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Review

RADIOACTIVE POLLUTION: AN OVERVIEW

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The civilian radioactive waste encompasses a wide range of materials, most of the current debate focuses on highly radioactive spent fuel from nuclear power plants. Other types of civilian radioactive waste have also generated by nuclear power plants, medical institutions, industrial operations, and research activities. Disposal of radioactive waste will be a key issue in the continuing nuclear power debate. Without a national disposal system, spent fuel from nuclear power plants must be stored on-site indefinitely. the strategy for the management and disposal of used nuclear fuel and high-level radioactive waste has highlighted agreement with many of the principles of the IAEA recommendations and has outlined actions that, with legislative authorization by Congress, can lead to a safe and responsible solution to managing the nation's nuclear waste. Indeed, action by Congress in the form of new authorizing legislation and appropriations is necessary.
Key words: radioactive spent, nuclear power plants, radioactive waste.

Radioaktivno onečišćenje: Pregled. Civilni radioaktivni otpad obuhvaća široki raspon materijala; većina aktualne rasprave usmjerena je na visoko radioaktivno istrošeno gorivo iz nuklearnih elektrana. Druge vrste civilnog radioaktivnog otpada također generiraju nuklearne elektrane, medicinske ustanove, industrijski procesi i istraživačke aktivnosti. Zbrinjavanje radioaktivnog otpada bit će ključno pitanje u kontinuiranoj raspravi o nuklearnoj energiji. Bez nacionalnog sustava zbrinjavanja, istrošeno gorivo iz nuklearnih elektrana mora se pohraniti na neodređeno vrijeme. Strategija upravljanja i zbrinjavanja korištenog nuklearnog goriva i visokoradioaktivnog otpada istaknula je suglasnost s mnogim načelima preporuka IAEA (Međunarodna agencija za atomsku energiju) i opisala aktivnosti koje uz zakonodavno odobrenje Kongresa mogu dovesti do sigurnog i odgovornog rješenja za upravljanje nacionalnim nuklearnim otpadom. Doista, Kongres treba poduzeti aktivnosti u obliku nove legislative i izdvajanja proračunskih sredstava.
Ključne riječi: radioaktivno onečišćenje, nuklearne elektrane, radioaktivni otpad.

INTRODUCTION

Certain elements that compose matter emit particles and radiations spontaneously. This phenomenon is referred to as 'radioactivity'; it cannot be altered by application of heat, electricity or any other force and remains unchangeable. Three different kinds of rays, known as alpha, beta and gamma rays are associated with radioactivity. The alpha rays consist of particles (nuclei of helium atoms) carrying a positive charge, beta rays particles have negative charge (streams of electrons) and gamma rays are charge less electromagnetic radiation with shorter wavelengths than any X-rays. These 'rays' can penetrate living tissues for short distances and affect the tissue cells. But because they can disrupt chemical bonds in the molecules of important chemicals within the cells, they help in treating cancers and other diseases. Every element can be made to emit such rays artificially. If such radioactive elements are placed in the body through food or by other methods, the rays can be traced through the body. This use of tracer elements is extremely helpful in monitoring life processes. Geologists use radioactivity to determine the age of rocks. As atoms lose particles as heavy as nuclei of helium, they become atoms of some other element. That is, the elements change or ‘transmute’ into other elements until the series ends with a stable element. Radioactive elements decay at different rates. Rates are measured as half-lives – that is, the time it takes for one half of any given quantity of a radioactive element to disintegrate. The longest half-life is that of the ‘isotope’ ^{238}U of uranium is 4.5 billion years [1]. Some isotopes have half-lives of years, months, days, minutes, seconds, or even less than millionths of a second. Every inhabitant on this planet is constantly exposed to naturally occurring ionizing radiation called back- ground radiation. Sources of background radiation include cosmic rays from the Sun and stars, naturally occurring radioactive materials in rocks and soil, radionuclide normally incorporated into our body’s tissues, and radon and its products, which we inhale. We are also exposed to ionizing radiation from man-made sources, mostly through medical procedures like X-ray diagnostics. Radiation therapy is usually targeted only to the affected tissues [2].

In this lesson we will discuss about the radiations which are the cause of radioactive pollution. These radiations are emitted by radioactive decay of unstable heavy atoms nuclei. Exposure of these radiations can cause damage to living cells and environment. Concern for radioactive pollution increased after the discovery of artificial radioactivity, development of nuclear weapons and installation of nuclear reactors for generating electricity. We shall discuss the possible threat to human health and environment due to nuclear radiations both from natural and anthropogenic (man-made) sources. Radioactive waste, arising from civilian nuclear activities as well as from defence-related nu- clear-weapon activities, poses a formidable problem for handling and protecting the environment to be safe to the present and future generations. This article deals with this global problem in its varied aspects and discusses the cause for concern, the magnitude of the waste involved and various solutions proposed and being practised. As nuclear power and arsenal grow, continuous monitoring and immobilization of the waste over several decades and centuries and deposition in safe repositories, assumes great relevance and importance [3]. Methods for the safe disposal of nuclear waste materials will also be discussed. This method is the state-of-the-art in nuclear waste disposal technology. It is the single viable means of disposing radioactive waste that ensures non return of the relegated material to the biosphere. At the same time, it affords inaccessibility to eliminated weapons material. The principle involved is the removal of the material from the biosphere faster than it can return. It is considered that ‘the safest, the most sensible, the most eco- nominal, the most stable long-term, the most environmentally benign, the most utterly obvious places to get rid of nuclear waste, high-level waste or low- level waste is in the deep oceans that cover 70% of the planet’[4].

Figure 1. The world's largest nuclear power plant, Kashiwazaki-Kariwa in Japan
Slika 1. Najveća nuklearna elektrana na svijetu, Kashiwazaki-Kariwa u Japanu

WHAT IS RADIOACTIVE POLLUTION?

Production of electricity per capita is considered as one of the major development index of a country .Among the power generation technologies, nuclear fission is one of them .The nuclear power generation has been developed since 1960 and now around 450 nos. of atomic fission power reactors are there over the world. In nuclear power production, the power generated from 1 gm of U is equivalent to the power generated from 2083 kg of coal. A large amount of energy released in exchange of small amount of nuclear fuel but the major problem in producing nuclear power is its radioactive waste. The future development of nuclear power largely depends on the success of programmed and management of radioactive waste generated at various stages of the nuclear fuel cycle.

Apart from the biological pollution, the industrial and the chemical pollution of the soil, nowadays there is also the radioactive pollution and the man is guilty for all of them. The nuclear experiments have led in some areas on Earth to radioactive waste storage and to emanations from the nuclear centres where there had been accidents (for example the accident from Chernobyl – Ukraine and Fukushima Daiichi nuclear power station –Japan). The radioactive pollution represents a big danger for the humans' and animals' lives. The most dangerous long-lived radio- nuclides are those emitted by nuclear reactors: they can last even for a century! These radioactive killers are conserved in soil, from where they go to the plants and animals. For example, in the Northern areas of Europe and America, where nuclear experiments were made, the lichens store caesium radioactive and the reindeer eat the lichens, which store isotopes in return. By eating reindeer meat, the Lapland was loaded with radioactive isotopes 10 times more than other [5].

Figure 2. Picture of radioactive waste materials
Slika 2. Slika radioaktivnog otpada

RADIATION NATURE & TYPE

Radiation is energy travelling through space. Energy can be transported either in form of electromagnetic waves (radiations) or a stream of energetic particles, which can be electrically charged or neutral.

These radiations are of two types:

- Non-ionizing radiations
- Ionizing radiations

Non-ionizing radiations are the electromagnetic waves of longer wavelength from near ultraviolet rays to radio waves. These waves have energies enough to excite the atoms and molecules of the medium through which they are moving, causing them to vibrate faster. These do not have enough energy to ionize them.

Ionizing radiations are the electromagnetic radiations having high energy, such as short wavelength ultra violet radiations, x-rays and gamma rays. The energetic rays like produced in radioactive decay can cause ionization of atoms and molecules of the medium through which they pass and convert them into charged ions. For example in water molecule, it can induce reaction that can break bonds in proteins, DNA and or other important molecules. Alpha, beta and gamma radiations are produced by the process called radioactive decay. The unstable nuclei decay spontaneously and emit these radiations. These rays (radiations) can affect some other non-radioactive atoms to become radioactive (unstable) and give out radioactive radiations [6].

RADIOACTIVE POLLUTION & THEIR SOURCES

Living organisms are continuously exposed to a variety of radiations called background radiations. If the level of the radioactive radiations increases above a certain limit it causes harmful effects to living beings. This harmful level of radiations emitted by radioactive elements is called radioactive pollution. There are two types of sources [7].

1. Natural sources
   - Cosmic rays
   - Terrestrial radiation
2. Man-Made sources
   - Medical sources
   - Industrial sources
   - Nuclear Explorations
   - Nuclear Power
   - Nuclear & Radiation accidents

Natural sources

Throughout the history of life on earth, organisms continuously have been exposed to cosmic rays, radionuclide produced by cosmic ray interactions in the atmosphere, and radiation from naturally occurring substances which are ubiquitously distributed in all living and nonliving components of the environment. It is clear that contemporary life have adjusted or are doing so to all features and limitations of the environment, including the natural radiation background. Although high levels of radiation are definitely harmful to organisms, some environmental radiation is of importance to life, as we know it. For example, background radiation has contributed, though we do not know how much, to the fundamental processes of chemical and biological evolution. Of clearer importance is the fact that the earth's heat content is principally provided and maintained by the heat of decay of primordial, naturally occurring radionuclide.

- ***Cosmic rays***

Radiation of extraterrestrial origin, which rain continuously upon the earth, is termed "cosmic rays". The fact that this highly penetrating radiation was impinging upon the earth from space, rather than emanating from the earth, was deduced from balloon experiments in which ionization measurements were made at various altitudes from sea level to 9,000 m. It was found that the ionizing radiation rate decreased for some 700 m and from that point increased quite rapidly with elevation. The initial decrease could be explained by a decreased intensity of terrestrial gamma rays, while the increasing component was due to cosmic rays. The likely origin of cosmic rays is the almost infinite number of stars in the Universe. Evidence for this is the increased cosmic ray intensity observed on earth following solar flares. However, it is clear that the sun is not normally a major contributor to the total cosmic flux since diurnal variations are very small. Cosmic rays may be termed "primary" or "secondary". Those, which have not yet interacted with matter in the earth's atmosphere, lithosphere, or hydrosphere, are termed primary. These consist principally of protons (≈85%) and alpha particles (≈14%), with much smaller fluxes (<1%) of heavier nuclei. Secondary cosmic rays, which are produced by interactions of the primary rays and atmosphere, consist largely of subatomic particles such as pions, muons, and electrons. At sea level, nearly all the observed cosmic radiation consists of secondary cosmic rays, with some 68% of the flux accounted for by moons’ and 30%

by electrons. Less than 1% of the flux at sea level consists of protons.

- ***Terrestrial Radiation***

Radionuclide's, which appeared on the Earth at the time of formation of the Earth, are termed "primordial". Of the many radionuclides that must have been formed with the Earth, only a few have half-lives sufficiently long to explain their current existence. If the Earth was formed about 6·109 years ago, a primordial radionuclide would need a half-life of at least 108 years to still be present in measurable quantities. Of the primordial radionuclide that are still detectable, three are of overwhelming significance. These are K-40, U-238 and Th-232. Uranium and thorium each initiate a chain of radioactive progeny, which are nearly always found in the presence of the parent nuclides (Table 2). Although many of the daughter radionuclide are short-lived, they are distributed in the environment because they are continually being forming from long-lived precursors.

Man-maide sources

- ***Medical source***

Radiations are employed for diagnostic and therapeutic applications. X-rays are used in general radiology and CT scan. Gamma rays are used in treatment of cancer. In all these procedures we are exposed to varying doses of radiations.

- ***Industrial source***

Radioisotopes are much more widely used in industry than is generally recognized and represent a significant component in the man-made radiation environment. The principal applications include industrial radiography, radiation gauging, smoke detectors and self-luminous materials. Because most of these applications entail the utilization of encapsulated sources, radiation exposures would be expected to occur mainly externally during shipment, transfer, maintenance, and disposal. In the past decade, radiation exposures in research and industrial applications were roughly half those due to medical occupational exposure; hence, their contribution to the direct population dose is substantial.

- ***Nuclear explorations***

Nuclear explosions are a serious source of radiations hazard. The effects of atomic explosions in Nagasaki and Hiroshima are still not forgotten.

- ***Nuclear power***

Nuclear explosion tests especially when carried out in the atmosphere are a major cause of radiation pollution. It is responsible for increasing the background level of radiation throughout the world. During atmospheric nuclear explosion tests, a number of long-lived radionuclides are released into the atmosphere. This radioactive dust (also known as radioactive fallout) gets suspended in air at a height of 6 to 7 km above the earth's surface and is dispersed over long distances by winds from the test site. This radionuclide's often settle down by rain and get mixed with soil and water. From there they can easily enter the food chain and finally get deposited in the human body where they cause serious health hazards. Some of the radioactive isotopes given off during nuclear test affect the human body.

- ***Nuclear & Radiation Accidents***

Radiations may leak from nuclear reactors and other nuclear facilities even when they are operating normally. It is often feared that even with the best design, proper handling and techniques; some radioactivity is routinely released into the air and water. However, dangers of radiation leakage are from possibility of accidents that could result in the release of radioactive material which raises the level of radioactive (ionizing) radiations. Such accidents took place at the 'Chernobyl nuclear power plant' in USSR in 1986 and at the 'Three Mile Island Power Plant' in USA in 1979. The accidents of 'Three Mile Island' plant in Middletown (U.S.A.) in 1979 and at Chernobyl nuclear power plant (U.S.S.R.) in 1986 were the worst disasters in the history of nuclear power industry. In both incidents, a series of mishaps and errors resulted in the overheating of the nuclear core. In both cases radiation was released in the atmosphere. The leakage from the 'Three Mile Island' nuclear reactor has been claimed to be very low with no immediate injuries to workers or people. But the leakage at Chernobyl was very heavy causing death to many workers and radiation was spread over large areas spread all over Europe. The earthquake and tsunami in Japan on 11 March 2011 led to releases of radioactive material into the environment from the Tokyo Electric Power Company's Fukushima Daiichinuclear power station.

Table 1. FDA and FSIS derived intervention levels for imported food after the chernobyl accident, bq/kg (pci/kg)
Tablica 1. FDA i FSIS izvedene intervencijske razine za uvezenu hranu nakon černobilske nesreće, bq/kg (pci/kg)

	FDA LOC		FSIS Screening Value
Radionuclide I-131	Infant Food 55 (1500)	Other Food 300 (8000)	Meat & Poultry 55 (1500)
Cs-134 + Cs-l37	370 (10,000)	370 (10,000)	370 10,000

RADIATION & MATTER

When radiation passes through matter, it deposits energy in the material concerned. Alpha & beta particles, being electrically charged, deposit energy through electrical interaction with electrons in the material. Gamma rays and X ray lose energy in a variety of ways, but each involves liberating atomic (orbiting) electrons, which then deposit energy in interaction with other electron. Neutron also loses energy in various ways, the most important being through collision with nuclei that contain protons. The protons are then set in motion and being charged, they again deposit energy through electrical interactions. So in all cases, the radiation ultimately produces electrical interaction in the material. In some cases an electron in the material may receive enough energy to escape from an atom leaving the atom or molecule thus formed positively charged. The figured illustrate this process for molecule o water. The molecule has ten electrons altogether, but only nine atomic electrons remain after a charged particle passes by, the molecule as whole is left with one excess positive charged [8].

RADIOACTIVE CONTAMINATION

Radioactive contamination and radiation exposure could occur if radioactive materials are released into the environment as the result of an accident, an event in nature, or an act of terrorism. Such a release could expose people and contaminate their surroundings and personal property. Radioactive waste is any material that contains or contaminated with radioactive nuclide at concentration greater than a safe level. In other word radioactive waste containing radioactive element that do not have practical purpose.

What radioactive contamination is?

Radioactive contamination occurs when radioactive material is deposited on or in an object or a person. Radioactive materials released into the environment can cause air, water, surfaces, soil, plants, buildings, people, or animals to become contaminated. A contaminated person has radioactive materials on or inside their body [9].

What External contamination is?

External contamination occurs when radioactive material, in the form of dust, powder, or liquid, comes into contact with a person's skin, hair, or clothing. In other words, the contact is external to a person's body. People who are externally contaminated can become internally contaminated if radioactive material gets into their bodies [9,10].

What Internal contamination is?

Internal contamination occurs when people swallow or breathe in radioactive materials, or when radioactive materials enter the body through an open wound or are absorbed through the skin. Some types of radioactive materials stay in the body and are deposited in different body organs. Other types are eliminated from the body in blood, sweat, urine, and faces [9-11].

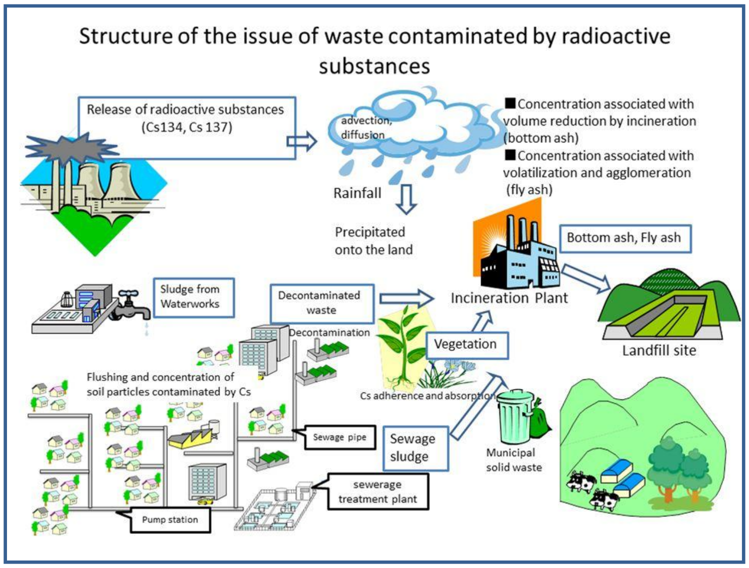

Figure 3. Pictorial diagram of radioactive contamination
Slika 3. Slikovni dijagram radioaktivnog onečišćenja

How dangerous is radiation?

Although radiation appears very dangerous, we should remember that individuals are struck by about a million particles of radiation every minute from natural sources. One third of this radiation comes from outer space, another third comes from radio-active materials like uranium, thorium, and potassium, which are found in the ground and in materials we derive from the ground; the remainder comes from radioactive materials in our bodies, especially potassium, a substantial quantity of which is vital to life. In addition to these sources of radiation, which affect all our organs, radon gas (a derivative of uranium) exposes our bronchial regions to radiation from the very air we breathe. Natural radiation is not insignificant. It is hundreds of times larger than the well-publicized radiation exposure from the nuclear industry. In Colorado, where the high altitude reduces the thickness of air that shields us from radiation coming from outer space and where the amount of uranium and tonal average; in Florida, it is 20 percent below average. Choice overbuilding materials can have a substantial effect on radiation ex-posture. Living in a brick or stone house typically results in 20 per-cent higher exposure than living in a wood house, and some particular building materials, like the granite used in New York's Grand Central Station and in the congressional office buildings, can more than double a resident's exposure. Finally, in some houses radon levels are 10 or even 100 times higher than outdoor levels, because air leakage has been reduced. Besides natural radiation, to which mankind has always been exposed, there is an important new source of radiation introduced this century: medical X-rays. A typical X-ray exposes us to 100billion particles of radiation, or about one fourth as much radiation exposure as the average American receives annually from natural sources. This is hundreds of times more radiation than we can ever expect to receive from the nuclear industry. There are many techniques for reducing radiation exposure in X-rays without com-promising their medical usefulness. Moreover, many X-rays are not thorium in the ground is abnormally large, the average exposure from natural sources is more than 50 percent larger than the nawever, and natural radiation exposure varies considerably. Made for medical purposes, but to protect hospitals and physicians against libel suits, thus, a change in the legal structure could helps avoid unnecessary medical X-rays. If we are all being struck by a million particles of radiation every minute, why don't we all develop cancer at an early age? The reason we don't is not because this level of radiation is 'safe.'' Even single particle of radiation can cause cancer, but the probability for it to do so is very small, about one chance in 30 quadrillion (i.e., 30 million billion). Hence, the million particles that strike us each minute have only one chance in 30 billion of causing a cancer. A human lifespan is about 30 million minutes; thus, all of the natural radiation to which we are exposed has one chance in 1000 (30million/30 billion) of causing a cancer. Statistics show that our overall chance of dying from cancer is one in five, so only one in200 of all cancers may be due to natural radiation. The average exposure from a nuclear power plant to those who live closest to it is about one percent of their exposure to natural radiation; hence, if they live there for a lifetime, there is one chance in 100,000 that they will die of cancer as a result of exposure to radiation from the nuclear plant [12].

RADIATION EFFECTS

Radiation is the emission of particle or energy in wave form. This is stated as electromagnetic radiation. Examples consist of: visible light, radio waves, microwaves, infrared and ultraviolet lights, X-rays, and gamma-rays [13]. Radiation can be described as two basic types, ionizing and non-ionizing radiation. The discussion will include a review of radiation of radioactivity. There are three main kinds of ionizing radiation which are included alpha particles, beta particles and gamma rays. Beside these there forms of ionizing also we have neutrons, protons, heavy charged particles, X-ray and others. Radioactive substance can penetrate into the body by inhalation, in-gestation or dermal absorption. In addition, gamma radiation external to the body can enter the skin and produce a dose various tissues [14]. Non ionizing radiation refers to radioactive energy which as opposed to produce charged ions when passing through matters has enough energy only for excitation. However it is known to cause biological effects. Non ionizing radiations usually work together with tissue through the generation of heat. The hazard depends on the ability to go through the human body and the absorption characteristics of different tissues [15]. If each and every one of these types of radiation added by human activities can cause radiation pollution. The meaning of radiation pollution is that while there are omnipresent sources of radiation, generally the high-energy radiations cause radiation pollution with a serious health risk (such as cancer or death) [16]. As has been mentioned air pollution can caused by radioactivity which are in the air as gas or aerosols that emit such ionizing radiation as alpha and beta particles, gamma rays, neutrons and other high energy quanta. From the beginning of the life story the man has been exposed to ionizing radiations from radioactive isotopes and other sources by development of atomic reactor. This kind of pollution has been raised considerably [17,18]. Exposure radiation can cause tissue and organ injury unless suitable precautions are taken. The more important health effects described as being caused by radioactive isotopes are blood abnormalities, skin changes, bon changes and so forth. Physical half-life of radioactive isotopes causes the amount of injury in human body. The most in danger part of body is where have many actively dividing cells such as the skins, intestine, gonads and tissues that grow blood cells [19]. The Radiation has most damaging effect on single celled organisms because a single cell damaged by radiation can in a roundabout way affect other cells in the individual. Cells which exposed with low energy radioactivity can have biochemical repair system which can repeal some damage. Actually it is good to mention that all humans during their life are exposed to radiation in really small doses. Radioactive pollution is a vital ecological crisis. It could be much worse if extreme caution is not utilized in the handling and use of radioactive material, and in the design and operation of nuclear power plants .There are three basic tools that can provide protection against a radiation source. These are time, distance and shielding. The goal of the protection is to prevent over exposure from external radiation and to minimize the en-try of radionuclides into the body or minimize internal radiation. Controlling Radiation Pollution can be done at various levels, such as usage and treatment of radiation waste, the control and mitigation of nuclear accidents, as well as the control and minimization of personal expo-sure to radiation at an individual level .Apart from being an inevitable series of negative effects of radiations, it is the duty of humans with regard to Radiation Standards Organizations to help in reducing the harmful effects of this kind of pollution. Radiation effects are also classified in two other ways, namely somatic and genetic effects. Somatic effects appear in the exposed person. The delayed somatic effects have a potential for the development of cancer and cataracts. Acute somatic effects of radiation include skin burns, vomiting, hair loss, temporary sterility or sub fertility in men, and blood changes. Chronic somatic effects include the development of eye cataracts and cancers. The second class of effects, namely genetic or heritable effects appears in the future generations of the exposed person as a result of radiation damage to the reproductive cells, but risks from genetic effects in humans are seen to be considerably smaller than the risks for somatic effects [20].

(a) Blistering of the right hand injury (b) Nuclear Test victim

Figure 4. Picture of radioactive hazarders' effects.

Slika 4. Slika radioaktivnih efekata

RADIOACTIVE WASTE

Radioactive waste, arising from civilian nuclear activities as well as from defence-related nu-clear-weapon activities, poses a formidable problem for handling and protecting the environment to be safe to t-he present and future generations. This article deals with this global problem in its varied aspects and discusses the cause for concern, the magnitude of the waste involved and various solutions proposed and being practised. As nuclear power and arsenal grow, continuous monitoring and immobilization of the waste over several decades and centuries and deposition in safe repositories, assumes great relevance and importance [21].

Classification of Radioactive Waste

Nuclear waste can be generally classified as ‘low-level’ radioactive waste, ‘intermediate level’ radioactive waste and ‘high-level’ radioactive waste [22].

Low Level Radioactive Waste

Basically all radioactive waste that is not high-level radioactive waste or intermediate-level waste or transuranic waste is classified as low-level radioactive waste. Volume-wise it may be larger than that of high-level radioactive waste or intermediate-level radioactive waste or transuranic waste, but the radioactivity contained in the low-level radioactive waste is significantly less and made up of isotopes having much shorter half-lives than most of the isotopes in high-level radioactive waste or intermediate-level waste or transuranic waste. Large amounts of waste contaminated with small amounts of radionuclide’s, such as contaminated equipment (glove boxes, air filters, shielding materials and laboratory equipment) protective clothing, cleaning rags, etc. constitute low-level radioactive waste. Even components of decommissioned reactors may come un-der this category (after part decontamination procedures. The level of radioactivity and half-lives of radioactive isotopes in low-level waste are relatively small. Storing the waste for a period of 10 to 50 years will allow most of the radioactive isotopes in low-level waste to decay, at which point the waste can be disposed of as normal refuse methods of landfills are adapted for radioactive waste also. However, during incineration of ordinary waste, fly ash, noxious gases and chemical contaminants are released into the air. If radioactive waste is treated in this manner, the emissions would contain radioactive particulate matter. Hence when adapted, one uses fine particulate filters and the gaseous effluents are diluted and released. Recycling to some extent is feasible. We have already dealt with the reprocessing approach, whereby useful radioactive elements are recovered for cyclic use. But it still leaves some waste that is a part of the high-level radioactive waste [23].

High Level Radioactive Waste

High-level radioactive waste is conceptualized as the waste consisting of the spent fuel, the liquid effluents arising from the reprocessing of spent fuel and the solids into which the liquid waste is converted. It consists, generally, material from the core of a nuclear reactor or a nuclear weapon. This waste includes uranium, plutonium and other highly radioactive elements created during fission, made up of fission fragments and transuranics. (Note that this definition does not specify the radioactivity that must be present to categorize a high-level radioactive waste. These two components have different times to decay. The radioactive fission fragments decay to different stable elements via different nuclear reaction chains involving α, β and γ emissions to innocuous levels of radioactivity, and this would take about 1000 years. On the other hand, transuranics take nearly 500,000 years to reach such levels.

Heat output lasts over 200 years. Most of the radioactive isotopes in high-level waste emit large amounts of radiation and have extremely long half-lives (some longer than 100,000 years), creating long time-periods before the waste will settle to safe levels of radioactivity. As a thumb-rule one may note that 'volumes of low-level radioactive waste and intermediate-level waste greatly exceed those of spent fuel or high-level radioactive waste'. In spite of this ground reality, the public concerns regarding disposal of high-level radioactive waste is worldwide and quite controversial [24].

Radioactive Waste Management System

Radioactive waste should be managed in such a way as to secure an acceptable level of protection for human health, provide an acceptable level of protection for the environment, assure that possible effects on human health and the environment beyond national borders will be taken into account, ensure that the predicted impacts on the health of future generations will not be greater than relevant levels of impact that are acceptable today, and that the management practice will not impose undue burdens on future generations. Also, radioactive waste should be managed within an appropriate national legal framework including clear allocation of responsibilities and provision for independent regulatory functions, the generation of radioactive waste shall be kept to the minimum practicable, interdependencies among all steps in radioactive waste generation and management should be taken into account and the safety of facilities for radioactive waste management shall be appropriately assured during their lifetime [25].

Radioactive waste Management System in India

Just as per capita consumption of electricity is related to the standard of living in a country, the electricity generation by nuclear means can be regarded as a minimum measure of radioactive waste that is generated by a country and hence the related magnitude of radioactive waste management. On the scale of nuclear share of electricity generation, India ranks fourth from the bot-tom in about 30 countries. As of the year 2000, India's share of nuclear electricity generation in the total electricity generation in the country was 2.65% compared to 75%, 47%, 42.24%, 34.65%, 31.21%, 28.87%, 19.80%, 14.41% and 12.44% of France, Sweden, the Republic of Korea, Japan, Germany, UK, USA, Russia and Canada, respectively. The reactors in operation produce in net Gig watts (one billion (109 Watts) (E) in the latter countries nearly 63, 9, 13, 44, 21, 13, 97, 20 and 10, respectively; India's reactors in operation yield 1.9 on this scale (both data are as per IAEA Report of 2000). Hence the magnitude of radioactive waste management in India could be miniscule compared to that in other countries, especially when one takes into account the nuclear arsenal already in stockpile in the nuclear weapons countries. As more power reactors come on-stream and as weaponization takes deeper routes the needs of radioactive waste management increase and in this context the experience of other countries would provide useful lessons. Radioactive waste management has been an integral part of the entire nuclear fuel cycle in India. Low-level radioactive waste and intermediate-level waste arise from operations of reactors and fuel reprocessing facilities. The low-level radioactive waste liquid is retained as sludge after chemical treatment, resulting in decontamination factors ranging from 10 to 1000. Solid radioactive waste is compacted, bailed or incinerated depending upon the nature of the waste [26].

Safety of Radioactive Waste Management

IAEA recommended that assessment studies have to be developed and well adapted to situations of concern to ensure the protection of human health and the environment. To apply this recommendation, an initial assessment of the planned waste 14management practice needs to be performed that identifies the radiological sources, foresees potential exposures, estimates relevant doses and probabilities, and identifies the required radiological protection measures. Various methodologies with varying complexity have been and are being developed to assist in the evaluation of radiological impact of nuclear and radioactive facilities. Glasses in lead-iron phosphate system loaded with simulated nuclear waste, were melted in the temperature range 750-950 degree. IAEA published procedure for conducting probabilistic safety assessment for non-reactor nuclear facilities. This procedure is consist of six interlinked steps, which include

- Management and organization,
- Identification of source of radioactive releases, exposure and accident initiator
- Scenario modelling,
- Sequence quantification,
- Documentation of the analysis and interpretation of the results
- Quality assurance

Figure 5. Protection against radioactive radiation.
Slika 5. Zaštita od radioaktivnog zračenja

RADIOACTIVE DISPOSAL

Nuclear waste has sometimes been called the Achilles' heel of the nuclear power industry. Much of the controversy over nuclear power centres on the lack of a disposal system for the highly radioactive spent fuel that must be regularly removed from operating reactors. Low-level radioactive waste generated by nuclear power plants, industry, hospitals, and other activities is also a long-standing issue because the spent fuel removed from a nuclear reactor is highly radioactive, it must be disposed of in a way that protects the environment from contamination and living organisms from exposure. Radioactive isotopes can be spread by air or water, and can also become part of the food chain. While the radioactivity of spent fuel drops with time, according to a 1995 National Academy of Sciences study, the "peak risks [from a repository] might occur tens to hundreds of thou-sands of years or even farther into thefuture."96 Isolating spent fuel from the environment is therefore a highly demanding task—for comparison, human civilization has existed for only some 10,000 years. Several potential ways of handling spent fuel in the long term have been proposed—none of which are ideal. These include burying the waste below the seabed, launching it into outer space, and storing it on remote islands. However, the international scientific consensus is that spent fuel and other high-level waste should be stored underground in a "geologic" repository, where the geological properties of the surrounding area would provide the long-term stability needed to isolate the waste from the environment. The waste would sit inside tunnels drilled deep into the earth. UCS concurs with this consensus, and believes that such a repository—if properly sited and constructed—can protect the public and the environment for tens of thousands of years [28]. The Nuclear Waste Policy Act of 1982 (NWPA, P.L. 97-425), as amended in

1987, required the Department of Energy (DOE) to focus on Yucca Mountain, Nevada, as the site of a deep underground repository for spent nuclear fuel and other highly radioactive waste. The state of Nevada has strongly opposed DOE's efforts on the grounds that the site is unsafe, pointing to potential volcanic activity, earthquakes, water infiltration, underground flooding, nuclear chain reactions, and fossil fuel and mineral deposits that might encourage future human intrusion. Under the George W. Bush Administration, DOE determined that Yucca Mountain was suitable for a repository and that licensing of the site by the Nuclear Regulatory Commission (NRC) should proceed, as specified by NWPA [29]. DOE submitted a license application for the repository to NRC on June 3, 2008, and projected that the repository could begin receiving waste in 2020, about 22 years later than the 1998 goal established by NWPA. However, the Obama Administration had made a policy decision that the Yucca Mountain repository should not be opened, largely because of Nevada's continuing opposition, although it requested FY2010 funding to continue the NRC licensing process. But the Administration's FY2011 budget request reversed the previous year's plan to continue licensing the repository and called for a complete halt in funding and elimination of the Office of Civilian Radioactive Waste Management (OCRWM), which had run the program. In line with the request, the FY2011 Continuing Appropriations Act (P.L. 112-10) provided no DOE funding for the program. DOE shut down the Yucca Mountain project at the end of FY2010 and transferred OCRWM's remaining functions to the Office of Nuclear Energy. DOE filed a motion to withdraw the Yucca Mountain license application on March 3, 2010, "with prejudice," meaning the application could not be resubmitted to NRC in the future [30]. DOE's motion to withdraw the license application, filed with NRC's Atomic Safety and Licensing Board (ASLB), received strong support from the state of Nevada but drew opposition from states with defence-related and civilian radioactive waste that had been expected to go to Yucca Mountain. State utility regulators also filed a motion to intervene on March 15, 2010, contending that "dismissal of the Yucca Mountain application will significantly undermine the government's ability to fulfil its outstanding obligation to take possession and dispose of the nation's spent nuclear fuel and high level nuclear waste [31, 32].

Figure 6. Methods of Radioactive Disposal system
Slika 6. Načini zbrinjavanja radioaktvnog otpada

CONCLUSION

The rapidly expanding applications of radioactive materials and of nuclear energy must inevitably lead to a vast increase in radioactive pollution of the atmosphere unless effective preventive measures are taken without delay. Such measures, which are essential for safeguarding the health of both radiation workers and the population at large, must be conceived as part of programme for the control of air pollution in general. The results of the radiological assessments show that the only significant exposures result from the occupancy and use of the contaminated floodplains, particularly if hot particles are present. Doses of several millisieverts a year could result from some of the most contaminated sites. The levels of floodplain contamination are very variable; samples taken at the same approximate location can be very substantially different. There is also no simple correlation with contamination levels and distance from the discharge.

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