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The Development of Nuclear Technology: The Benefits, Risk and Protection

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Abstract

There is no doubt now, that energy crisis, is the major problem confronting developing Countries and yet, these countries had continued to embark on and nurture a no-growth Program of energy supply such as Mini-Hydro, Thermal, Solar, Wind Power etc. Hence, there is over-dependence on Industrialized Nations for the supply of essential goods and services and worse to the quality of life. This research work is meant to create an awareness of alternative and sustainable source of energy supply such as Nuclear Electricity, too cheap to meter. Uranium, which is the fuel used in Nuclear Power Stations, is available in large quantities throughout the world.

The study delves into the mechanisms of Nuclear Reaction, Radioactive Substances, Radioactive Isotopes, and peaceful application of Nuclear Science, production of Nuclear Electricity, risk and protection.

A practical approach was also adopted, aimed to galvanize readers' interest towards Nuclear Electricity generation and enormous potentials offered by Nuclear Science.

1.0 Introduction

Many intellectuals must have been wondering about the different phenomenon taking place in our world today, in all spheres of our everyday life. For instance, the development taking place in Aviation, Medicine, Industry, Agriculture, Space Science, Communication, Pollution Control and Electricity Production. I shall be touching very carefully, on the various aspects of the proceedings but to lay more emphasis on the later, which is electricity production.

By the method, the advancement in Nuclear Technology today is of significant importance and its roles cannot be underestimated. The Director-General of International Atomic Energy Agency, Dr Hanx Blix, at Annual Symposium, at the Uranium Institute in United kingdom in 1986, once said that, we can't disinvent Nuclear Science. All we need to do, is to demystify it instead. That is, by making people more familiar not only with Nuclear Electricity but also with the whole range of Nuclear Techniques at work in today's world to improve the lot of mankind, especially those linked with Radiation and Radioisotopes. Some people will disinvent Nuclear Science altogether if they could but to do so, would be, to block improvements to the standard of living of a whole nation and worse to their quality of life.

The reminder must be taken seriously that the exuberance about our ability to harness and manipulate the force of atom and the general processes of Physics and Chemistry for the benefit of our own species, need to be tempered by some individuals. In some people, the earlier optimism had turned to pessimism. They appear to turn the clock back when they urge that we abandon Pesticides, Fertilizers, Irradiated foods and Nuclear Power Stations and switch to Biodynamic Agriculture, solar Power, Wind Power, Biomass and Mini-Hydro.

A call for no-growth and change of life style, has come from many young Intellectuals in the affluent societies. They feel with some justification that, application of modern Science and Technologies have taken to several brooks of disaster: Thermonuclear war, Ozone Layer depletion, Global Warming, Desertification, Genetic Diseases etc. The diagnosis of danger, may be right but the therapies sometimes recommended are not so.

2.0 Theory

2.1 All About Nuclear Power Station

Nuclear-generated Electricity, can make a substantial contribution to conserving other fuel. Fossil fuels will not last for ever and it is vital that we do not waste them. Oil should be conserved for our transport needs and coal will be needed increasingly to replace oil as an important raw material for the production of chemicals, plastics and fertilizers.

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Uranium, which is the fuel use to generate Nuclear Electricity, has no other significant use but are available in large quantities through-out the world. It is moreover, a very concentrated fuel. One Tone of Uranium, can produce as much energy as 20,000 Tones of Coal. An added advantage of Uranium, is that, it can be reprocessed after use and recycled into more fuel.

Processing also allows for the recovery of a by-product, plutonium which can be made into fuel for fast Reactors. In addition to generating power, fast Reactors produce fresh Fuel, thus increasing the energy obtainable from Uranium by about sixty times. Nuclear Power has a major part to play in preserving a balance energy policy; it offers diversity in the fuels used in the generation of electricity and provides security against shortage of supply due to international or industrial disputes.

2.2 The First Nuclear Reactor.

The following are some of the reactors widely in used today: The Pressurized-water Reactor **(PWR),** the advance gas-cooled Reactor **(AGR),** the Magnox Design, the Boiling-water Reactor **(BWR)** and **RBMK-** the unique Russian Design. The process that leads to the mentioned designs, was first demonstrated by Mr. Ferni (Italian physicist). Nuclear fission was discovered in 1939 by 1942, in a Swatch Court at the University of Chicago in U.S.A, demonstrated with his Team that the Atom of Uranium is capable enough to undergo Nuclear Fission [1].

The Uranium Atom was self- sustained in a chain Reaction, in a reactor, built with a thick concrete wall shield, far different from the modern Reactors in use today. Although the reactor worked for only 28 minutes, but it has brought enormous potential toward the advancement in Nuclear Technology [2].

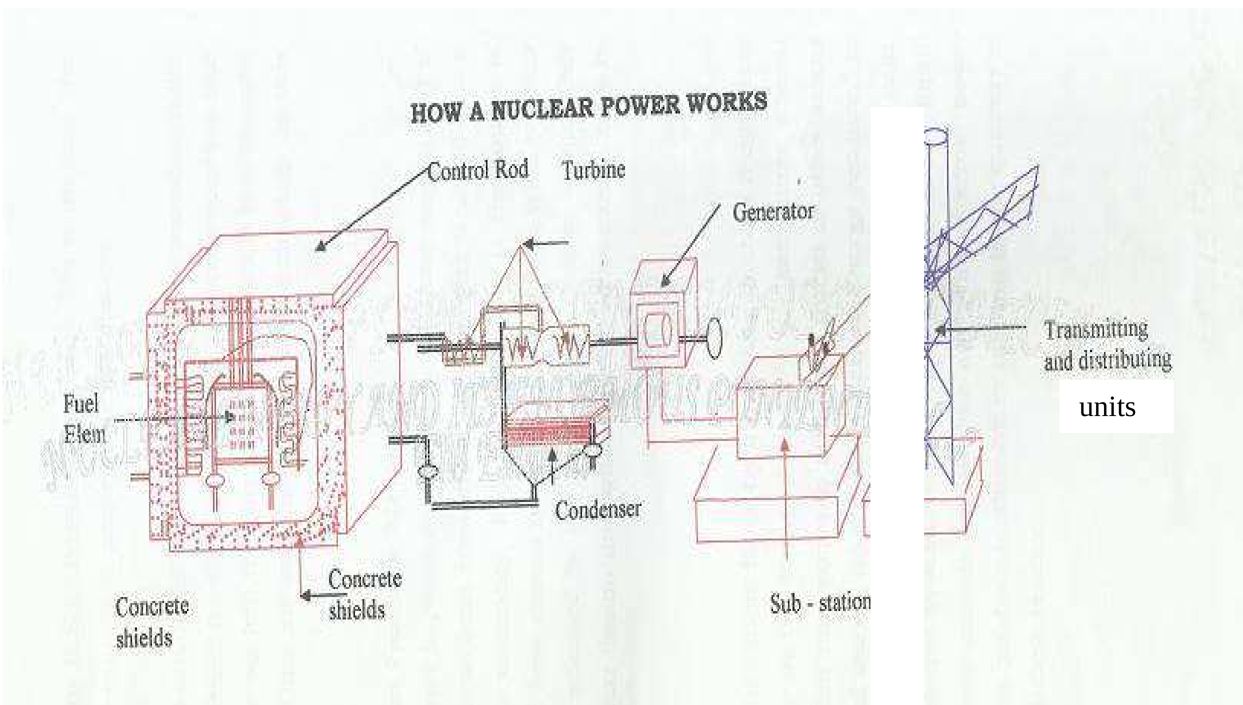

Fig 1: How a Nuclear Power Station Works

2.3 How Nuclear Power Station Produces Electricity

Electricity from Nuclear Power Station, is generated as much the same way as that of Coal or Oil-Fired Power Station. Heat converts water to steam which drives a Turbo Generator to produce electricity. The only difference, is the source of heat. With coal and oil, the heat comes from burning the fuel. As for Nuclear Power Station, the heat is released by the splitting of Uranium Atom (see Fig. 1). This splitting is known as Nuclear Fission and within a nuclear Reactor, it occurs in a controlled way.

2.3.1 Nuclear Fission

When the Nucleus of Uranium Atom is hit by a traveling Neutron, it split into two parts, releasing energy in the form of heat. At the same time, several Neutrons are released, which may go on to strike the Nuclei of other Atoms, causing further fission and setting up a chain Reaction. Energy produced in this way, is controlled in a Nuclear Reactor to provide a steady supply of heat. The heat produced, is transferred to a Boiler by a coolant, either gas or liquid, and from then on, a Nuclear Power Station will operate like any other Thermal Power Station. The amount of heat produced, is massive in relation to the quantity of fuel required within the Nuclear Reactor.

2.4 Mechanism Of Nuclear Reactions.

Radioactive substances, give three types of Radiations: α (Alpha),
β (Beta) and γ (Gamma) Rays. They all cause certain substances such as Zinc Sulphide to luminize and they all ionize gases through which they pass. They differ in their response to an electric field, in the manner shown in Fig. 2. The uncharged rays, γ (Gamma), are similar to X-Rays. They have high penetrating power, being able to pass through 0.1m of metal. Measurements of e/m identified α (Alpha) Rays as the Nuclei of Helium Atom and α Rays can penetrate no more than 0.01m of metal.

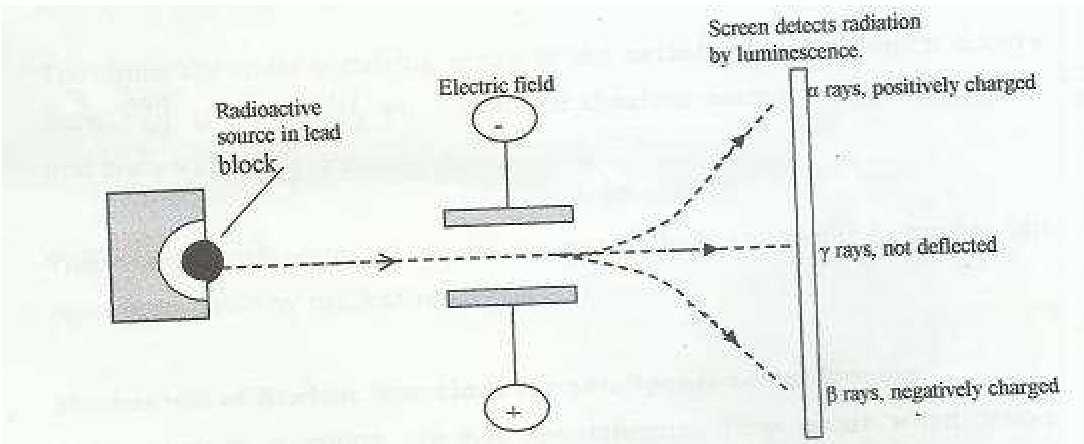

Fig 2: Emission of **α, β** and **γ** particle

2.4.1 Mechanism Of Nuclear Reactions For Spontaneous Processes

A brief insight into the mechanism of Nuclear Reaction, both for Spontaneous and Non-Spontaneous Processes and the enabling equations, have been articulated to explain Uranium Isotopes as they occur in Fission Processes. A detailed analysis of the Fission of Uranium Atom and the advantages of Neutron over Alpha and Beta particles, will be discussed in the future.

There are three naturally occurring series of Radioactive Elements. The Uranium Series, starts with ${}^{238}_{92}U$ and decays through a series of unstable isotopes to ${}^{206}_{82}Pb$. The first two steps in the decay are:

${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He\ (\alpha - decay)$ (1)

${}^{234}_{90}Th \rightarrow {}^{234}_{91}Pa + {}^{0}_{-1}e\ \ (\beta - decay)$ (2)

When an Isotope undergoes α- decay (with the emission of an α- particle), its Proton Number decreases by 2 and its Nucleon Number, decrease by 4. The isotope produced, is two groups to the left in the Periodic Table. When an isotope undergoes β-decay (with the emission of an electron), its Proton Number increases by 1 and its Nucleon Number, is unchanged. The isotope produced, is one group to the right in the Periodic Table.

The other naturally occurring series, is the Actinium Series, which decays from ${}^{235}_{92}U$ to ${}^{207}_{82}Pb$ and the Thorium Series, which starts with ${}^{232}_{90}Th$ and ends with ${}^{208}_{82}Pb$.

There is a fourth series of Radioisotopes, which do not occur in nature but have been made by Nuclear Reactions.

2.4.2 MECHANISM OF NUCLEAR REACTIONS FOR NON SPONTANEOUS PROCESSES

Some Nuclear Reactions are not spontaneous. They occur when stable Isotopes are bombarded with particles such as **α-** particles or Neutrons. Rutherford was the first person to bring about a Nuclear Reaction. He was experimenting on the bombardment of Nitrogen with **α-** particles in a Cloud Chamber of the type invented by **C T R Wilson.** The diagram below shows the kind of photograph he obtained.

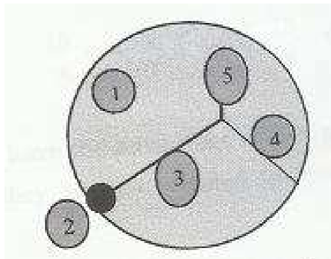

Fig3: Bombardment of nitrogen with α particle

1. The cloud chamber is filled with air which is supersaturated with a water vapor. If any ions are produced, they cause condensation.

2. Radioactive source of **α-** particle.

3. This track is a trail of condensation produced by an **α-** particle.

4. Long, thin track of $^{1}_{1}H$

5. Short, thick track of $^{17}_{8}O$

Fig. 3 shows the track of an **α-** particle coming to an end and being replaced by a short, thick track and a long, thin track. Rutherford realized that two particles had been formed in a Nuclear Reaction. He attributed the short, thick track to $^{17}_{8}O$ and the long, thin track to $^{1}_{1}H$. He proposed that, they had been formed by the nuclear reaction.

$$^{14}_{7}N + \,^{4}_{2}He \rightarrow \,^{17}_{8}O + \,^{1}_{1}H \;\; (\alpha, p) \qquad (3)$$

(α, p) This is classified as an **(α, p)** reaction since the projectile is an **α-** particle and a Proton (p), is produced in the reaction. Other bombarding particles were used and more Nuclear Reactions were observed. Examples are

$$(\alpha, n)\; ^{9}_{4}Be + \,^{4}_{2}He \rightarrow \,^{12}_{6}C + \,^{1}_{0}n \qquad (4)$$

$$(p, \alpha)\; ^{7}_{3}Li + \,^{1}_{1}H \rightarrow 2\,^{4}_{2}He \qquad (5)$$

$$(n, \alpha)\; ^{16}_{8}O + \,^{1}_{0}n \rightarrow \,^{13}_{6}C + \,^{4}_{2}He \qquad (6)$$

Neutrons (n) have the advantage over α- particles and protons in that, being uncharged, they are not repelled by the positive Nuclei of the bombarded Atoms. Since 1940, a set of new elements with Proton numbers greater than 92, the Proton Number of the heaviest naturally occurring Element, Uranium, have been made. They are called the **Transuranium Elements.** (Ramsden, 1985).

2.4.3 BALANCING NUCLEAR EQUATIONS

In the equation for a Nuclear Reaction, the sum of the Nucleon Numbers (mass numbers), is the same on both sides and the sum of the Proton (Atomic Numbers), is the same on both sides of the equation. For example, Nitrogen undergoes β- decay in the following way:

$$^{16}_{7}N \rightarrow ^{a}_{b}O + ^{0}_{-1}e \quad (7)$$

And it is clear from (7) that a =16 and b= 8, hence the isotope produced is $^{16}_{8}O$

The final Equation is thus;

$$^{16}_{7}N \rightarrow ^{16}_{8}O + ^{0}_{-1}e \quad (8)$$

2.5 Effect:

The miracle of life is possible because the cells that are present in all living matter, can grow and reproduce themselves. Radiation is one of many ways in which these processes can be affected. It does so as a result of the Energy of Radiation being absorbed by the cell. This can produce electrical effect called Ionization, which in turn leads to chemical changes in the cell. Such changes are happening all the time and the body has a very effective way of repairing them. An adult person, contains about 6.10^{13} cells, several billions of these die every day and are replaced by new ones. Most of the cells are killed by a low moderate dose of Radiation. However, 1000 units or more, can kill so many cells, that the body cannot replace them rapidly enough. This result in serious effect such as skin burns and vomiting. At about 10,000 units or over, death will occur within days or weeks as a result of Nuclear Power Exposure.

Genetic Disease such as Cancer and Leukemia, form part of delayed Effect, resulting from excessive doses of Radiation. For instance, children whose parents receive high dose of Radiation from the two atomic Bomb, Hiroshima and Nagasaki in Japan in1945, hardly live above 20 years.

The negative health Effects of the Fukushima Nuclear Disaster, include a moderately increased risk of Thyroid cancer (a comparatively rare form of cancer) for girls, from the most contaminated area and a slightly increased risk of other cancers for infants, from the most contaminated areas. One study found that, more than a third (36%) of children in Fukushima Prefecture, have abnormal Growths in their Thyroid glands, which are not attributed to the effects of Radiation alone. In particular, a WHO report found that, there is a 70% higher-risk of developing Thyroid cancer for girls exposed as infants, in the most contaminated area, a 7% higher- risk of Leukemia in males exposed as infants in the most contaminated area, a 4% higher- risk, overall, of developing solid cancers for females.

3.0 Benefits of Nuclear Science.

The benefits of Nuclear Science cannot be overemphasized. Uranium Nuclear Power Station, now account for about 70% of the utilities in America and European Communities. Improved Medical Research, Diagnosis and Treatment, are also being facilitated by this Science for effective Health-care system. The following are fields in which Nuclear Technology is used.

3.1 Medicine:

- Radioactive materials are use to produce brain Scans (typical of Alzheimer's diseases).
- Radioactive Techniques to mark materials, are used in many field including genetic Research and Genetic Engineering.
- Medical items like Surgical Gloves and Syringes are sterilized by Irradiation on a large scale. This has radically cut the risk of infections in clinics and hospitals.

3.2 Agriculture

- Irradiation of certain foodstuffs, is used instead of chemical treatments in some countries to enhance deterioration and food-borne diseases. Foodstuffs so treated, do not themselves, become radioactive nor do the consumers receive any Radiation.
- Insects that cause excessive damage to Agricultural crops, can be controlled by releasing large numbers of male insects that have been sterilized by Irradiation. Thus, breaking the breeding cycle. For instance, the pupa of harmful insect like the screw-worm, the Mediterranean fruit-fly and the Tsetse Fly, can be irradiated to produce sterile but otherwise normal insect. So, when the sterile males mates, there are no offsprings. That is how the pest slowly dwindles in number and eventually disappears. In America, the screw-worm which can have a devastating effect on cattle and even on humans, has been pushed back to Southern Mexico. A rearing factory there, producing 500 million sterile screw-worms every week, keeps the country from being re-infected from South America. The Economic Benefits are in Multi-Billion Dollar range. The Ecological ones, are that, no residues are left behind (contrast that with pesticides). The spread of the screw-worm, has now spread to Libya without a programme of instant Sterilization through Irradiation; this creature could bring great suffering to cattle and wild life of all Africa.

- Radiation is use to provoke Mutation in seeds and produce new kinds of food crops. In 1960, there were 15 Radiation- induced Mutants varieties and today, there are over 130 breeds for richer harvest, higher quality and better resistance to pest and illnesses. In China, Eight Million Hectares or 10% of the country's cultivated land**,** are planted with seeds of this type, offering a benefit of about 1000 million US Dollars in a year to the Chinese Society. Sixty Percent (60%) of the Durum Wheat, grown in Italy to make pasta, come from this type of grain.
- A Nitrogen Isotope has been used to work out the best ways of applying Nitrogenous Fertilizers. This save money and spares the environment surplus Nitrogenous fertilizer which has negative Effect. For example, Groundwater, Rivers, and Lakes.
- Whiskey is made from the Golden- Promise type of Barley, a favorite among Scottish distillers, for malt making, and a pure Gamma Ray induced Mutant.

3.3 Industry and Pollution Control

- Underground leaks in water or fuel pipes, can be detected by introducing a short-lived Radioisotope into the pipe. Radioactivity on the surface, can be monitored. A sudden increase of surface Radioactivity, shows where water or fuel is escaping.
- Radioactive materials are used in luminous signs
- Smoke Detector work by sensing changes in the amount of Radiation reaching a detector from a radioactive source in the presence of smoke.
- Radioactive materials can be used to produce photographic Image of the combustion chambers within Jet engines.
- Radioactive materials, are use to measure cylinder wear in car engines. Engine wear can be measured by using Radioactive Piston Rings. As the piston rings wear away, the lubricating oil becomes radioactive. In this way, the Efficiency of various lubricating oils can be tested.

3.4 Research

Carbon-14 dating, can be used to calculate the age of plant and animals remains. Living plants and animals take in carbon, which include a small proportion of the radioactive Isotope, carbon -14. When a plant or animal dies, it takes in no more carbon -14 and that which is already present, decays. The rate of decay, decreases over the years and the activity that remains, can be used to calculate the age of the plant or animal material. Carbon-14 dating, is also used to measure the age of Archeological, Geological and other specimens, from a few hundred to about fifty thousand years old. This technique was used to date a body found in a pit bog in Cheshire England.

Radioactive techniques to mark materials, are use in many fields including Genetic Research and Genetic Engineering.

Investigations of isotopic Content of water, can tell us if Groundwater in the arid Region like, Mali or Niger, came from rainfall thousands of years ago or whether it comes from a system still being recharged, such as a distant mountain range.

4.0 Risk and Protection

In discussing the risk resulting from the development of Nuclear Science, it is important to involve the sources of Radiation in order to bring the readers to full details of the subject matter, to prevent the author been misjudge of facts hoarding. The following are sources of radiation

4.0.1 Natural:

This includes Cosmic Radiation, air (Radon and thoron), food and drinks (nuts, tea, coffee and bread contain more radio activities).

4.0.2 Man-made:

This include medical (diagnostic x-ray), Fallout from Nuclear Explosion, Nuclear Power Stations.

Miscellaneous:

These include watches and clocks ionized with radioactive Materials, Tv Sets and Smoke Detectors including air travel

4.1 Risk:

As previously mentioned, like any man's discovery, it has potentials for both good and for harm. The development of Nuclear Science, has brought about the evolution of Thermal- Nuclear war. For example, the 1945 incident in Japan, which lead to the deployment of Atomic Bomb in two cities-Hiroshima and Nagasaki, in Japan, by the Americans. This incident was made to discourage the advancement of Nuclear Science. However, the Security Council of the United Nation and The International Atomic Energy Agency Programme of Disarmament and Testing of Long Range Nuclear Weapons, by member states, had enabled world peace and eroded Thermo-Nuclear war. (Ramsden, 1985).

Few cases of Nuclear Accident, world over, such as, **Bhopal Incident in 1958,** in the United Kingdom, American Nuclear Accident in 1983, Chernobyl in USSR in 1986 and Fukushima Daiichi Disaster in Japan in 2011, have brought about apprehension, not minding the enormous Potential derived from the application of Nuclear Science. For instance, the Chernobyl Nuclear Accident in USSR in 1986, was described by many as the worst Nuclear Accident ever in our planet. The Accident was seen by many as the worst Nuclear Accident, not because of inadequate operation but because of safety Test. After all, the Reactor had operated several years before the Accident. What happen was that, the Russian Design **RBMK**, has a cooling power embodied in the Reactor, should the Reactor loses power and the electricity supply to the cooling pump fails. The standby Generators are Diesel Generators and it takes 50 seconds to reach full power, too long for the Reactor to be without fully working pumps. The Experiment was to see whether the Inertia, the latent Mechanical Power in the spinning Turbines, would bridge the gap. Contrary to the operational instructions, the engineers, set the Reactor at low power output and made some fatal errors. After that disaster, Nuclear Science is seen by many as particularly serious problem.(Alexey et al, 2007).

The Fukushima Daiichi Nuclear Power Plant Accident, in Japan, occurred on 11 March 2011 as a result of human Error, just as Chernobyl in USSR in 1986. It is the biggest Nuclear Disaster in recent time after Chernobyl. The Accident occurred after the Tohoku Earthquake and Tsunami, having level 7 rating in the International Nuclear Event scale.(James and Mark, 2012).

According to the Report of the inquiry by the commission set up by the Japanese Diet, stated that, the Hazard was foreseeable and that the plant was incapable of withstanding the Earthquake and Tsunami and that the regulatory Bodies, all failed to correctly develop the most basic safety Requirements such as, assessing the probability of the damage, preparing collateral damage from such a disaster and developing evacuation plans for the public in the case of a serious radiation release.

Pessimist has argued that it was time to disinvent Nuclear Science and the whole range of its operation. To do this, is to lower the standard of living of a whole Nation and worse to the quality of life of the people

4.2. Protection

The International Atomic Energy Agency (IAEA), is saddled with the responsibility of regulating the operation and management of Nuclear Industries and providing the enabling legislature. Such laws were first adopted in 1959 and are regularly reviewed in the light of the available information on Radiation and its Effect. Particular attention is given to the recommendations of International Commission on Radiological Protection (ICRP). The banning of toys and items of Jewelries, watches and clocks, are no longer made luminous by Radium, since alternatives are available that gives much smaller doses of Radiation. Nearly everyone agrees that medical uses of Radiation and Radioactive Materials, are justified but often, more could be done to reduce dozes without reducing the benefits to patient. Smoke Detectors, containing Radioactive Materials, are justified because they save lives and only give extremely small dose of radiation.

4.3 Waste Disposal:

This is not a problem that is unique to the Nuclear Industry. Although, some Radioactive waste remain potentially hazardous for very long time. Many other industrial waste such as toxic chemicals, may also affect future generations. Nevertheless, Radioactive Waste Disposal, is seen by many as a particularly serious long- term risk and correspondingly high standards of safety have been set.

Conclusion

Evidently, about 60% of the Nuclear Reactors that make up the utilities in the US, are runned by private Sectors and no known case of Nuclear Disasters have been recorded since the 1983 Episode in USA. I believe Nuclear power, is necessary because of the damage the alternatives of coal, oil and gas-fired Station, do to the environment. There is little doubt now, that 'Global warming,' due to 'The green house effect', are real problems which will have far reaching effect on the climate. These Fuels, make Carbon Monoxide (Co), Carbon dioxide (Co_2), Sulphur dioxide (So_2) and other Green-House Gases, can also produce Acid- Rain, but Nuclear Power Stations do not.

Having gone through this Research Work, you could see that the advantages in Nuclear Technology, clearly outnumber the risk. A better quality of life would not come from turning our back on Science and Technology, whether Biotechnological or the peaceful application of Nuclear Science.

It is important to be sure that if you reject a Technology, you were doing it for the right reason. The deplorable state of the Chernobyl Nuclear Accident and the subsequent Fukushima Daiichi Nuclear Disaster, cannot be used to misjudge the enormous Potentials offered by Nuclear Science and it's peaceful application. After all, the two major underlined world-worse Nuclear Disaster, occur as a result of human error and lacking the major basic safety Standard; meaning, the Chernobyl and Fukushima accident could have been avoided. With respect to Research New-Knowledge, I think political obstacle is the major constraint of the Nuclear Industry in recent time. Review of a design project in line with previous Historical data on the environment for foreseeable Harzards and the provision of funds for the execution of such projects, ought not to be politicized. Absolute monopoly on the design operation, management and regulation of Nuclear Industry, if restricted to experts discretion alone, devoid of Government Interference, would have solved the former problem. With the recent challenges in the Nuclear Industry around the world, I think also, that we have recognized and put behind us, the problem of proliferation of quacks, operational randomness, without ethics among experts and have embraced best practices as the only road-map that will take the Industry to a greater height. Experiment has shown that the Radiation Dozes from Nuclear Power Station, are far less than natural Radiation people received daily from their homes and environment. Nuclear science remains the safest, too cheap to meter and should be encourage for the advancements and benefits to mankind. I'm confident of the benefits of Nuclear Power and the whole range of Nuclear Technology and the safety of its operation.

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