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NORMS: Pathways and Related Health Risks

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ABSTRACT

Naturally occurring radioactive materials (NORM), such as, ^{226}Ra, ^{232}Th, and ^{40}K in raw materials has become a matter of concern as their exposure in environment cause various health risks. This paper reviews the variety of pathways by which NORMS get introduced in environment and hence, are ingested by humans and animals resulting in several health hazards. NORMS can enter in our surroundings during the extraction and milling processes. Their deposits are highly stable and insoluble however, the precipitates of Radium are not thermodynamically stable which might result in its fractional release in the environment. A certain amount of NORMS also exist in construction materials such as, marble and ceramics. People living and working in NORM contaminated environment are mainly exposed to external γ-rays and contaminated dust. Thus, inhalation of airborne nuclides and ingestion of NORM contaminated food and water cause many health problems. Therefore, to assess the possible radiological health hazards, the knowledge and development of standards and guidelines is essential.

Keywords: Hazards, ^{40}K, NORM, Pathways, ^{226}Ra, ^{232}Th, γ-rays.

I. INTRODUCTION

Naturally Occurring Radioactive Materials (NORM), are found throughout the natural environment such as, in earth's crust, rocks and soil, in water, food, air and in human tissues. Various human activities such as, milling, mining and processing of uranium ore, general underground mining for the extraction of crude oil, fertilizer manufacture and its use etc. enhance the level of NORMS [1-2]. Petroleum oil production is a predominant source of NORM [3, 4]**.** The produced water extracted with the petroleum contains dissolved mineral salts, some of which may be radioactive because of the presence of uranium, thorium and their decay products [5]. The knowledge of various radionuclides is essential because their exposure pose several health risks. The man made materials such as, marble and ceramics are also not free from NORMS. Therefore, the study of activity of various radionuclides (^{226}Ra, ^{232}Th, ^{40}K), present in conventional raw materials, industrial wastes, and by products which are potentially being used in building and ceramic industries, had become a worldwide concern [6-8]. Each of the processes or activities producing NORM has associated with it a series, or several series of pathways by which the radioactive material can reach humans. These pathways depend on the process, but fall into several broad categories such as, on-site, off-site, airborne, waterborne etc. The radiological impact on humans, plants and animals depends upon the NORM producing or concentrating process and the various pathways by which it is transferred from the source to humans [9].

The subject of this paper is to review the several series of pathways which lead the NORM exposure to humans and other living creatures and various health hazards which it may cause.

II. ORIGIN

The exploitation of mineral resources by various human activities such as, uranium mining and milling, phosphate industries, metal mining, crude oil production, fertilizer manufacturing, coal mining and power generation from coal, building materials, ceramic industries etc., often results in contamination of natural environment and hence, naturally occurring radionuclide for example, ^{226}Ra, ^{210}Pb, ^{228}Th, ^{227}Ac, ^{40}K, are concentrated as waste in the surroundings. These enhanced naturally occurring radionuclides by means of above mentioned human activities are formally termed as technologically enhanced NORM (TENORM). The subsequent increase in NORMS in our surroundings has also enhanced the level of their exposure to humans, animals and plant which in turn increase the health risks.

Nuclear explosions carried out for mining result in addition of radionuclides in atmosphere, which stay there for some time depending upon their life span, altitude and latitude. It has been observed that the larger explosions inject radionuclides in stratosphere which can stay there for years whereas, the smaller explosions add the radionuclides in troposphere and the concentration fallout in days or weeks. Long-lived radioactive materials such as strontium-90 with half life of 28 years, carbon-14 having half-life of 5700 years, caesium-137 with half life of 30 years, are the cause of highest radiation exposure for humans [1].

III. PATHWAYS

Naturally occurring radioactive materials enter the surrounding from several different sources and pathways. These various modes by which NORM can reach humans include On-site pathways and Off-site pathways.

3.1 On Site Pathways:

These are direct pathways which include external and internal exposure of NORMS. External exposure can result because of the accumulation of radioactive dust on equipment surfaces and floors whereas, internal exposure occurs due to the inhalation of radioactive dust or Radon descendants. Analysis of on-site pathways is critical because it involves deep knowledge of manufacturing and mining processes at the site. People who may get exposed to radionuclides are employees who work at the site of mines, individuals residing on or near a disposal site. Such people are supposed to be the receivers of large dose as compared to general population [9].

The gamma radiations emitted by Radium can penetrate through vessels and pipes of the equipments on site and its presence can be detected from the outside of process equipments. However, in most cases, it has been studied that worker annual exposure due to gamma radiation from equipments are zero or far below legal exposure limits [10].

3.2 Off-Site Pathways:

These are indirect pathways of exposure which can occurs due to the transfer of TENORM by means of environmental pathways such as, food chains or by inhaling NORM contaminated dust, air and water [9, 11-12].

3.2.1 Airborne Release:

Figure 1 represents the airborne cycle of NORM release in environment. It is vivid from the figure that radionuclides accumulate in soil from air which in turn is absorbed by plants grown in it. Further, animals and humans either ingest certain amount of NORMS by having contaminated plants or by direct inhalation from air. Animals also become a source of NORM exposure for non vegetarian people. The biological decay of plants again adds NORM back to the soil [9].

NORM contaminated dust particles are also obtained during the process of handling and processing of scrap metals and other non ferrous metals. This contaminated dust is then inhaled into the body. This type of processing of metals arises in oil and gas extraction industries [13].

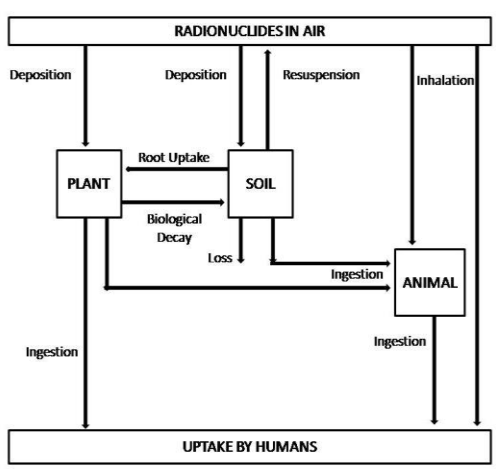

Fig. 1: Environmental cycle of airborne release NORMS and the pathway to reach humans [9].

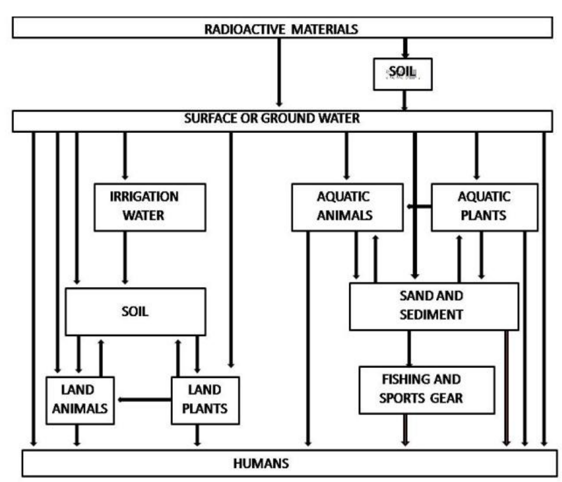

Fig. 2: Environmental cycle of waterborne release of radionuclide [9].

3.2.2 Waterborne Release:

Figure 2 depicts the waterborne cycle of NORM exposure. It is clear from the figure that there are various pathways in which water act as the basic source to carry radionuclides to humans. NORM contaminated water used for irrigation results in contamination of soil and hence, of plants grown in it. These plants ingested by humans and animals can cause several health risks. A certain dose of radioactive materials can also reach humans by ingesting aquatic plants and animals which have taken the NORMS from ground water directly [9].

Apart from this, Phosphate rock is an important raw material used to manufacture different types of phosphate fertilizers, which become the source for uranium and radium in soil. But uranium may leach into ground water that drains from fields and result in water contamination [14].

Additionally, it has been observed that a certain amount of radium remains underground as radioactive deposit due to spontaneous co-precipitation or water treatment technologies, but several tens of MBq of ^{226}Ra and even higher activity of ^{228}Ra are released daily into the rivers along with the other mine effluents from coal mines in Poland as investigated by the authors [15].

3.2.3 Pathways related to constructional material:

In today scenario, with the advancement in industries and technology, people spent most of their time indoors. So, it is essential to know whether the situations inside the premises are favorable to reside or not. In all the constructional materials ionizing radiations is the primary source of radiation exposure. Numerous conventional raw materials produce natural radioactivity due to inhabitance of radionuclide ^{226}Ra, ^{232}Th and ^{40}K. These radionuclides are responsible for radiation exposure in soil and rocks and hence, in buildings [7]. The radiation exposure from these radionuclides occurs externally and internally. Externally, due to their tendency to emit gamma radiations and internally by the radionuclide radon and its efficiency to radiate alpha particles [1, 8]. Moreover, specific radioactivity in building materials, solid industrial waste and its by-products has been found in many countries. Many materials which contain high amount of radioactivity had been identified [7]. A widely used constructional material due to its availability in attractive colors is marble. It is composed essentially from sediments i.e. crystalline form of calcite and Dolomite. Porous Uranium rich rock also possesses large amount of radioactive material [8].

In general, a large amount of radiation contaminated waste is produced by NORM industries and the various byproducts of that contaminated waste are found in construction material such as, fly ash, phosphogypsum, bauxite residue during production of alumina. Fly ash is a byproduct of pulverized coal and mostly used in supplementary cementitious material. It is widely used as a filling material in road construction. Basically, due to the presence of large content of ^{222}Rn in fly ash, it enhances the indoor gamma radiation dose rate. Furthermore, phosphogypsum is a byproduct of phosphoric acid and it is used as a substitute of natural gypsum which is further used as a component of plaster in plasterboard production. Phosphogypsum contains a high concentration of ^{226}Ra than gypsum. Apart from this, the digestion of bauxite during the production of alumina forms a mud which is called red mud. It contains a certain amount of radionuclides ^{226}Ra and ^{232}Th. In recent years, these byproducts of contaminated waste are not only used in cement composition but are also used for the preparation of concrete and bricks [16]. Bricks contain a certain concentration of uranium, thorium and potassium. During the manufacturing of bricks by firing process, amount of these radioactive element increases specially potassium is increased by a significant amount. Bricks which are made up by vinofiline and by NORM contaminated waste carry high amount of uranium and thorium. Usage of this type of NORM contaminated bricks in construction may act as a source of radiation exposure for general public [17].

IV. HEALTH HAZARDS

Inhalation of NORM contaminated food, air and water produces the risk of harmful tissue reactions in the body of living beings resulting in either the destruction of cells and tissues or their malfunctioning and hence, increases the risk of many health hazards for example, organs may damage due to the high dose of radionuclides. Such NORM effects are called deterministic effects. These effects occur when the NORM dose exceeds 0.5-1 Gy [18].

Further, stochastic effects involve the development of cancer and heritable effects due to the mutation of somatic cells and reproductive cells respectively, if individuals are exposed to the overdose of NORM contaminated environment for a long time [18]. For instance, if not protected, overexposure of Radium and Radium daughter products produce the risk of Lung Cancer and ingestion of ^{224}Ra becomes the cause of Leukemia [10, 19]. Moreover, excessive radiation exposure to the fetus may increase the risk of cancer after birth because it is more sensitive than the adults [10]. Therefore, the study of the type of radioactivity, the activity of the contaminants and their half life times etc. forms an important framework to understand the environmental and human dependence on the radiation dose.

Migration of ^{222}Rn from soil and rocks and its accumulation in enclosed areas such as homes and underground mines increases the risk of lung cancer. ^{222}Rn, which itself is an inert gas, has short lived alpha particle emitting progeny, which have the potential to damage epithelial cells in the lungs. Therefore, the inhalation of ^{222}Rn gas results in the damage of lungs [20-21].

Health risks due to the presence of uranium contents in drinking water of Bathinda have been investigated by Nisha Sharma and Jaspal Singh. They have found that 94% of the water samples were contaminated to a level more than the maximum limit recommended by WHO (2012), which is 30μg/L. Their study of uranium burden in kidneys and skeletons of humans of different age groups, because of contaminated drinking water, reveals that children's kidneys are deposited with more uranium dose than that of other age groups because of more water consumption by them per kilogram of their body weight and lesser kidney mass as compared to others. Kidney burden is found to be 20 times more than the safe limit for the children of age 1 year. The same case is observed for uranium burden in skeleton.

Children's skeleton is found to be more exposed to uranium even when compared to that of an adult. Further, in comparison with females, the skeleton of males are more deposited with uranium because they intake more water. Hence, contaminated drinking water increases the cancer risk in population [14].

In most animal studies, the injection of radium was investigated to affect the bone structure and make alterations in the process of creating new blood cells in body called hematopoiesis. Both ^{226}Ra and ^{228}Ra were found to induce changes in the structure of bones and the process of creating blood cells [19, 22].

V. PROTECTION

As far as, the health issues are concerned, the monitoring of NORM contamination and to follow safe guidelines is essential, especially for the individuals working on the site of extractions as these are the prone areas of exposure where radionuclides may enter the human body either by inhaling contaminated dust or through cuts and wounds if injured. Therefore, one can follow the following safety measures to minimize the dose:

- Shielding oneself from the dust inhalation by using proper masks to cover nose and mouth.
- Improvising the existing technology and implementing new methods which produce minimum dust.
- Monitoring personal hygiene carefully.
- Evaluating the equipments cautiously by using certain radiation detectors.
- Classifying and managing the NORM wastes and by-products to diminish the contamination.

VI. CONCLUSION

This review concludes that the exposure of naturally occurring radioactive materials is increasing in whole environment (soil, air and water) with the increase in industrial development. This has affected not only the individuals working on the site of NORM exposure such as, mines but also has its impact on the complete environmental life. Even, some building materials are reported to be highly NORM contaminated such as red mud, phosphogypsum etc. Depending upon the lifespan and activity of radionuclides, various health hazards such as, lung cancer, effect on kidneys, bone structures etc. have been detected by the exposure dose more than the safe limit set by WHO. Moreover, in Malwa belt of Punjab, Uranium burden in kidneys and skeleton of people of different age groups has been observed due to the ingestion of contaminated water. Therefore, the worldwide study of the presence of Naturally Occurring Radioactive Materials in air, water and soil, including various pathways responsible for their transfer from the point of origin to the point of its uptake by humans, several health hazards related to NORM contamination and clinical requirement is essential.

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