The Very High Background Radiation Area in Ramsar, Iran: Public Health Risk or Signal for a Regulatory Paradigm Shift?

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Abstract

Ramsar, a city on the Caspian Sea in northern Iran hosts the highest measured natural background radiation levels in the world. These are due to the local geology and hydrogeology and, in some places, deliver radiation doses far in excess of those recommended for radiation workers. A population of about 2000 is exposed to average annual radiation levels of 10.2 mGy/yr and the highest recorded doses are about 260 mGy/yr. These high radiation levels are due to the deposition of 226Ra in local rocks and, because these rocks are used in the construction of many local houses, interior radiation levels are often similar to those found outside.

The presence of areas such as Ramsar raises an interesting public health policy question: Is it necessary to relocate the inhabitants to areas of lower natural background radiation levels in the interests of public health? According to the linear, no-threshold (LNT) hypothesis, there is no doubt that relocating the population of Ramsar will result in a reduction in cancer incidence. Therefore, under any reasonable policy based on the LNT hypothesis, the public health is best served by relocating many of Ramsar's inhabitants to other areas along the Caspian Sea.

At present, there is no reliable epidemiological data on cancer incidence among the inhabitants of Ramsar's high background radiation areas (HBRAs), but local physicians feel that local cancer incidence rates are lower than in neighboring cities. Furthermore, preliminary results indicate that there is a statistically significant radioadaptation in the inhabitants of Ramsar. Interestingly, it seems that the frequency of chromosome aberrations in the lymphocytes of the inhabitants of Ramsar is no higher than the control areas. This important finding suggests that the cancer rate in Ramsar should be no higher than in other comparable parts of Iran. In other HBRAs such as Yangjiang, China it has been reported that mortality from all cancers and those from leukemia, breast and lung is no higher than in control areas.

These facts suggest there is no public health advantage to measures such as relocating Ramsar's inhabitants. This conclusion brings with it a corollary question: Do our public health policies require revision if Ramsar's inhabitants are unaffected by these high radiation levels? If on-going studies confirm that the cancer rates and

life spans of Ramsar's inhabitants do not differ significantly from those of other areas, then the effort of a large relocation is unnecessary. In a ddition, such findings would also suggest that our current radiation safety policies are overly conservative, requiring "protective" measures that, in actuality, offer no benefit. If this is the case, many nations may be wasting time and money in preventing non-problems.

In this paper, we will discuss the factors responsible for Ramsar's high natural radiation levels. We will then present the evidence accumulated thus far that suggests these radiation levels have no measurable effect on the health of Ramsar's inhabitants. Finally, we will discuss how these findings, if confirmed by studies currently in progress, may call for a re-evaluation of current radiation safety recommendations.

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Introduction

Humans, animals and plants have been exposed to natural radiation since the creation of life, and levels of natural radiation can vary greatly around the world. Inhabited areas with high levels of natural radiation are found in Yangjiang China, Kerala India and Guarapari Brazil. Ramsar, a northern coastal city in Iran, has some areas with the highest levels of natural radiation studied so far. Annual background doses of the inhabitants of some areas around the world are summarized in Table.1.

Table.1 Mean and maximum annual background doses of the inhabitants of some areas around the world.

Area	Mean Dose (mGy/year)	Maximum Dose (mGy/year)
Ramsar, Iran	**10.2**	**260**
Guarapari, Brazil	5.5	35
Kerala, India	3.8	35
Yangjiang, China	3.51	5.4
Hong Kong, China	0.67	1.00
Norway	0.63	10.5
France	0.6	2.2
China	0.54	3.0
Italy	0.50	4.38
World Average	**0.50**	
India	0.48	9.6
Germany	0.48	3.8
Japan	0.43	1.26
USA	0.40	0.88
Austria	0.37	1.34
Ireland	0.36	1.58
Denmark	0.33	0.45

Source: Health Research Foundation, Kyoto, Japan
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The radioactivity of the high background radiation areas (HBRAs) of Ramsar is due to ^{226}Ra and its decay products, which have been brought up to earth surface by hot springs. There are more than 9 hot springs with different concentrations of radium around the city. These springs are usually used as spas by the visitors as well as residents. According to the results of the surveys performed by the Atomic Energy Organization of Iran (AEOI), the radioactivity seems to be primarily due to the hot springs passing through streams and secondarily to some travertine deposits having a thorium content more than that of uranium (Sohrabi 1990). The results of environmental gamma exposures measured in different areas of Ramsar, both indoor and outdoor ranged from 0.05 to 9 mR/h. The dose received by the individuals monitored in the area, ranged up to 132 mSv/y. It can be concluded that the effective dose equivalents of inhabitants of HBRAs of Ramsar can be few times higher than the accepted dose limits for radiation workers (Sohrabi 1990). Considering the reported dose rates, it can be claimed that Ramsar has the highest level of natural radioactivity studied so far (Sohrabi 1990). The basic aim of this paper is to answer the question on whether we need any regulations to protect the inhabitants.

Chromosome Aberrations

Cytogenetic analysis of chromosome aberrations in peripheral blood lymphocytes is widely used as an assay to detect and quantify exposure to radiation and other clastogens (Hoffmann and Schmitz-Feuerhake 1999). Previous cytogenetic studies had shown a statistically significant difference between the results of the inhabitants of HBRAs and a normal background radiation area (NBRA) (Fazeli 1990). However, our experiments showed no significant difference even in the case of the inhabitants who lived in houses with extraordinary elevated levels of natural radiation. (By the way inhabitants still appreciate enjoying the beautiful natural environment.) Although at present there is no substantial radio-epidemiological data on the incidence of cancer in the inhabitants, local physicians report anecdotally that the persons who live in the HBRAs of Ramsar do not show any increased cancer, or leukemia. Obviously this may be attributed to the difference in individual susceptibilities to radiation exposure, so we conducted an experiment to assess the possible existence of a radioadaptive response in the inhabitants of these areas.

Radioadaptation

It is now clearly known that ionizing radiation and a variety of DNA damaging stresses such as UV, alkylating or oxidizing agents and heat can induce responses which are related to repair of the initial damage (Ikushima 1996). The results of many studies indicated that when cells are exposed to low doses of these agents, they often become less sensitive to the harmful effects of a subsequent higher dose. This type of induced repair is called adaptive response (AR). Epidemiological evidences have indicated that the natural radiation in HBRAs is not harmful to residents (Chen and Wei 1991, Cohen 1995, 1996, Zha *et.al.* 1996, Wei 1997, Jagger 1998). Furthermore, cancer mortality rate is significantly lower in the high background areas than in the control areas (Ikushima 1999). This is one of typical examples of radiation hormesis, but if we want to claim that high background radiation act as an adapting dose, we should study the radio-resistance of residents in these areas after receiving a high dose (Ikushima 1999).

Our experiments showed that when the lymphocytes of the inhabitants of HBRAs and a neighboring NBRA are exposed to 1.5 Gy gamma rays, the frequency of chromosome aberrations in the lymphocytes of the inhabitants of HBRAs is significantly lower than that of the NBRA.

Hematological Alterations

Since 1999, National Radiation Protection Department (NRPD) of the Iranian Nuclear Regulatory Authority (INRA) has performed an integrated multi-disciplinary study on the health effects of relatively high levels of natural radiation. Immunological changes were among the main endpoints of this project. The main purpose of this part of the study was to investigate the effects of the prolonged high level natural radiation on hematological parameters. In this regard, healthy donors of both sexes who lived in VHBRAs as well as donors from a neighboring normal background radiation area (NBRA) were examined for hematological changes. Hematological parameters such as counts of leukocytes (WBC), lymphocytes,

monocytes, granulocytes, red blood cells (RBC), hemoglobin (Hb), hematocrit (Ht), MCV, MCH, MCHC, RDW, PLT, and MPV were studied in all of the individuals. Our results indicated that there is no any statistically significant alteration in hematological parameters of the inhabitants of VHBRAs of Ramsar and the neighboring control area.

Immunological Changes

It is a well-known fact that ionizing radiation can suppress the activity of the immune system. On the other hand low-level whole body irradiation (WBI) can induce immuno-enhancement. To assess whether relatively high doses of natural radiation can alter humoral immune parameters, an experiment was conducted on the inhabitants of VHBRAs of Ramsar, who consistently living in houses with elevated levels of natural radiation. Immunological factors such as the concentration of serum immunoglobulins of IgA, IgG, IgM and C3, C4 components of the complement system in healthy donors from VHBRAs and a neighboring area with a normal background radiation (NBRA) were studied. Our findings indicate that there is a slight increase in IgA and IgG levels of the inhabitants of VHBRAs compared to those of matched controls. IgM, C3, and C4 complements were in the normal range. In spite of the fact that the increase in IgA and IgG were not so marked to show probable enhanced immunological capability, it can be concluded that relatively high doses of natural radiation are not immunosuppressive. More research is needed to clarify the immunological alterations induced by different levels of natural radiation.

Scope of the Future Studies

These results suggest it is inappropriate to estimate the hazard of the low radiation doses by straight extrapolation of the data obtained with much higher doses and during shorter time periods. Conclusions drawn from experiments, clinical observations and epidemiological studies following intermediate to high radiation exposures attribute a mutagenic and carcinogenic competence to all radiation doses. These conclusions cannot be confirmed experimentally nor by epidemiological studies of populations living under different conditions from natural sources of radiation. Nevertheless, a change in the present restrictive radiation protection policy does not yet appear appropriate (Roth et.al, 1996). Radio-epidemiological studies on the inhabitants of HBRAs provide valuable findings from direct observation, without extrapolation of the dose-responses from detrimental effects of high dose to low dose levels. Needless to say, due to statistical considerations, these studies should be usually very long-term experiments. In Ramsar, the population who live in the HBRAs is estimated to be about 2000 persons. In this regard, to obtain statistically reliable results, only a long-term study can provide considerable person-years of observation. On the other hand there are some published reports on the increased life span of A-bomb survivors (Mine *et.al*, 1990) or the increased survival of laboratory animals that exposed to low doses of ionizing radiation (Jaworowski, 1997). Therefore the life span of the inhabitants should be studied as a major part of the future long-term studies.

HBRAs, LNT and Problems of Policy Makers

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 (Keller 2000). Current radiation protection recommendations are based on the predictions of linear, no-threshold theory (LNT). The health effects of low levels of ionizing radiation or prolonged exposure to high levels of natural radiation such as the beneficial effects or lack of detrimental effects in the inhabitants of HBRAs are inconsistent with this theory. In HBRAs of Yangjiang county (annual doses are about 330 mR) in China 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 HBRA than that of a control area (Chen and Wei, 1991). Despite the lack of radio-epidemiological data on HBRAs of Ramsar, these findings strongly indicate the existence of hormetic effects in HBRAs. Furthermore, in 1996 it was reported that based on the substantive data as cancer mortality, hereditary disease, congenital malformations, chromosome aberrations and immune functions of the inhabitants of the Yangjiang county, no harmful impact induced by natural radiation (Zha *et.al,* 1996). These effects contradict the linear no-threshold theory. Similar health surveys should be performed in the HBRAs 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 reconfirmed that a threshold 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. lifetime doses up to 3 Sv in VHBRAs of Ramsar).

Conclusion

Several statistically significant epidemiologic studies contradict the validity of LNT concept by showing risk decrements, i.e., hormesis, of cancer mortality and mortality from all causes in populations exposed to low-dose radiation (Pollycove, 1998). Populations in areas with high background radiation rates show no adverse health effects when compared to low-dose populations. Several studies of large populations with significant differences in doses indicate beneficial health effects, i.e., lower mortality and disease rates (Cohen 1995, 1996, Wei 1997, and Jagger 1998). To assess the health effects of high level natural radiation, chromosome aberrations, induction of radioadaptive response, hematological and immunological alterations were studied in the inhabitants of VHBRAs of Ramsar. Our findings on the biological effects of prolonged exposure to high levels of natural radiation in the inhabitants of VHBRAs of Ramsar showed no harmful bio-effects. In spite of the lack of any data on harmful effects of natural radiation in HBRAs of Ramsar, as the annual dose of the inhabitants is much higher than other HBRAs in the world, we recommend that whenever it is reasonable (e.g. the construction of new schools or

any other public places in the VHBRAs) the unnecessary irradiation of the inhabitants should be decreased. In this regard it can be concluded that the Iranian Nuclear Regulatory Authority (INRA) should control the construction of any new buildings, especially public places in the VHBRAs of Ramsar in the future. In addition, special medical care as well as periodical clinical examinations should be provided for all of the inhabitants. Other measures, such as relocating large populations or taking action to dramatically reduce population exposure do not seem to be warranted because of the apparent lack of observable health effects on the current population, in the absence of such measures.

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