿಜ್ಞಾನದ ಮಾನವ ಕಲ್ಯಾಣ ಕಲ್ಪನೆ ವೈರುಧ್ಯದ ತುಟ್ಟತುದಿ ತಲುಪಿದ್ದಕ್ಕೆ ಇದು ಉತ್ತಮ ನಿದರ್ಶನ ಎಂದು ಹೇಳಬಹುದು. ಇಷ್ಟಲ್ಲದೆ ಎಲ್ಲ ಕಾರ್ಖಾನೆಗಳೂ ಕೃತಕ ರಾಸಾಯನಿಕಗಳನ್ನೆ ಆಧರಿಸಿ ತಮ್ಮ ಚಟುವಟಿಕೆ ಮತ್ತು ಉತ್ಪನ್ನಗಳನ್ನು ಕೈಗೊಂಡಿವೆ. ಇದರಿಂದ ನದಿ ಸಾಗರಗಳು ಕೊಳಚೆ ಗುಂಡಿಗಳಾಗಿ ಬದಲಾಗುತ್ತಿವೆ. ಇವು ಈಗ ಉಂಟುಮಾಡುತ್ತಿರುವ ಮತ್ತು ಮುಂದೆ ಇನ್ನೂ ಹೆಚ್ಚು ಮಾಡಬಹುದಾದ ಪರಿಣಾಮಗಳು ಊಹೆಯನ್ನು ಮೀರಿದ್ದಾಗಿವೆ. ಕೃತಕ ರಾಸಾಯನಿಕಗಳ ಮೇಲಿನ ಅವಲಂಬನೆ ಮತ್ತು ಬಳಕೆ ಹೆಚ್ಚಿದಂತೆಲ್ಲ ಅದರ ಘೋರ ಪರಿಣಾಮಗಳು ಹೆಚ್ಚುತ್ತ ಸಾಗಿ ಭೂಲೋಕವೆ ನರಕ ಲೋಕವನ್ನು ಮೀರಿಸುವಂತಾಗುತ್ತದೆ.

ಮಾನವ ಕಲ್ಯಾಣಕ್ಕಾಗಿ ಪ್ರಕೃತಿ ಶಕ್ತಿಯನ್ನು ಬಯಲು ಮಾಡಲು ತೊಡಗಿದ ವಿಜ್ಞಾನ ಮತ್ತು ತಂತ್ರಜ್ಞಾನ ಎಡವಿದ್ದಾದರೂ ಎಲ್ಲಿ? ವೈಜ್ಞಾನಿಕ ಮನೋಭಾವದ ಬೌದ್ಧಿಕ ಅಸೀಮ ಸಾಹಸ ಮತ್ತು ತನ್ನ ಬಗ್ಗೆ ತಾನೇ ತಳೆದ ಸರ್ವಶಕ್ತತೆಯ ನಿಲುವು ಇದಕ್ಕೆ ಕಾರಣವೆ? ನನಗೊಂದು ಕತೆ ನೆನಪಿಗೆ ಬರುತ್ತಿದೆ. ಅದು ತೈತರೀಯ ಉಪನಿಷತ್ತೋ ಕಠೋಪನಿಷತ್ತೊ ಎಲ್ಲಿಯದೋ ಗೊತ್ತಿಲ್ಲ. ಆ ಕತೆಯ ನಾಯಕ ವಿದ್ಯೆ ಕಲಿಯುವ ಹುಡುಗ (ಹೆಸರು ನೆನಪಿನಲ್ಲಿಲ್ಲ). ಅವನು ಪಪ್ಪಾಯಿ ಮರ ನೋಡುತ್ತಾನೆ. ಆ ಮರದ ತುಂಬ ಹಣ್ಣು ಬಿಟ್ಟಿರುತ್ತದೆ. ಆ ಮರ ಹೇಗೆ ಹುಟ್ಟಿತು ಎಂಬ ಪ್ರಶ್ನೆಗೆ ಬೀಜದಿಂದ ಎಂದು ಉತ್ತರ ಸಿಗುತ್ತದೆ. ಅವನು ಪಪ್ಪಾಯಿ ಕುಯ್ದು ಅದರೊಳಗಿನ ಬೀಜ ನೋಡುತ್ತಾನೆ. ಬೀಜಗಳು ಕಪ್ಪಗೆ ಸಣ್ಣಗಿರುತ್ತವೆ. ಅಷ್ಟು ಸಣ್ಣ ಬೀಜದಿಂದ ಅಷ್ಟು ದೊಡ್ಡ ಗಿಡ ಹುಟ್ಟುತ್ತದೆಯೆ ಎಂದು ಅವನಿಗೆ ಅನುಮಾನವಾಗುತ್ತದೆ. ಇದು ನಿಜವೇ ಆಗಿದ್ದಲ್ಲಿ ಅದರೊಳಗೇನಿರಬಹುದು ಎಂದು ಬೀಜವನ್ನು ಕುಯ್ದು ಎರಡು ಹೋಳು ಮಾಡುತ್ತಾನೆ. ಆ ಬೀಜದೊಳಗೆ ಅವನಿಗೆ ಅಂಥ ವಿಶೇಷವಾದದ್ದು ಏನೂ ಕಾಣುವುದಿಲ್ಲ. ಕೊನೆಗೆ ಕತೆ ಶೂನ್ಯ ತತ್ವದೊಂದಿಗೆ ಮುಗಿತಾಯ ಕಾಣುತ್ತದೆ. ನಮಗಿಲ್ಲಿ ಕಾಣುವುದು ಪ್ರಕೃತಿಯ ರಹಸ್ಯವನ್ನು ಅರಿಯುವಲ್ಲಿ ನಮಗಿರುವ ದಾರಿಗಳು ಪರಿಮಿತವಾಗಿವೆ, ಈ ಸತ್ಯವನ್ನು ನಾವು ಒಪ್ಪಿಕೊಳ್ಳಬೇಕು ಎಂಬುದು. ಆಗ ಮಾತ್ರ ನಾವು ಪ್ರಕೃತಿಗೆ ಹಾನಿಯಾಗದಂತೆ ನಮ್ಮ ಅರಿವನ್ನು ವಿಸ್ತರಿಸಿಕೊಳ್ಳಲು ಸಾಧ್ಯ. ಪ್ರಕೃತಿಯ ಭಾಗವಾಗಿದ್ದೂ ಪ್ರಕೃತಿಯ ರಹಸ್ಯ ಶಕ್ತಿಯನ್ನು ನಮ್ಮ ಅನುಕೂಲಕ್ಕೆ ತಕ್ಕಂತೆ ಮಣಿಸುವುದು ಅತಿರೇಕದ್ದೆಂದು ಸೂಚಿತವಾಗುತ್ತದೆ. ಅಂಥ ಪ್ರಯತ್ನದಿಂದ ತೋರಿಕೆಗೆ ಅನುಕೂಲವಾದರೂ ಮೂಲದಲ್ಲಿ ನಮ್ಮ ಇರುವಿಕೆಗೆ ದೊಡ್ಡ ಪೆಟ್ಟು ಬೀಳುತ್ತದೆ. ಇದಕ್ಕೆ ವೈಜ್ಞಾನಿಕ ಮನೋಭಾವವೆ ಪ್ರಕೃತಿ ಬಗ್ಗೆ ತಳೆದ ಪೂರ್ವ ನಿರ್ಲಕ್ಷಿತ ಧೋರಣೆ ಕಾರಣವಾಗಿರುವಂತೆ ತೋರುತ್ತದೆ. ಇದನ್ನು ವಿಜ್ಞಾನದ ಪರಿಸರ/ಪ್ರಕೃತಿ ವಿರೋಧಿ ನಿಲುವು ಎಂದು ಗುರುತಿಸಬಹುದು.

ಹಾಗಿದ್ದಲ್ಲಿ ವಿಜ್ಞಾನದ ಪರಿಸರ ಸ್ನೇಹಿ ನಿಲುವು ಅಥವಾ ಮನೋಭಾವ ಯಾವುದಿರಬಹುದು ಎಂಬ ಪ್ರಶ್ನೆ ಮುಂದೆ ಬರುತ್ತದೆ. ಪ್ರಕೃತಿ/ಪರಿಸರ ಸ್ನೇಹಿ ವಿಜ್ಞಾನಕ್ಕೆ ಒಂದು ಉದಾಹರಣೆ ನೀಡಿ ಈ ಬರೆಹ ಮುಗಿಸಬಹುದೆಂದುಕೊಳ್ಳುತ್ತೇನೆ. ಮುಕ್ಕಾಲು ಪಾಲು ನೀರಿರುವ ಮನುಷ್ಯನ ದೇಹ ಭೂಮಿಯ ಪ್ರತಿರೂಪವೆಂದು ನಾನು ತಿಳಿಯುತ್ತೇನೆ. ಭೂಮಿಯಲ್ಲಿರುವ ಎಲ್ಲ ಅಂಶಗಳು ಮನುಷ್ಯನ ದೇಹಕ್ಕೆ ಅಗತ್ಯವಿದೆ. ಯಾವುದೇ ಅಂಶವೊಂದರ ಕೊರತೆಯುಂಟಾದಲ್ಲಿ ಅನಾರೋಗ್ಯ ಉಂಟಾಗುತ್ತದೆ. ಮಾನವನ ರೋಗಗಳಿಗೆ ಕೃತಕ ರಾಸಾಯನಿಕ ಗುಳಿಗೆಗಳು ಸಮರ್ಪಕ ಔಷಧೋಪಚಾರವಾಗಿರಲಾರದು. ಆದ್ದರಿಂದಲೇ ಗುಳಿಗೆಗಳಿಂದ ಅಡ್ಡ ಪರಿಣಾಮಗಳು ಉಂಟಾಗುತ್ತವೆ. ಸೂಕ್ತ ಔಷಧೋಪಚಾರ ಎನ್ನುವುದು ಗಿಡಮೂಲಿಕೆಗಳು (ಬೇರೆ, ಆಯುರ್ವೇದ ಬೇರೆ) ಮತ್ತಿತರ ಭೂಮಿಯ ಅಂಶಗಳಿಂದ ಮಾತ್ರ ಸಾಧ್ಯವಿದೆ. ಈ ಕುರಿತು ಅಧ್ಯಯನಗಳು ನಡೆದೇ ಇಲ್ಲ ಎಂದು ಹೇಳಬೇಕು. ಇತ್ತೀಚೆಗೆ ಕ್ಯಾನ್ಸರ್ ತಗುಲಿದ ಕೋಶಗಳನ್ನು ಕೊಲ್ಲಲು –ರೋಗ ಯಾವುದೇ ಹಂತದಲ್ಲಿರಲಿ– ಲಿಂಬೆಹಣ್ಣಿನ ಹುಳಿ ಕಿಮೊ ಥೆರಪಿಗಿಂತ ಹತ್ತು ಸಾವಿರ ಪಟ್ಟು ಹೆಚ್ಚು ಪರಿಣಾಮಕಾರಿ ಔಷಧವಾಗಿದೆ ಎಂದು ಇನ್ಸಿಟ್ಯೂಟ್ ಆಫ್ ಹೆಲ್ತ್ ಸೈನ್ಸಸ್, 819 ಎನ್ ಎಲ್ ಎಲ್ ಸಿ, ಚಾರ್ಲ್ಸ್ ಸ್ಟ್ರೀಟ್, ಬಾಲ್ಟಿಮೋರ್, ಎಂಡಿ 1201 ವಿಳಾಸದ ಸಂಸ್ಥೆಯೊಂದು ಪ್ರಚಾರ ಮಾಡುತ್ತಿದೆ.

ಸಿಹಿ ರುಚಿ ನೀಡುವ ಮಾವು, ಕಬ್ಬು, ಹಲಸು ಅಲ್ಲದೆ ನಮಗೆ ತಿಳಿಯದ ಬಹಳಷ್ಟು ಗಿಡಮರಗಳ ಹಣ್ಣುಗಳಿವೆ. ಬೇವಿನ ಹಣ್ಣಿನ ಸವಿರುಚಿಯನ್ನು ನಾವಾರೂ ಸವಿದಿಲ್ಲ. ಪ್ರತಿಯೊಂದೂ ಹಣ್ಣು ಬೇರೆಯೆ, ಅದರ ರುಚಿಯೂ ಬೇರೆಯೇ ಆಗಿವೆ. ಅವುಗಳಲ್ಲಿನ ಭೂಮಿಯ ರಾಸಾಯನಿಕ ಸಾರಾಂಶಗಳು ಕೂಡ ಬೇರೆ ಬೇರೆಯಾಗಿದ್ದು ಅವೆಲ್ಲವೂ ಮನುಷ್ಯ ದೇಹಕ್ಕೆ ಅಗತ್ಯವಿವೆ. ಯಾವ ಅಂಶಗಳ ಕೊರತೆ ಯಾವ ರೋಗಗಳಿಗೆ ಕಾರಣವಾಗುತ್ತದೆ. ಅಂಥ ಯಾವ ಅಂಶಗಳು ಪ್ರಕೃತಿ/ಪರಿಸರದ ಯಾವ ಗಿಡ ಮೂಲಿಕೆ ಅಥವಾ ಇತರ ಸಸ್ಯ ಮತ್ತು ಪ್ರಾಣಿಗಳ ಅಂಶದಲ್ಲಿ ಅಡಗಿದೆ ಎಂಬುದು ಬಹುಶಹ ಇದುವರೆಗೂ ಅಧ್ಯಯನದ ವ್ಯಾಪ್ತಿಗೆ ಒಳಪಟ್ಟಿಲ್ಲ. ಮಾನವ ಮತ್ತು ಪ್ರಕೃತಿಗೆ ಪೂರಕವಾದ ಇಂಥ ಕೃತಕ ರಾಸಾಯನಿಕಗಳ ನಿರ್ಮಾಣವನ್ನು ಒಳಗೊಳ್ಳದ ಅಧ್ಯಯನಗಳು ಪರಿಸರ ಸ್ನೇಹಿಯಾಗಿರಬಲ್ಲುದಾಗಿವೆ. ಇದೊಂದು ಸಣ್ಣ ಉದಾಹರಣೆಯಾಗಿದ್ದು ಯಾವುದೇ ಜ್ಞಾನದ ಶೋಧ ಪ್ರಕೃತಿ/ಪರಿಸರಕ್ಕೆ ಹಾನಿಯುಂಟಾಗ ಬಾರದೆಂಬ ಎಚ್ಚರದಿಂದ ಕೈಗೊಂಡಲ್ಲಿ ಅಂಥ ಎಲ್ಲ ಅಧ್ಯಯನಗಳು ಪರಿಸರ ಸ್ನೇಹಿಯಾಗಿರ ಬಹುದಾಗಿದೆ. ವಿಜ್ಞಾನ ಮತ್ತು ತಂತ್ರಜ್ಞಾನ ತನ್ನಿಂದ ಪ್ರಕೃತಿ/ಪರಿಸರಕ್ಕೆ ಹಾನಿಯಾಗದ ಆಶಯ, ಉದ್ದೇಶ ಮತ್ತು ವಿಧಾನಗಳನ್ನು ತುರ್ತಾಗಿ ಅಳಡಿಸಿಕೊಳ್ಳ ಬೇಕಾದುದು ಭೂಮಿ ಮೇಲಿನ ಇಡೀ ಜೀವ ಸಂಕುಲದ ಅವಶ್ಯಕತೆಯಾಗಿದೆ. ಇಂಥ ಧೋರಣೆಯ ಅಳವಡಿಕೆ ಮಾತ್ರ ಪ್ರಕೃತಿಯ ಭಾಗವಾದ ಮನುಷ್ಯಾದಿ ಸಕಲ ಜೀವ ಸಂಕಲಗಳ ಕಲ್ಯಾಣದ ಹಾದಿಯಲ್ಲಿ ವಿಜ್ಞಾನವನ್ನು ಮುನ್ನಡೆಸಲು ಸಾಧ್ಯ.

☐

NUCLEAR SHUTDOWN IN GERMANY

- Germany until March 2011 obtained one quarter of its electricity from nuclear energy, using 17 reactors.
- A coalition government formed after the 1998 federal elections had the phasing out of nuclear energy as a feature of its policy. With a new government in 2009, the phase-out was cancelled, but then reintroduced in 2011, with eight reactors shut down immediately.
- Public opinion in Germany remains ambivalent and at present does not support building new nuclear plants.

  Germany's electricity production in 2009 was 597 billion kWh gross, about 6400 kWh per capita. Coal provides two thirds of the country's electricity. Gas supplied 13%, wind 6% in 2009. Electricity exports exceedrd imports by about 20 billion kWh in 2008, but Germany is one of the biggest importers of gas, coal and oil worldwide, and has few domestic resources apart from lignite and renewables (but see later section).

The country's 17 operating nuclear power reactors, comprising 15% of installed capacity, supply about 28% of the electricity (133 billion kWh net in 2010). Many of the units are large (they total 20,339 MWe), and the last came into commercial operation in 1989. Six units are boiling water reactors (BWR), 11 are pressurised water reactors (PWR). All were built by Siemens-KWU. A further PWR has not operated since 1988 because of a licensing dispute.

Responsibility for licensing the construction and operation of all nuclear facilities is shared between the federal and Länder governments, which confers something close to a power of veto to both.

When Germany was reunited in 1990, all the Soviet-designed reactors in the east were shut down for safety reasons and are being decommissioned. These comprised four operating VVER-440s, a fifth one under construction and a small older VVER reactor.

In 2000 the European Commission approved the merger of two of Germany's biggest utilities, Veba and Viag, to form E.ON, which owned or had a stake in 12 of the country's 19 nuclear reactors which were operating then.

● Internet Download

Germany has about one third of Europe's installed wind generating capacity, amounting in 2008 to about 17% of its total capacity. This provided 6.4% of the electricity then.

Nuclear power policy

German support for nuclear energy was very strong in the 1970s following the oil price shock of 1974, and there was a perception of vulnerability regarding energy supplies. However, this policy faltered after the Chernobyl accident in 1986, and the last new nuclear power plant was commissioned in 1989. Whereas the Social Democratic Party (SPD) had affirmed nuclear power in 1979, in August 1986 it passed a resolution to abandon nuclear power within ten years.

The most immediate effect of this change of policy was to terminate R&D on both the high-temperature gas-cooled reactor and the fast breeder reactors after some 30 years of promising work, since much of the work was in North Rhine-Westphalia, which was governed by the SPD. A Christian Democrat (CDU) federal government then maintained support for existing nuclear power generation nationally until defeated in 1998.

In October 1998 a coalition government was formed between the Social Democratic Party (SPD) and the Green Party, the latter having polled only 6.7% of the vote.

As a result, these two parties agreed to change the law to establish the eventual phasing out of nuclear power.

Long drawn-out "consensus talks" with the electric utilities were intended to establish a timetable for phase out, with the Greens threatening unilateral curtailment of licenses without compensation if agreement was not reached. All operating nuclear plants have unlimited licences with strong legal guarantees.

In June 2000 a compromise was announced which saved face for the government and secured the uninterrupted operation of the nuclear plants for many years ahead. The agreement, while limiting plant lifetime to some degree, averted the risk of any enforced plant closures during the term of that government.

In particular, the agreement put a cap of 2623 billion kWh on lifetime production by all 19 operating reactors, equivalent to an average lifetime of 32 years (less than the 35 years sought by industry). Two key elements were a government commitment to respect the rights of utilities to operate existing plants, and a guarantee that this operation and related waste disposal will be protected from any "politically-motivated interference".

Other elements included: a government commitment not to introduce any "one-sided" economic or taxation measures, a recognition by the government of the high safety standards of German nuclear plants and a guarantee not to erode those standards, the resumption of spent fuel transports for reprocessing in France and UK for five years or until contracts expire, and maintenance of two waste repository projects (at Konrad and Gorleben).

In June 2001 the leaders of the Red-Green coalition government and the four main energy companies signed an agreement to give effect to this 2000 compromise. The companies' undertaking to limit the operational lives of the reactors to an average of 32 years meant that two of the least economic ones - Stade and Obrigheim - were shut down in 2003 and 2005 respectively, and the one non-operational reactor (Muelheim-Kaerlich, 1219 MWe) commenced decommissioning in 2003. It also prohibited the construction of new nuclear power plants for the time being and introduced the principle of on-site storage for spent fuel.

The agreement was a pragmatic compromise which limited political interference while providing a basis and plenty of time for formulation of a national energy policy. An industry leader reminded his government that "Reliable and cost-effective energy supply must remain an important component of German economic policy". Some speculation centred on the future of the agreement and the revised Atomic Energy Act which followed it under any new government. Parliamentary opposition party leaders said that they would reverse the decision when they could*.

* A major element in the federal government's war of attrition through 1999-2000 against the nuclear utilities was a law retrospectively to tax funds amounting to DM 50 billion which have been contributed by electricity users and set aside in trust as provision for waste management, decommissioning nuclear power plants and rehabilitating lignite mines. Early in 1999 industry promptly served notice that this would be vigorously contested as "a blatant breach of German constitutional rights and legal principles", as depletion of these funds by some DM 25 billion through the tax will leave future generations liable for much of the future costs. However, despite a scathing attack on it by the Chancellor, Mr Schroeder, in cabinet, the tax measure was approved by the upper house on the last day that the new coalition enjoyed a majority there.

The Federal Ministry of Economics & Technology (BMWi) implements national energy policy.

Utilities wanted to extend the lifetimes of all 17 reactors initially to 40 years (from average 32 years) and then individually seeking extensions to 60 years as in the USA.

The new Christian Democrat (CDU) and Liberal Democrat (FDP) coalition government elected in September 2009 was committed to rescinding the phase-out policy, but the financial terms took a year to negotiate. If reactor lifetimes were extended from average 32 years to 60 years, the four operating companies would have reaped additional gross profit of EUR 100 billion or more, and the government was keen to secure more than half of this - much more than its extra tax revenue.

In September 2010 a new agreement was reached, to give 8-year licence extensions (from 2001-agreed dates) for reactors built before 1980, and 14-year extensions for later ones. The price exacted for this was several new measures: a tax of EUR 145 per gram of fissile uranium or plutonium fuel for six years, yielding EUR 2.3 billion per year (about 1.6 c/kWh), payment of EUR 300 million per year in 2011 and 2012, and EUR 200 million 2013-16, to subsidise renewables, and a tax of 0.9 c/kWh for the same purpose after 2016. However, utilities may reduce their contribution to renewables if safety upgrades to particular individual nuclear plants cost more than EUR 500 million. At the end of October these measures were confirmed by parliamentary vote on two amendments to Germany's Atomic Energy Act, and this was confirmed in the upper house in November.

All these arrangements were thrown into doubt when in March 2011 the government declared a three-month moratorium on nuclear power, in which checks would take place and nuclear policy would be reconsidered. Chancellor Angela Merkel decreed that the country's nuclear power reactors which began operation in 1980 or earlier should be immediately shut down. Those units then closed and were joined by another unit already in long-term shutdown, making a total of 8336 MWe offline under her direction, about 6.4% of the country's generating capacity.

The reactors affected are Biblis-A, Neckarwestheim 1, Brunsbuettel, Biblis-B, Isar 1, Unterweser, Phillipsburg 1. Already in a long-term shutdown was Kruemmel and this was included despite having started up in 1984. Over the three months the impact on the German government from loss of income via its unique nuclear fuel tax could be around €235 million. RWE filed a lawsuit against the government regarding closure of its Biblis-B.

Then on 30 May 2011, after increasing pressure from anti-nuclear federal states, the government decided to revive the previous government's phase-out plan and close all reactors by 2022 but without abolishing the fuel tax, thus reneging on the new fuel tax trade-off. The Bundestag passed the measures by 513 to 79 votes at the end of June, and the Bundesrat vote on 8 July confirmed this. Both houses of parliament approved construction of new coal and gas-fired plants despite retaining its CO2 emission reduction targets, as well as expanding wind energy.

This leaves the eight oldest reactors closed, and will result in the remaining nine closing by the end of 2022. France, Poland and Russia (Kaliningrad) are expecting to increase electricity exports to Germany, mostly from nuclear sources, and Russia is expected to export significantly more gas.

Fukushima and the Future of Nuclear Power
A Green Cross International Perspective

The nuclear disaster resulting from the unprecedented earthquake and tsunami that hit Japan in early March has revived the debate over the future of nuclear power worldwide. Public opinion polls around the world reveal record anti-nuclear public attitudes. According to recent surveys, 87% of people in Switzerland (Le Matin,19.03.2011) and around 70% in the US want to move away from nuclear energy. A number of countries, such as Germany, Italy, China, India, Russia and Venezuela, have either put their plans for new plants on hold, called for reviews of their safety procedures, or called for upgraded security measures for new plants. The disaster in Japan has highlighted the limits of human ability in keeping dangerous technologies free from catastrophic accidents. Natural disasters, combined with human error and negligence, have once again proven a potent force for undermining even the best-laid plans. The faith in human perfection reflects a hubris that has led to other major failures of dangerous technologies in the past, and will continue to do so in the future. Of course, what has occurred accidentally in Japan as a result of the confluence of natural disaster and human error could be triggered deliberately by an act of terrorism or war.

As Japan struggles to confront a nuclear disaster that could turn out to be the worst in history, it is vital that any discussion about the future of nuclear energy addresses the issue comprehensively and in all its complexity. Nuclear power, despite numerous accidents in many countries, has been presented as a financially sound, economically efficient, clean and safe solution that will bring about energy security and drive economic growth. Recently, the so-called "nuclear renaissance" has hitched a free ride on the back of the need to find low-carbon solutions to the climate crisis. One must note that Japan has a history of nuclear accidents dating back to 1978 when a malfunctioning nuclear reactor took seven hours to shut down. In 1995 the Monju fast-breeder reactor leaked sodium coolant and caught on fire; it did not reopen until 2010. In 2003 seventeen nuclear reactors were shut down after false inspection reports. And in 2007 a 6.8 earthquake started a fire at a reactor northwest Japan and led to a radioactive water leak.

Nuclear power is neither the answer to modern energy problems nor a panacea for addressing climate change. We should not overcome challenges by resorting to "solutions" that create even more problems. Nuclear energy does not add up economically, environmentally or socially. Of all the energy options, nuclear is the most capital intensive, decommissioning is prohibitively expensive and nuclear waste carries a multi-faceted burden that continues centuries after a plant is closed.

With all these shortcomings it is not surprising that global nuclear energy production has been declining since 2006. Its share of the world electricity mix has dropped even more rapidly as global energy demand has grown. Since its peak in 1986 at 16% of the total electricity mix globally, nuclear power's contribution has dropped down to 13-14% in 2009. Despite multi-billion dollar direct and even larger indirect subsidies to the nuclear energy sector – all at the expense of the taxpayer - private capital continues to shy away from the industry. Investments in nuclear power are primarily industry lobbied and taxpayer financed. In the US, for instance, direct subsidies to nuclear energy amounted to $115 billion between 1947 and 1999, with a further $145 billion in indirect subsidies. Most recently, the Obama administration has promised some $55 billion in new subsidies to nuclear power. In contrast, subsidies to wind and solar combined during the same period totaled only $5.5 billion. Nuclear power plants are outrageously expensive. Their construction and maintenance are plagued by delays and massive cost overruns. One of the newest nuclear power plants now under construction, a European Pressurized Water Reactor (EPR) at Olkiluoto, Finland, being built by the French company, Areva, is now over four years behind schedule and some 50% over budget.The decommissioning of ageing nuclear plants including deconstruction of the facility and long-term waste remains a drag on public finances and taxpayers long after a plant has closed. Power plants in the US have accumulated nearly 72,000 tons of nuclear waste across 31 states, reaching the capacity of temporary storage facilities with no permanent solution in sight. In the United Kingdom the cost of dismantling outdated plants amounted to £40.7 billion while the construction and lifetime costs of a deep geological disposal facility required a further £3.4 billion. The financial and safety liabilities of storage sites will be borne by many generations to come.

The bottom line on the economics of nuclear power is that it simply does not add up. That is why private investment is wisely focusing on better alternatives. In the US a dollar invested in energy efficiency can deliver five times more electricity than nuclear power while investments in wind energy can produce 100% more electricity. Renewable energy – wind, solar, and geothermal – comprised more then 90% of the increase in global electricity production in 2007 and 2008. Some 50% of new generating capacity in 2008 and 2009 was renewable. And in 2010 renewables won $151 billion of private investment and added over 50 billion watts in electric generating capacity. Since 2007, nuclear energy growth has added less than solar power in annual output.Nevertheless it would be a mistake to think that we can abandon nuclear power overnight. With 15 countries relying on nuclear for 25% or more of their electricity, we have to get to grips with the presence of nuclear plants for years to come. More than 440 nuclear reactors are operating in the world today. However, after what happened in Japan, we can anticipate growing calls for decommissioning older plants. 66 reactors are listed as "under construction", although some have been in that status for decades and most of them still have no start date. Interestingly, 50 are in just four countries – China, India, Russia and South Korea, all of them state subsidized. It is unlikely that the nuclear power industry will reverse its downward trend in the wake of the Japan disaster. Therefore, we believe that in order to exit the vicious circle of "poverty versus safe environment" the world must accelerate the transition to energy efficiency and renewables to bring about enormous economic, social and environmental benefits. After all, solar and wind energy have reached maturity and are already cost competitive in many markets, even with the direct and indirect subsidies and other "externalities" of fossil fuels and nuclear energy –costs not factored into market prices. Not to mention that these externalities often include negative and long-term impacts on public health - as dramatically shown by the Chernobyl and Fukushima accidents. The world needs to create a new energy policy model that integrates demand with supply within the limits of sustainable development. This integration does not need to bring about a decline in quality of life; on the contrary, in the midterm it will make it possible to extend decent living standards to the world's population. The lowest hanging fruit is implementing cost-effective, readily available energy efficiency measures. Energy waste and misuse is an enormous economic and environmental burden for rich and poor countries alike.

Estimates are that 20 to 30% of primary energy could readily be saved if governments and people applied the appropriate policies. Saved energy is the cheapest, safest and most readily available option for producing "new" energy supply. The pursuit of energy efficiency and renewable energy is not only important for the environment; it is important for our world's security. It would reduce many of the current international tensions and security issues created by policies that destabilizing the climate and intensify international competition for finite and declining resources – threats largely created by the power of special interests in the fossil and nuclear industries.It is imperative therefore that members of the international community work together to develop clean and renewable sources of energy and a realistic path to phase out nuclear power. We have an opportunity to reverse energyrelated environmental degradation before it becomes irreversible and to help alleviate energy poverty for nearly 2 billion people. In the process, we will help ensure stability and security for the world at large and prevent the next Windscales (1957), Three Mile Islands (1979), Chernobyls (1986) and Fukushimas (2011).

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About Green Cross International:
Green Cross International (GCI) is a leading environmental organisation.
Founded by President Mikhail Gorbachev in 1993, this non-profit and nongovernmental organisation relies on world-class experts and works to address the inter-connected global challenges of security, poverty and environmental degradation through a combination of high-level advocacy and local projects. GCI has been working in the Chernobyl affected areas helping the local population through its Social, Medical Care and Education programme. GCI is present in over 30 countries and has its headquarters in Geneva, Switzerland.
For more information about GCI, visit www.gcint.org

DESIGN AND SAFETY FEATURES OF EPR

1.0 INTRODUCTION

EPR™ is a Pressurized Water Reactor (PWR) with a generation capacity of 1650 MWe. Design of EPR has been evolved using the best features of N4 reactors (designed by Framatome, France) and Konvoi reactors (designed by Siemens, Germany) currently in operation in France and Germany respectively. The name Evolutionary Pressurized Water Reactor is derived from this genesis. The EPR belongs to the category of Generation III / III^{+} advanced reactor with enhanced safety features. The design complies with safety requirements as per the 'Technical Guidelines for the design and construction of the next generation of nuclear power plants with pressurized water reactors' evolved jointly by French and German experts and adopted by French Nuclear Safety Authority (ASN). One unit each is under construction in France (Flamanville-3) and in Finland (Olkiluoto-3). Two EPR units are under construction in China (Taishan) also. It is proposed to construct EPRs in Jaitapur, Maharashtra in India.

2.0 EPR DESCRIPTION

Refer the article on 'Safety Features in Nuclear Power Plants' for functioning of a PWR. The EPR consists of a Reactor assembly and is a four loop Reactor Coolant system. The design incorporates systems, equipment and components which are similar to currently operating PWRs.

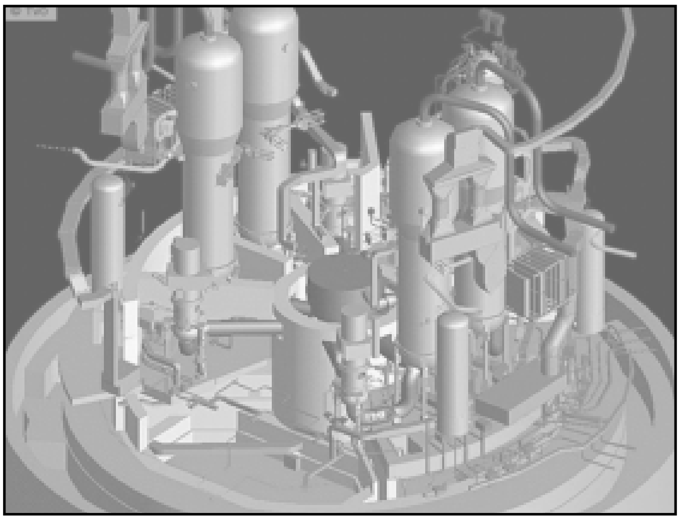
✍ **A.K.Balasubrahmanian**

3.0 SAFETY FEATURES

EPR has advanced safety features to ensure that abnormal events originating within the plant or from outside do not jeopardize the safety functions thereby assuring public safety. The safety features or systems perform the three safety function viz. control of fission chain reaction, cooling of fuel and containing radioactivity. The design of EPR is robust and the safety systems provided ensure defense in depth for a whole lot of postulated abnormal scenarios.

3.1 The EPR is provided with a fast shut-down system consisting of 89 Control Rods. The Control Rods are made of neutron absorbers silver-indium-cadmium alloy and boron carbide. The drive mechanism is designed to be fail-safe i.e. failure of electrical power supply results in dropping of the Control Rods, passively under gravity into the reactor. This feature ensures a high reliability of the system.

As a back up, to cater to a postulated scenario of the Control Rods not functioning (such postulations are made deterministically, although the probability of such an event in extremely low or nil), a system known as Extra Borating System (EBS) is provided. The EBS uses a liquid neutron absorber (boron dissolved in water) which is pumped into the reactor to effect shut down. This system is configured as two full capacity redundant trains to achieve, again, a high level of reliability.



EPR- Four Loop Reactor

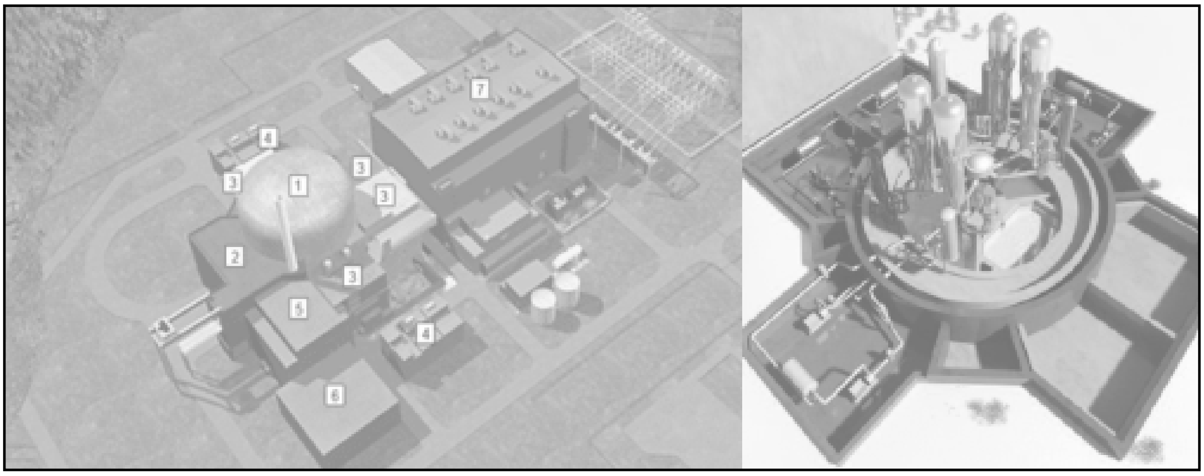
3.2 The safety systems for providing cooling of the fuel during any abnormal situations are designed as four full capacity redundant trains (circuits). This four train configuration ensures high level of availability besides providing operator with facility for on-line maintenance. This concept has gained wide acceptance of safety experts as well as the plant operators. Of the four trains, when a demand for actuation of the safety system arises,

- one train is assumed to fail on demand
- one train is assumed to be under maintenance.
- one train is assumed to be affected by the same event demanding the functioning of the safety system and hence becomes unavailable

This will still leave with at least a single, full capacity train to cater to the requirement. Such is the margin in the design of safety system in the advanced Nuclear Power Plants.

It should be understood that each of the train is provided with its own independent power supply (Emergency Diesel Generator) and secondary / tertiary cooling circuits. Also, all the equipment belonging to each train are housed in separate safeguard buildings as shown in the figure below.

1. Reactor Building 2. Fuel Building 3. Safegaurd Building 4. DG



EPR Plant Layout

Buildings 5. Nuclear Auxiliary Building 6. Waste Building 7. Turbine Building

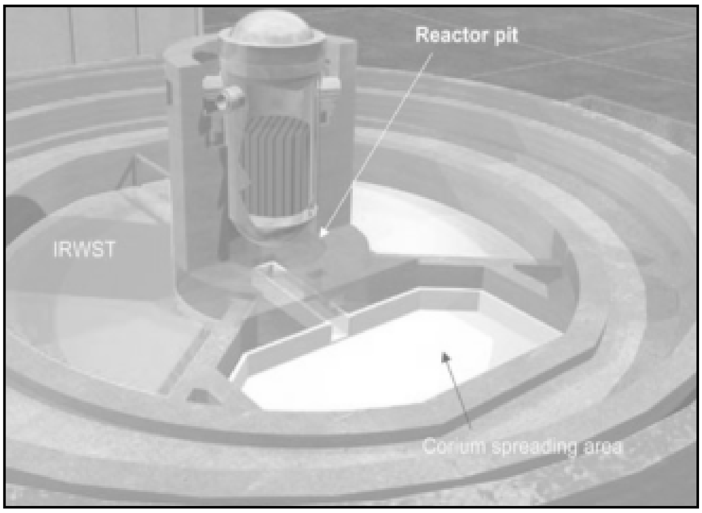
The Safety Injection System consists of two stages of pumping safety water to the reactor and passive accumulators. The source of water is a large pool situated inside the containment building.

In case of a situation, wherein all the Emergency Diesel Generators fail to come up on demand, then the power supply to the safety systems is still provided by a DG which is diverse in functioning and located separately. Provision of this DG, known as Station Blank Out (SBO) DG, thus ensures that power supply is always available for carrying out the safety function of cooling the fuel.

3.3 The nuclear systems of EPR are housed in a building known as Primary Containment. This concrete structure is designed to withstand the maximum pressure increase inside due to various postulated scenarios and acts as leak tight boundary. The inner surface of the Primary Containment is lined with steel plates in order to ensure high level of leak tightness. This building is enveloped by a Secondary Containment, with the annulus in between being maintained at a slightly negative pressure. The Primary Containment ensures leak tightness and the negative pressure in the annulus ensures that even if there is any leak, it does not go outside the building. These features give abundant assurance of public safety.

3.4 Further to the above safety features, the EPR is designed to cope up with extreme events. Let us postulate a scenario wherein the provisions of core cooling, mentioned above, do not work. The result could be damage to the fuel and a possible fuel melt. The objective here is to ensure that the radioactivity is contained and prevented from reaching the public domain.

The EPR is designed with a core melt retention feature. This feature allows the melted core to be spread in an area and be cooled as shown in the figure below.



Core melt retention area in EPR

Since the melted core is retained inside the containment, the radioactivity does not come out in the public domain.

During this scenario, it is necessary to control the pressure inside the contain- ment. The pressure rise is due to steaming of water cooling the fuel. A system, known as Containment Heat Removal System, douses the steam using water spray, the water being provided from external sources. Another potential cause of worry during this event is generation of hydrogen from the reaction between fuel clad and steam. Several passive Hydrogen Recombiners have been provided inside the containment to effectively recombine the hydrogen with the oxygen (available in the air) to form water.

4.0 The article describes design and safety features in EPR proposed to be built in India. The design of the EPR has been reviewed and licensed for construction in the country of origin, i.e France, besides in Finland and China. In India, the design will undergo safety review and consent by Atomic Energy Regulatory Board before construction.

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Some of our eminent Nuclear Scientists

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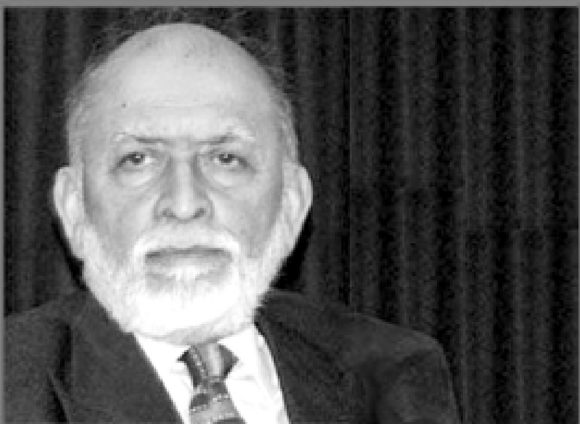

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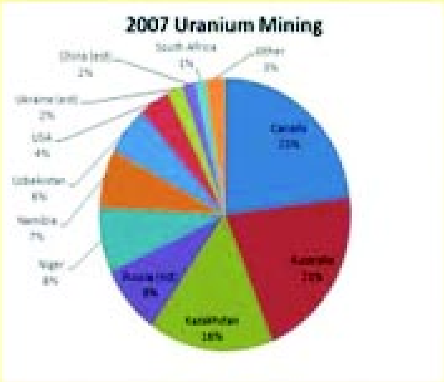

A nuclear power plant in Stade, Lower Saxony, Germany

An artist's view of a floating nuclear power station planned by Russians

The nuclear power plant in Belleville sur Loire, France

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