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Environmental Impacts of Radioactive Waste and Substances

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ABSTRACT

Use of radioactive substances in medical applications, research centers, operation of nuclear plants, and recycling of used fuel produces radioactive waste which contains radionuclides with average-to-high half-life often formed through recycling used fuels. Some of these substances are highly soluble in water and may enter the human body and lead to very harmful conditions, by contaminating surface and ground water and finding access to food chain. Authorities are therefore required to control and reduce the amount of radioactive waste, separate harmful and hazardous radioisotopes from wastes, and transform them for safe disposal in order to minimize their harmful impacts on the environment and radiations affecting staff and other people. Liquid wastes are prepared in treatment plants using ion exchange, sedimentation, co-precipitation, liquid extraction, and evaporation. After isolating radionuclides from liquid wastes, which often results in considerable reduction in the volume, the radionuclides are stabilized/solidified into cement, bitumen, or glass in order to prevent them from migrating into the environment and groundwater. The present paper provides an overview on environmental contamination caused by nuclear waste as well as the techniques used for stabilization and disposal of waste.
KEYWORDS: Radioactive, Waste, Contamination, Environment

INTRODUCTION

Since the formation of human life on this planet, human has always been looking for secrets of the nature and new ideas to provide people with an easy and convenient life.

In most of these discoveries, the humankind has used its mind to overcome the power of the nature and to harness this power in improving the conditions of life. However, curiosity and ambitions involved in these discoveries not only made them unhelpful but also resulted in damages to human and the environment.

Nuclear and radioactive substances are among natural powers that human has used and brought under control to change the course of life. However, the increase in the amount of nuclear tests and growth of nuclear plant operations have led to a rise in radioactive activities compared to the previous centuries and such activities, like any other form of activities, may bring about positive and negative impacts on the environment, soil, animal life, vegetation, and climate.

Although human ambitions might have led to the current undesirable situations but the desire to live longer has been equally important and forced human being to develop a number of preventive measures that can lower the risk, increase security and safety, and eliminate or minimize hazards caused by these conditions; accidents like the 1986 disaster in Chernobyl or dysfunction of the equipment in the Unit 1 of Fukuyama Nuclear Power Plant in 2011 need to be prevented, and therefore, a number of organizations are currently involved, directly or indirectly, in protection measures and preventing such disasters from happening. These organizations include, but not limited to,the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the International Atomic Energy Agency (IAEA), the World Health Organization (WHO), and the Food and Agriculture Organization (FAO).

Definition of Nuclear Pollution

In 1896, Henri Becquerel discovered the radioactive properties of uranium when he observed that a thin film became darkened when exposed to uranium ore, and in 1898, Marie Curie discovered the radioactive property of radium. Using a cathode ray tube, in 1895 Wilhelm Röntgen showed that similar forms of energy can be synthetically generated. However, it was not until July 16, 1945 that the atomic age began in Alamogordo, New Mexico, when human achieved the capability of splitting atoms of U-235 and using its energy in medicine, industry, agriculture, and research. With the growing depletion of reserves fossil fuels, including coal, oil, and gas,

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accompanied by a surge in prices of fuel, a large number of nuclear reactors were built around the world to produce electricity. The increase in the number of the sources of ionizing radiations and radioactive precipitations caused by testing atomic weapons, human became increasingly exposed to these hazards. Atoms of radioactive objects gradually change as a result of energy outflow. Radioactive radiation is the results of these changes within atoms which are transformed into new atoms, which in case of radioactive atoms, will in turn transform into a new form, and the transformation continues until a non-radioactive atom is obtained. Radioactive substances either occur naturally or artificially produced as man-made substances. Some ionizing radiations, like Gamma and X-ray, are eletromonitic radiations while others, such as alpha and beta particles, neutrons, and protons, move at a very high speed. Gamma ray is a highly penetrative radiation, passing through air and layers of tissues and causing deep complications. Beta particles are even more penetrative and more harmful to human health. Ionizing power of radioactive radiations, which contain ions existing in the air, gas, and living tissue, is directly related to ionization properties of the radiations which often cause harms in living cells. These effects are classified into somatic and genetic effects. Somatic effects remain only as long as the affected organism is alive while genetic effects will also appear in the next generations.

A History of Discovery of Radioactivity

A radioactive radiation consists of invisible rays passing through glass, thin metallic films, and soft tissues of human body.

It was first discovered in 1895 by the German physicist Röntgen and called after its discoverer's name. Röntgen ray is also called X-ray. In 1896, Henri Becquerel, a French physicist, accidentally put some uranium compounds beside a sensitive film used in photography. He developed the film after a few days and observed that the film was darkened. Later, it was found that the darkness was the effect of uranium. The French physicist also discovered that this ray occurs naturally as well. In 1898, Marie Curie, a Polish chemist, became curious about the Becquerel's experiment on uranium. With the help of her husband, Pierre Curie, she found another element in uranium ores: radium which also emits radioactive rays. Through four years of experiments and research, Marie Curie was able to obtain one gram of pure radium from uranium ore. However, affected by the experiments, she got leukemia and died a few years later in 1934.

Radioactivity and Its Influence in History

Years passed by after the discovery of X-ray and radium without anyone noticing harmful effects of radioactive radiations. Hundreds of doctors and assistants died of deadly diseases caused by exposure and contact with X-ray equipment and radium. Radiation is caused by emission of particles as a result of fission and splitting of nuclei in radioactive elements. The most important problem caused by radioactive substances is genetic changes. Lizards with three legs and two heads or those with no legs and deformed frogs can be seen around nuclear reactors where precautionary measures are not well implemented. Such changes reflect manipulation of genetic traits while high doses of radiation may also lead to poisoning and death of people, soil, plants, and animals. For example, the effects of disastrous event caused by failure of nuclear facilities in Chernobyl, USSR, travelled 5,000 km toward west of England where the British Government slaughtered and buried countless sheep affected by this event which contaminated the grass grown on a soil smeared by radioactive substances.

Nuclear tests have been run on international waters starting from July 1, 1944. A major accident caused by such tests was exposure of a Japanese fishing boat called FukuryūMaru. At the time of the accident in March 1, 1954, the boat was floating 250 km away from a danger zone in Enewetak where the United States was testing its hydrogen bombs. However, 22 sailors onboard burnt in radioactive ashes resulting from the explosion. In June 1954, the Japanese Government demanded compensation from the US authorities. At the same time, people of Marshall Islands asked the UN Trusteeship Council to place an unconditional ban on atomic tests and India and the Soviet Union demanded prohibition of new nuclear tests in the Pacific Ocean; consequently, the mechanism proposed by India, France, and Belgium to regulate these test was rejected. Finally, in 1995 experts of the international law put forth a legal argument concerning nuclear tests, with the majority regarding the nuclear tests conducted in the international waters as illegal for a number of reasons: (1) the right to freedom in the international water; (2) international obligations of any state within its own territory in avoiding any action which may harm another state; and (3) illegal nature of nuclear weapon.

Radiation and Radioactivity

Most radiations (90%) to which we are exposed have natural origins. However, in some cases human has created radiations which received more attention.

By burning and combusting fossil fuels, humans release radioactive substances but the atomic fuel cycle, which is the product of human activities for generating atomic energy, creates much more radiation.

Soil Contamination

Soil is an important and invaluable natural resource. Life on earth will be impossible without soil health. Ninety-five percent of human food comes from soil. Planning for ensuring soil health and protecting soil productivity is imperative for human survival. Soil quality is altered by substances, biological organisms, or energy, causing unnatural conditions in soil. Soil is composed of two parts: the living and the dead matter. The dead matter contains weathered rock and minerals produced by decayed plants and animals (these are also called organic matters or humus). Dead matter also includes air and water. But the living matter contains organisms like insects, worms, plants, fungi, bacteria, and other microbial organisms. A typical soil sample contains 50% minerals and organic substances and 50% air which fills the voids and keeps the living organism alive. Soil can be contaminated by different human activities.

Soil is regarded as a natural purifier. Not only it supplies nutrients, but it also has a decontaminating property due to physical properties (infiltration by water), chemical properties (adsorption and evaporation), and biological properties (decaying organic substances). Soil acts like a filter for contaminated water by creating sedimentation; soluble substances are absorbed by colloids, making changes in physical and chemical properties of soil. For example, they may lower pH, thereby facilitation dissolution of heavy metals.

Effects of Radioactivity on Soil and the Environment

Radioactive hazards are also of concern when it comes to water, soil, and air. Radioactive elements can penetrate into these resources in three ways:

(1) Underground nuclear tests
(2) Nuclear cycles formed in mines, processing, and isolation processes
(3) Accidental emission from nuclear power plants

Sometimes radon released from earth can also lead to environmental contamination. Release of radioactive substances is extremely important as even small amounts of them can stay around for a long time, leading to chromosome disorders and increased risk of cancers.

Increased number of sources of ionizing radiations along with radioactive precipitations caused by atomic weapon tests adversely affected human health by exposing people to radioactivity. Atoms of radioactive objects gradually change as a result of energy outflow. Radioactive radiation is the results of these changes within atoms which are transformed into new atoms, which in case of radioactive atoms, will in turn transform into a new form, and the transformation continues until a non-radioactive atom is obtained. Radioactive substances either occur naturally or artificially produced as man-made substances. Some ionizing radiations, like Gamma and X-ray, are eletromonitic radiations while others, such as alpha and beta particles, neutrons, and protons, move at a very high speed.

Radioactive Waste

Wastes produced at nuclear power plant are disposed of into industrial and municipal sewage and find their way to soil or surface and groundwater and then used by animals and plants. Humans are infected by consuming contaminated plants or meet or milk of contaminated animals. There are many evidences confirming risk of human infection through contaminated water, and therefore, disposal of radioactive waste into seas and oceans has been prohibited.

Radioactive wastes are classified into three groups based on the quantity and the type of radioactive substances:

Low-level wastes: these wastes are the least hazardous radioactive materials which can create radiation only for a short period of time. These include clothes, tools, and equipment used by people that come into contact with radioactive substances, filters, *etc*. Low-level wastes do not need special shielding; however, they still need a treatment different from that used for normal waste. They are often incinerated and buried at shallow depths in sea or land.

Intermediate-level wastes: these include chemical wastewater, metallic coating of fuels and many other wastes produced in nuclear power plants. They often have a short radiation period, but they must be shielded using special coatings since they create considerable radiation even within this short period. They are usually embedded between concrete blocks and stored at special sites.

High-level wastes: a typical example of this type of waste is nuclear fuel sludge which requires a costly and difficult process for storing. They must be particularly shielded and then stored at a temperature below zero degree centigrade at sites located at least 1.5 km below the earth surface.

Collection and Transportation of Radioactive Waste

The IAEA has classified solid radioactive wastes into four classes:

Class A – wastes with radiation field (dose rate) less than 0.2 R/h and emitting gamma and beta rays. These can be disposed of with no reference to particular rules of transportation.

Class B - wastes with radiation field between 0.2 R/h and 2 R/h and mostly emitting gamma and beta rays. These must be carried in special containers equipped with cement or lead shields.

Class C – these produce beta rays and a small amount of gamma ray. Their radioactive dose rate is above 2 R/h. These must be transported according to strict international rules. The rules are based on using shield containers for transportation and minimizing the risk for organism during or after burying the waste. Many have challenged the proposal for disposal of this type of waste at the depth of oceans or arid deserts which already suffer from many environmental issues. Another proposed method was to use spaceships or shuttles to carry them into the space. This is however considered problematic and inconsistent with the principles.

Class D- these produce alpha rays with very long half-life. Radiation for this type of waste is often reported in Curie per m^3.

Different Methods for Disposal of Nuclear Waste

Solid radioactive wastes can be disposed of through

(1) Temporary storage
(2) Permanent accessible storage (final disposal)
(3) Disposal at glaciers (*e.g.* North Pole)
(4) Disposal at seas and oceans (not allowed)
(5) Space disposal (not allowed)

The Best (Most Advanced) Existing Methods Used by Some Countries

To date, neither the burrowing of radioactive waste nor the disposal at glaciers in poles has been proved effective. Another method used by some European countries is to put the waste into an underground storage excavated in a proper rock mass which provides an ultimate barrier against migration of nuclear waste and minimizes the risk of fractures in waste treatment systems. Pakistan disposes of its waste into seabed. This is not safe at all and the sediments formed at the depth of seas ay release radioactive substances. Other techniques, like space disposal using rockets, have been discussed but they are not even close to testing.

The best method used by some countries, including the US, Britain, and France, is to dispose of waste into rock storage. A near surface storage is used to provide better precaution. Although it needs more protection, but this method is much safer compared to other methods which use shallow tunnels excavated in mountains. According to the regulations set by Environmental Protection Agency (EPA), nuclear waste disposal sites must be capable of quarantining nuclear waste from the environment for 10 thousand years since this is the minimum period during which nuclear substances remain hazardous. For Example, the Us Congress proposed Yucca Mountains in Nevada as the best available site as a nuclear repository, although two other regions in Texas and Washington are also used for disposal of the US atomic wastes.

Discussion and Conclusion

The discussion presented in this paper indicates that human tried to control the nature and its power to reach a safe and peaceful life, but the harmful power of nature is sometimes forgotten along with the fact that this unimaginable power can destroy human life and all animals and plants. Even with this in mind, human used the power of nature and disposed hazardous waste to nature to its own detriment.

While nuclear energy is useful in resolving the energy crisis, it is sometimes uneconomical and has created new problems for human. Nuclear energy emerged as a solution to problems in generating power while no significant attention was being paid to disposal of waste produced by nuclear plants. Most decisions makers expected the science to find an answer to this question. But now, a half of century since the emergence of nuclear power, wastes are still disposed of in improper manners with no new solution being proposed to resolve these problems.

The best practice is to find a safe and more environmental-friendly alternative for whatever we make, use, or obtain from our surroundings.

Challenges Ahead

1. It would be very naïve to think that human will be able to keep radioactive wastes in a safe place for 240,000 years without harming the environment.
2. Who will be responsible for problems inflicted on the next 6,800 generations?
3. What valid warning signs will be posted for this long period?
4. Who will bear the huge costs of meeting safety requirements at disposal sites?
5. Nobody wants these highly radioactive wastes.
6. There is no solution to eliminate radiations from radioactive wastes which can actively live for more than 240,000 years,
7. Transportation of radioactive waste is extremely dangerous.
8. Uranium mines and enrichment facilities emit a large quantity of radioactive substances and radiations.

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