H.M.Salem. / ICEHM2000, Cairo University, Egypt, September, 2000, page 580- 585

# URANIUM ORES AND THE ENVIRONMENTAL IMPACT ON HUMAN HEALTH RISKS

**Hanaa Mahmoud Salem**
*Geology Department, Faculty of Sciences, Cairo University, Egypt*
*Center for Environmental Hazards Mitigation, Cairo University, Egypt*
*Email: HanaaSalem@orex.org*

## ABSTRACT

This paper analyses the importance of the potential human health risks related to radionuclides and metals released from uranium mining and milling activities as well as the health effects of depleted uranium in the environment. Breathing or ingestion of abnormal levels of the radioactive gas radon, derived from natural sources such as rocks, has been considered as carcinogenic and kidney-related diseases. A strong concern should be given to the non-radioactive pollutants associated with uranium mining and tailing activities. Groundwater and soil contaminated with U should be removed for the safety of human health. Bioremediation is considered one of the cheapest and economic remediation technologies for uranium remediation that should be taken into consideration.

## INTRODUCTION

The main lithophile elements contributing to the natural terrestrial radioactivity are uranium (U), thorium (Th) and potassium (K). The average abundance of U, Th and K in crust is about 2.6 ppm, 10 ppm and 1% respectively (Taylor 1964). All three are concentrated mainly in acidic igneous rocks compared with intermediate, basic and ultrabasic rocks. Granites are considered to be one of the most radioactive rocks, although some shale contains more than ten times U than highly radioactive granites. Phosphate deposit of sedimentary origin contains higher concentration of $^{238}U$ and its decay products than phosphate from volcanic or biological origin. Some lignite and coal are also enriched in U as much as 0.25% U (Plant and Saunders 1996).
Uranium occurs as essential constituents in more than one hundred minerals. The most important ore minerals are uraninite, and the weakly crystallized variety, pitchblende, coffinite, brannerite, davidite, uranothorite and uranothorianite.

Uranium has two primary isotopes $^{238}U$ and $^{235}U$ in the proportion of 99.3% to 0.7% respectively. Although $^{235}U$ has a small environmental significance it forms the basis of nuclear energy production. $^{238}U$ has a greater number of decay products, several of which are long-lived and it is more radiotoxic.
$^{226}Ra$ (Radium) is a member of the $^{238}U$ natural decay series and is the most hazardous radionuclide released from uranium mining and milling. Because of its long half-life (1600 years) and radiological effects (Al-Masri and Blackburn 1995), It is among the

most toxic long-lived alpha-emitters present in the environment samples, as well as one of the most widespread (Sill 1987). Industrial wastes activities are indeed a potential hazard to human health (Salem, et al. 2000, this volume). Uranium mining and milling activities have the potential to remobilize radionuclides and heavy metals and make them available in the environment. For this reason, recently United States Department of Energy (D.O.E. 1997) hosted an international conference for cleaning up uranium mill tailings because of its potential hazard to public health. U.S. Department of Energy started in 1978 for remediating 24 U mill tailings piles in ten states. In 1988, the U Mill tailings Remediation Radiation Control Act (UMTRCA) project expanded to include groundwater remediation at these sites to meet the standard limits and they were completed successfully.

## ENVIRONMENTAL IMPACT ON HEALTH RISKS

### *(i) Health effects of uranium mining and milling wastes:*

Uranium is produced as a fuel for civilian nuclear power plants and for military programs. Mill tailings contain radioactive elements such as U, Th, Ra, Rn, and non-radioactive heavy metals in low concentrations. Inappropriate conditioning and disposal of tailings waste permit the contaminants to spread into air, soil, sediment, surface water, and groundwater. If not properly disposed of, uranium mill tailings constitute a potential hazard to public health for very long period of time. Uranium is a suspected human carcinogen and a known kidney chemotoxin (Cothern and Lappenbusch 1983).

Extraction of Uranium ore from earth's crust, milling, and chemical processing, are producing large amounts of residues from which heavy metals are leachable by rain. Uranium and heavy metals are hazardous and may found their way to the groundwater in concentrations exceeding groundwater and drinking water standard limits (Salem, et al. 2000, this volume).

Uranium deposits can be weathered naturally by oxidizing groundwater flowing through fractured rock and infiltrating from the surface (Otton et al. 1989; Yanase et al. 1995). The predominant mechanism of dissolution of uranium from ores is oxidation (Francis et al. 1991). Uranium that goes into solution can migrate over long distances and can be concentrated both in surface and groundwater. Such concentration is enhanced by the ability of U to form complexes, which are most stable in solutions where the pH is greater than 7.5.

Uranium contents of groundwater vary markedly depending mainly on the bedrock type and on the proximity to U deposits as well as to the composition of the water. In many cases example in the vicinity of uranium tailings one or more toxic species are found to exceed concentration set by groundwater protection standards. The geochemistry of groundwater and stream sediments at the vicinity of some uranium host rocks has revealed the highly mobility of the uranium that is contaminated the groundwater and the stream sediments. Yanase et al. (1995) found that U deposit at Koongarra in Australia had migrated for a distance of about 200 m over a time period of 1-1.5 million years.

Generally, levels of more than 4 ppb U are considered to be anomalous. However, in arid continental conditions contents of several hundred ppb U have been recorded, and in the vicinity of U deposits it would reach 2000 ppm U or more (Thornton 1983). Leaching and erosion of mill tailings and mine not only can cause contamination of groundwater but also it can pollute the nearby rivers and lakes. This can led to contamination of fish, or even plants if the water is used for irrigation. Air pollution may result from wind erosion.

The main sources of radium from the nuclear fuel cycle are mine drainage waters, mill wastewaters, spoil piles and uranium tailings. These waters represent the most important mechanisms in transporting, concentrating and dispersing radium. UNSCEAR (1988) reported that occupational exposures to radiation hazard mainly occur during mining, processing and transportation and utilization of phosphate fertilizers.

Transportation of the radioactive materials through the Suez Canal in Egypt exposed Port Said, Ismailia and Suez cities to potential hazard to human health. Suez city has the highest radiation contamination and the estimated health effects were genetic effects and cancer diseases (Sabek et al. 1997).
Uranium mining and milling activities have the potential to remobilize radionuclides and other pollutants such as heavy metals and make them released into the environment. A strong concern should be given to the non-radioactive contaminants associated with uranium mining and tailings such as manganese, iron, copper, nitrate and fluoride, which increase the probabilities of human health adverse effects (Veiga et al. 1998).

It is very important to give a special consideration to the ventilation systems inside the exploration tunnels for the safety of the workers. During mining activities, workers are highly exposed to the radiation hazard from inhalation of radon gas and daughters, inhalation of airborne dust, ingestion of radionuclides in food, water and external irradiation (mainly by $\gamma$ rays, sometimes also by $\beta$ particles, Van Dam et al. 2000). Consequently, lung cancer caused in miners by the accumulation of radon, the uranium decay product, in the subsurface shafts.

***(ii) Health effects of Depleted Uranium (DU):***

Depleted uranium is the by-product in the process of converting natural uranium for use as nuclear fuel or weapons. It is used in Armor piercing munitions, shielding for tanks and diverse civil uses, such as stabilizers for aircraft and boats. The disintegration of a depleted uranium shell on impact is associated with high temperature effects, the production of fragments as shrapnel and finely divided particulate matter as a consequence of volatisation processes. There is very strong association between elements in the air and levels in lung and lymph nodes organs (Hamilton 1979, 1988a & 1988b), which are associated with the source and spread of cancers.

Depleted uranium was used during the recent conflicts: a- Gulf war, 1991; b- Bosnia-Herzegovina, 1995; and c- Kosovo, 1999. During these conflicts, depleted uranium rounds were used and were left in the battlefields.
A special concern must be given to the health of personnel who were exposed to depleted uranium, used in munitions during the Gulf War (320 tons), Bosnia-Herzegovina (approximately 3 tons) and Kosovo (>10 tons) air strikes (DoAF, 1997; Harley, et al., 1999; Hamilton, 2000). Considering the long period of time that has passed since the end of the Gulf War and the more recent Kosovo conflict, it is still little human data available. No special monitoring of the environment or human to understand the fate of depleted uranium munitions debris seems to have been carried out for the Gulf or the Kosovo region.

Depleted uranium can enter the body in the form of uranium metal from fragments and as uranium oxides from oxidized DU formed after impact on hard targets. Uranium is absorbed into the blood, carried and retained in body tissues, bones, kidneys and other organs (Lin et al., 1993; Harley et al., 1999). Direct ingestion of contaminated soil, in particular for children, through hand contamination must be taken into consideration as well as cattle and sheep as a pathway to humans from contaminated soils (Tsukada and NaKamura, 1998). US studies on test sites did not reveal any contamination of local groundwaters (Morris and Meinhold, 1995), although high amounts of DU were dispersed to the ground. The highest concentration was found in suspended sediment carried by run-off water (Becker and Varta, 1995).

Inhalation of dust is considered to be the major pathway for DU and the kidneys are the critical organ for uranium chemotoxicity (ATSDR, 1999). Precipitation of uranium in bodies is in the form of uranyl-carbonate complexes, after long exposures which lead to renal failure (ATSDR, 1999).

Wound contamination can occur from embedded fragments of DU, not removed, in their bodies. The effects of sixty-two American soldiers wounded during the Gulf War in 1991 show that the DU metal slowly dissolves in the body fluids, and several years after the war, blood and urine levels of uranium are elevated up to two orders of magnitude (Hooper et al., 1999). The study on the effect of DU embedded fragments in rats by Pellmar et al. (1999) and Miller et al. (1998) showed that kidney and bones are primary reservoirs for the uranium redistribution from embedded fragments.

Although chemical toxicity is the most significant risk related to uranium, radiation exposure has been related to cancers among soldiers and civilians exposed to DU radioactivity (Harley et al., 1999; Fulco et al., 2000; McDiarmid et al., 2000).

Black (1984), NRPB (1984) and COMARE (1988) reports and Doll (1999) have reported childhood leukemia from exposing to depleted uranium along the Cumbrian coast close to the British Nuclear Fuel Ltd. Sellafield, Cumbria, England.

For any uranium mining activities we must consider the remediation and mitigation process for the safety of human health. Various methods have been suggested for the removal of uranium from contaminated sites. New technologies have been developed and tested as better, faster, and cheaper methods for cleaning up uranium from contaminated sites (Abdelouas et al. 1999). Bioremediation technology of uranium in surface and subsurface has been applied successfully in different countries for example Canada, United States, Germany, and South Africa. It is highly recommended the use of bioremediation technology in Egypt for the removal of U from contaminated sites to protect human health from serious diseases.

## CONCLUSIONS

Any industrial operation involves risks to human health, both to workers and to members of the public. In the case of uranium mining and milling, these include risk of radiation exposure and non-radiological risk associated with uranium intake, which cause carcinogenic and kidney diseases. Groundwater and soil contaminated with U should be removed for the safety of human health. Bioremediation techniques must be taken seriously to decrease the potential hazard to public health. Nuclear weapons must be eliminated, destroyed and never used for our children safety.

## REFERENCES

**Abdelouas** A., Lutza, W., Nuttall E. 1999: Uranium contamination in the subsurface: Characterization and Remadiation. In Burns and Finch ed.: Uranium: Mineralogy, Geochemistry and the Environment. Reviews in Mineralogy, vol 38: 433-473.

**Al-Masri,** M. S., Blackburn, R., 1995: Radiochemical determination of $^{236}$ Ra using Cerenkov counting. J. Radional. Nucl. Chem. 195, 339-344.

**ATSDR** (Agency for Toxic Substances and Disease Registry), 1999: US Public Health Service, Department of Health & Human Services. Toxicological Profile for Uranium, Atlanta, GA.

**Becker,** A.M., Varta, E.B., 1995: Hydrologic transport of depleted uranium associated with open air dynamic range testing. LA-UR-95-1213, Los Alamos National Laboratory.

**Black,** B. D., 1988: Investigation of the possible increased incidence of cancer in west Cumbria. London:HMSO, 1984. Report of the independent advisory group.

**COMARE,** 1986: Committee on medical aspects of radiation in the environment (COMARE). First report: The implications of the new data on the releases from Sellafield in the 1960s for the conclusions of the report on the investigation of the possible increased incidence of cancer in west Cumbria.

**Cothern,** C.R., Lappenbusch W.L. 1983: Occurrence of uranium in drinking water in the United States. Health Phys. 45:89-99.

**DoAF** (Department of the Air Force), 1997: Memorandum from Headquarters, Ogden Air Logistics Center, Subject: Gulf War depleted uranium monitions expenditure, April 30, 1997.

**D.O.E.** This month 1997: In the aftermath of the Cold War, cleaning up uranium mill tailings has become a worldwide problem. August 1, 1997, vol 20, p 11.

**Doll,** R., 1999: The seascale cluster: a probable explanation. Br. J. Cancer, 310: 3-5.

**Francis,** A. J., Dodge C. J., Gillow J. B., Cline J. E., 1991: Microbial transformations of uranium inwastes Radiochim. Acta 52-3: 311-316.

**Fulco,** C.E., Liverman, C.T., Sox, H.C., 2000: Gulf War and Health. Vol. 1: Depleted uranium, Sarin, Pyriodostigmine Bromide, Vaccines. Institute of Medicine, Washington, D.C., USA.

**Hamilton,** E. I., 1979: The concentration and distribution of uranium in human skeletal tissue. Calcif Tisse Res, 7:150-162.

**Hamilton,** E. I., 1988a: Geobiocoenosis: the chemical elements and relative abundances in biotic and abiotic systems. Science Total Environ, 71:253-267.

**Hamilton,** E. I., 1988b: The concentration of uranium in man and his diet. Science Total Environ, 71:253- 267.

**Hamilton,** E. I., 2000: Depleted uranium (DU): a holistic consideration of DU and Related matters. The Science of the Total Environment 281, 5-21.

**Harley,** N.H., Foulkes, E.C., Hilborne, L.H., Hudson, A., Anthony, C.R., 1999: A review of the scientific literature as it pertains to Gulf war illnesses, Vol. 7, Depleted Uranium. RAND, Corporation National Defense Research Institute, Washington, USA.

**Hooper,** F.J., Squibb, K.S., Siegel, E.L., McPhaul, K., Keogh, J.P., 1999: Elevated urine uranium excretion by soldiers with retained uranium shrapnel. Health Physics 77, 512-519.

**Lin,** R.H., Wu, L.J., Lee, C.H., Lin-Shiau, S.Y., 1993: Cytogenetic toxicity of uranyl nitrate in Chinese hamster ovary cells. Mutation Research 319, 197-203.

**McDiarmid,** M.A., Keogh, J.P., Hooper, F.J., McPhaul, K., Squibb, K.S., Kane, R., DiPino, R., Kabat, M., Kaup, B., Anderson, L., Hoover, D., Brown, L., Hamilton, M., Jacobson-Kram, D., Burrows, B., Walsh, M., 2000: Heath effects of depleted uranium on exposed Gulf War veterans. Environmental Research 82, 168-180.

**Miller,** A.C., Fuciarelli, A.F., Jackson, W.E., Ejnick, E.J., Hogan, J., Strocko, S., Emond, C., Page, N., Pellmar, T.C., 1998: Urinary and serum mutagenicity studies with rats implanted with depleted uranium or tantalum pellets. Mutagenesis 13, 643-648.

**Morris,** S.C., Meinhold, A.F., 1995: Probabilistic risk assessment of nephrotoxic effects of uranium in drinking water. Health Physics 69, 897-908.

**NRPB**. 1984: The riska of leukemia and other cancers in Seascale from radiation expore. NRPB-R171, 291p.

**Otton** J. K., Zielinsky R. A., Beem J. M., 1989: Uranium in Holocene valley-fill sediments, and uranium, radon, and helium in waters, lake Tahoe-Carson Range area, Nevada and California, USA. Environ Geol. Water Sci 13: 15-28.

**Pellmar,** T.C., Fuciarelli, A.F., Ejnik, J.W., Hamilton, M., Hogan, J., Strocko, S., Emond, C., Mottaz, H.M., Landauer, M.R., 1999: Distribution of uranium in rats implanted with depleted uranium pellets. Toxicological Sciences 49, 29-39.

**Plant** J.A., Saunders A.D. 1996: The radioactive Earth. Radiation Protection Dosimetry 68: 25-36.

**Sabek,** M. G., El-Shinawy, R.M.K., Gomaa, M., 1997: Risk assessment during transport of radioactive materials through the Suez Canal. Radiat. Phys. Chem. Vol. 49:3, pp. 331-336.

**Salem**, Hanaa M., Eweida, E.A., Farag, A. 2000: Heavy metals in drinking water and their environmental Impact on human health. Proceeding of the international conference for the environmental hazard Mitigatin, September 2000, Cairo University. 542-556.

**Still** C. W., 1987: Determination of Ra-226 in ores, nuclear wastes and environmental samples by high resolution alpha-spectrometry. Nucl. Chem. Wate Manage 7, 239-256.

**Taylor** S.R. 1964: Abundance of chemical elements in the continental crust: a new table. Geochim Cosmochim Acta 28: 1273-1284.

**Thorton** I., 1983: Applied Environmental Geochemistry. Academic Press. 501p.

**Tsukada,** H., Nakamura, Y., 1998: Transfer factors of 31 elements in several agricultural plants collected from 150 farm fields in Aomori, Japan. Journal of Radioanalytical and Nuclear Chemistry 236 (1-2), 123-131.

**UNCEAR** 1988: Ionizing radiation: Siurces and biologic effects. United Nations Scientific Committee on the effects of Atomic Radiation Report.

**Van Dam,** R. A., Humphrey, C. L., and Martin, P. 2000: Mining in the Alligator Rivers Region, northern Australia: Assessing potential and actual effects on ecosystem and human health. J. Toxicology 181-182: 505-515.

**Veiga** L. H. S., Amaral, E. C. S., Fernandes, H. M., 1998: Human Health Risk of Radioactive and Nonradioactive Contaminants due to uranium industry. J. Environ. Radioactivity, vol. 39, no. 1, 69-85

**Yanase** N., Payne T. E., Sekine K., 1995: Groundwater geochemistry in the Koongarra ore deposit, Australia (1) Implications for uranium migration. Geochem J 29: 1-29.