

• **Review article**

Is it time to shed some light on the black box of health policies regarding the inhabitants of the high background radiation areas of Ramsar?

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Although there are substantial experimental, epidemiological and clinical evidences that high doses of ionizing radiation cause cancer and other detrimental biological effects, the health effects of human exposure to chronic low dose radiation exposures are still poorly known. People in some areas around the world live in dwellings with radiation and radon levels as much as more than 200 times the global average. Inhabited areas with high levels of natural radiation are found in different areas around the world including Yangjiang, China; Kerala, India; Guarapari, Brazil and Ramsar, Iran. Ramsar in northern Iran is among the world's well-known areas with highest levels of natural radiation. Annual exposure levels in areas with elevated levels of natural radiation in Ramsar are up to 260 mGy y⁻¹ and average exposure rates are about 10 mGy y⁻¹ for a population of about 2000 residents. Due to the local geology, which includes high levels of radium in rocks, soils, and groundwater, Ramsar residents are also exposed to high levels of alpha activity in the form of ingested radium and radium decay progeny as well as very high radon levels in their dwellings. Based on the findings obtained by studies on the health effect of high levels of natural radiation in Ramsar, as well as other high background radiation areas, no consistent detrimental effect has been detected so far. Further research is needed to clarify if the regulatory authorities should set limiting regulations to protect the inhabitants against such extraordinary elevated levels of natural radiation. **Iran. J. Radiat. Res., 2012; 10 (3-4): 111-116**

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INTRODUCTION

Despite the rapid rise in average annual doses from medical exposures over the past years ⁽¹⁾, natural radiation is still

among the major sources of human exposure to ionizing radiation. People living in high natural background radiation areas (HNBRA) such as Ramsar (Iran), Guarapari (Brazil), Yangjiang (China), Orissa and Kerala (India), receive radiation doses much greater than the worldwide average background dose for a human being (2.4 mSv per year) ⁽²⁻⁵⁾. All living organisms evolved in an ocean of ionizing radiation, much of which is internal. More than 3.5 billion years ago, when the living organisms appeared on the Earth, the level of natural radiation was about 3 times higher than its current level. Also in the early days of life, there may have been as many as 100 million natural reactors, such as found in Oklo, Gabon. It has been estimated that the dose rate around natural reactors was up to 47 Gy per minute ⁽⁶⁾.

It has been proposed that the mutation repair mechanism that exist today, reflect the response of early life to the high background radiation environment under which they evolved. Although background radiation presently accounts for 1-6% of background mutations, it has been estimated that high levels of background radiation in the early days of life, account for up to 33% of mutations to the first life forms ⁽⁷⁾.

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While there is no debate over the detrimental effects of high doses of ionizing radiation, there have been two different views on the detrimental effects of low doses of ionizing radiation since the beginning of the discovery of X-ray and radioactivity. The first view states that even low-dose radiations pose a danger and there is no threshold dose for the side effects. The other view not only believes in the existence of a threshold dose, but also emphasizes the beneficial or stimulatory effects of low levels of ionizing radiation based on phenomena such as radiation hormesis and adaptive response⁽⁸⁻¹⁰⁾.

The annual per caput effective doses from natural and man-made sources for the world's population is currently about 2.8 mSv. Nearly 85% of this dose (2.4 mSv) comes from natural background radiation⁽¹¹⁾. Levels of natural radiation can vary greatly. Ramsar (figure 1), a northern coastal city in Iran, has some areas with one of the highest levels of natural radiation studied so far.

The effective dose equivalents in HNBRAs of Ramsar in particular in Talesh Mahalleh, are few times higher than the dose limits for radiation workers. Inhabitants who live in some houses in this area receive annual doses as high as 132 mSv from external terrestrial sources and



Figure 1. Ramsar, a city in northern Iran has some inhabited areas with highest levels of natural radiation in the world. The city lies between the Elburz mountains and the Caspian sea and has many attractions such as beaches, mountain and jungle for the tourists.

the maximum credible annual radiation exposures were up to 260 mGy (figure 2).

External exposure rates from terrestrial gamma radiation in Iran and the annual background doses to the inhabitants of some areas around the world are summarized in tables 1 and 2 respectively.

Origin of the high levels of natural radioactivity

Radioactivity in the HNBRAs of Ramsar is mainly due to ^{226}Ra and its decay products, which have been brought up to the earth's surface by the water of hot springs. There are at least 9 hot springs with different concentrations of radium in this city that visitors as well as residents use as spas. According to the results of the surveys performed by the Atomic Energy Organization of Iran (AEOI), the radioactivity seems to be firstly due to the mineral water and secondly due to some

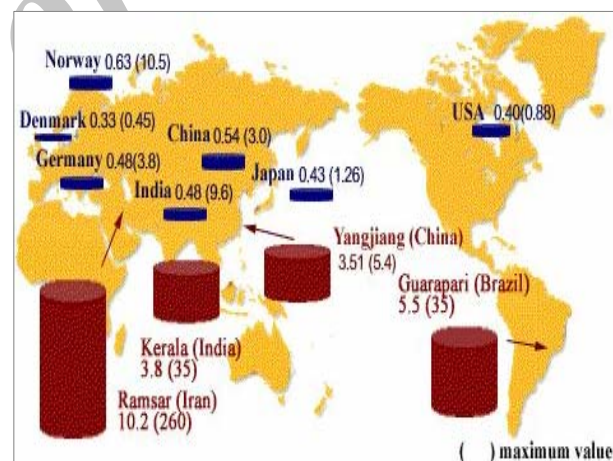


Figure 2. High Background Radiation Areas Around the World. Numbers given are in mSv/year. Ramsar, in northern Iran, has some inhabited areas with the highest known natural radiation levels in the world (Figure adapted from Health Research Foundation, Kyoto, Japan, with permission).

Table 1. External exposure rate from terrestrial gamma radiation in Iran.

Iran's Important Radiological Data	
Population in 1996 (10^6)	69.98
Average absorbed dose rate in air (nGy h^{-1}):	71
Outdoors	
Average absorbed dose rate in air (nGy h^{-1}):	115
Indoors	
Indoors/outdoors ratio	1.6

Source: Survey of natural radiation exposure, UNSCEAR 2000.

Table 2. Mean and maximum annual natural terrestrial radiation doses to the inhabitants of some areas around the world.

8.5	Area	Approximate population	Absorbed Dose rate in air ^a (nGy h ⁻¹)
Brazil	Guarapari	73 000	90-170 (street) 90-9000 (beaches)
Iran	Ramsar ^b Mahallat	2 000	70-17 000 800-4000
India	Kerala	100 000	200-4 000
China	Yangjiang	80 000	370 (average)

^a includes cosmic and terrestrial radiation.

^b it should be noted that the monazite sand beaches at Guarapari in Brazil have a higher dose rate, but these areas are uninhabited. Therefore it can be claimed that Ramsar has the highest level of natural radioactivity studied so far.

Source: UNSCEAR 2000.

travertine deposits having thorium content higher than that of uranium ⁽¹²⁾.

As shown in figure 3, igneous bedrocks have high concentrations of uranium. Although uranium is not soluble in anoxic ground water, it decays into radium-226, and radium is soluble in ground water. Dissolved radium is carried by groundwater to the surface, passing through pores and fractures in the rock. When underground water reaches the surface at hot spring locations, calcium carbonate precipitates out of solution and radium-226 substitutes for calcium (RaCO₃). High concentrations of radium carbonate (white color, molecular weight 286.03) can be found in the residue of hot springs. In some cases the residents of the hot areas used the Ra-enriched rock from the hot springs as building materials to construct their houses ⁽⁴⁾. Due to levels of natural radiation in these areas, up to 200 times higher than normal background, some radiation experts have suggested that dwellings having such high levels of natural radiation need urgent remedial actions ^(12, 13). In spite of this nearly all inhabitants still live in their unaltered paternal dwellings. Because of the expense of remedial actions and the long history of high background radiation levels, it is nearly impossible to ask the inhabitants to carry out remedial actions. Furthermore, any detrimental effect caused by high levels of natural radiation in Ramsar has not been detected so far.

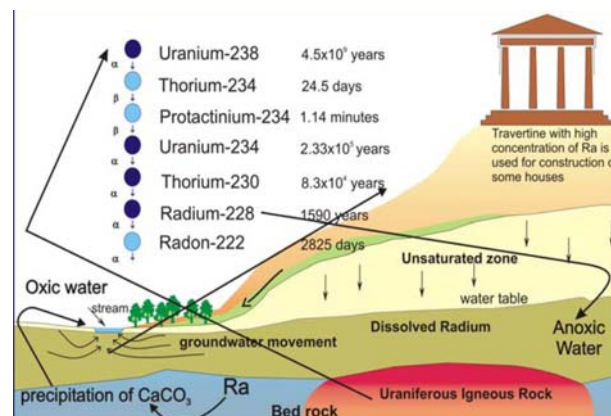


Figure 3. The origin of high levels of natural radioactivity in Ramsar (Originally from Mortazavi et al. 2001 reproduced in Introduction to Medical Geology by C. B. Dissanayake, Rohana Chandrajith).

Worldwide studies on HNBRAs

Epidemiological evidence has indicated that the natural radiation in HNBRAs is not harmful to residents. Furthermore, cancer mortality rate is significantly lower in the high background areas than in the control areas. A summary of current findings are discussed:

Kerala, India

Some areas in India have high levels of natural radiation due to presence of monazite along with other heavy minerals such as ilmenite, rutile, zircon, garnet, etc. The monazite contains approximately 9% thorium and 0.3% uranium (Paul 1998). Over 140,000 inhabitants in Kerala, on the southwest coast of India, receive an annual average dose of 15-25 mGy ⁽¹⁴⁾. The average life span of the inhabitants of Kerala was previously reported to be 72 years while for all India it is only 54 years ⁽¹⁵⁾. A comprehensive study on the residents of HNBRAs of Kerala showed no evidence that cancer incidence is consistently higher because of the levels of external gamma radiation exposure in the area ⁽¹⁶⁾. In another study the incidence of congenital malformations in the densely populated monazite bearing sands of Kerala, the stratification of newborns with malformations, stillbirths or twinning showed no correlation with the natural radiation levels in different areas. No significant

differences were observed in any of the reproductive parameters between 26,151 newborns from HNBRAs and 10,654 from a NLNRA ⁽¹⁷⁾.

Yangjiang, China

A health survey study on the inhabitants of HNBRAs of Yangjiang, China was started in 1972. In HNBRAs of Yangjiang county in China (annual doses are about 330 mR) it has been indicated that mortality from all cancers and those from leukemia, breast and lung were not higher than that of the control area (110 mR/y). Furthermore, it was shown that when samples of circulating lymphocytes taken from the inhabitants were tested *in vitro* for mitotic response to phytohemagglutinin (PHA) and the degree of unscheduled DNA synthesis (UDS), there were higher responsiveness and UDS rates in the HLNRA samples than in those from the control area ⁽¹⁸⁾. It was found that in a HLNRA in China the cancer (non-leukemia) mortality was 14.6% lower than in NBRA, and the leukemia mortality among men was 15% lower and among women 60% lower. No difference in the frequency of various genetical diseases was observed between Chinese HLNRA and NBRA ⁽¹⁹⁾. To date, based on the data as: cancer mortality from 1,008,769 person-years in HBRA and 995,070 person-years in CA; hereditary diseases and congenital malformations from 13,425 subjects in HBRA and 13,087 subjects in CA; human chromosome aberrations, and immune function of the inhabitants, no detrimental effect associated with the high levels of natural radiation detected ⁽²⁰⁾. Tao *et al.* have previously reported that on the contrary the mortality due to all cancers in HNBRAs was generally lower than that in the control NBRA. However, the difference was not statistically significant ^(21, 22). Recently these investigators confirmed their previous findings and reported that the cumulative high background radiation dose in Yangjiang residents was not related to the mortality due to cancer or all non-cancer diseases ⁽²³⁾.

Other HLNRA or radon prone areas

In the United States a negative correlation of normal background radiation with overall cancer death was observed. In Rocky Mountain states, where the level of natural radiation is 3.2 times higher than that in Gulf states, the age adjusted overall cancer death was 79% of that in Gulf states ⁽²⁴⁾. Misasa town in Tottori prefecture, Japan, where radon spa has been operating for long time, consists of high radon background area with relatively large and stable population. A study on the cancer incidence showed no difference in the incidence of all-site cancers, while stomach cancer incidence seemed to decrease for both sexes and lung cancer incidence for males only seemed to increase in the elevated radon level area ⁽²⁵⁾. Later a case control study was performed. The case consisted of 28 people who had died of lung cancer in the years 1976-96 and 36 controls were randomly selected from the residents in 1976, matched by sex and year of birth. This study could not detect the risk pattern of lung cancer, possibly associated with residential radon exposure ⁽²⁶⁾.

HNBRAs and the current controversies

Substantial evidence indicate that it may be incorrect to estimate the hazard of the low radiation doses and very low dose rates by straight extrapolation of the effects of much higher doses and dose rates higher by more than ten orders of magnitude, such as encountered by the survivors of nuclear attacks in Hiroshima and Nagasaki. Radio-epidemiological studies on the inhabitants of HNBRAs provide a unique opportunity to study effects of relatively high doses at low dose rates, such as experienced in the normal practice of radiological protection. Due to statistical considerations, these studies should rather be of long duration. In Ramsar, the population who live in the HNBRAs is estimated to be about 2000 persons. In this regard, to obtain statistically reliable results, only a long-term study can provide considerable number of person-

years of observation. On the other hand there are published reports on the increased life span of A-bomb survivors ⁽²⁷⁾ or the increased survival of laboratory animals exposed to low doses of ionizing radiation ⁽⁶⁾. Therefore the life span of the inhabitants of VHNBRAs of Ramsar should be also studied as a part of the future long-term studies.

Considering the well experienced major problems of relocation of the residents of areas contaminated after the Chernobyl accident, it can be concluded that relocation of the inhabitants of high background radiation areas of Ramsar not only is not necessary, it may lead to considerable social, economical and psychological problems ⁽²⁸⁾. It is generally believed that the risk of low-dose radiation exposures has for a variety of reasons been highly politicized. This has led to a frequently exaggerated perception of the potential health effects, and to lasting public controversies ⁽²⁹⁾. Current radiation protection recommendations are based on the predictions of an assumption on linear, non-threshold dose-effect relationship (LNT). Using LNT and ALARA, public health is best served by relocating HNBRAs inhabitants. However, relocation is upsetting to the residents ^(3, 30-32). Beneficial effects and lack of detriment after irradiation with low levels of ionizing radiation, including a prolonged exposure to high levels of natural radiation of the inhabitants of HNBRAs, are inconsistent with LNT. These unexpected observations contradict the linear non-threshold theory (for a review see ⁽³³⁾). Similar health surveys should be performed in the HNBRAs of Ramsar, where the annual doses are much higher than the Yangjiang County. There are many other areas with high levels of background radiation around the world, and epidemiological studies have indicated that natural radiation in these areas is not harmful for the inhabitants. It can be claimed that a threshold possibly separates the health effects of natural radiation from the harm of large doses. This threshold seems to be much higher than the

greatest level of natural radiation (e.g. life-time doses up to 18 Sv in VHNBRAs of Ramsar).

CONCLUSION

Using LNT and ALARA, public health is best served by relocating HNBRAs inhabitants. Several statistically significant epidemiological studies contradict the validity of LNT concept by showing hormetic effects in a form of risk decrements of cancer mortality and mortality from all causes in populations exposed to low-dose radiation. Populations in areas with high level natural radiation show no adverse health effects when compared to low-dose populations. Furthermore, relocation is upsetting to the residents and several studies of large populations indicate beneficial health effects of low doses of ionizing radiation. Preliminary findings on the biological effects of prolonged exposure to high levels of natural radiation in the inhabitants of VHNBRAs of Ramsar, showed no harmful health effects. It can be concluded that in HNBRAs the LNT model might be inappropriate to use as the basis for public health measures. However, more research is needed to clarify if the regulatory authorities should set limiting regulations to protect the inhabitants against elevated levels of natural radiation.

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