THE HIGH BACKGROUND RADIATION AREA IN RAMSAR IRAN: GEOLOGY, NORM, BIOLOGY, LNT, AND POSSIBLE REGULATORY FUN

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ABSTRACT

The city of Ramsar Iran hosts some of the highest natural radiation levels on earth, and over 2000 people are exposed to radiation doses ranging from 1 to 26 rem per year. Curiously, inhabitants of this region seem to have no greater incidence of cancer than those in neighboring areas of normal background radiation levels, and preliminary studies suggest their blood cells experience fewer induced chromosomal abnormalities when exposed to 150 rem "challenge" doses of radiation than do the blood cells of their neighbors. This paper will briefly describe the unique geology that gives Ramsar its extraordinarily high background radiation levels. It will then summarize the studies performed to date and will conclude by suggesting ways to incorporate these findings (if they are borne out by further testing) into future radiation protection standards.

INTRODUCTION

Life evolved in an environment with higher radiation levels than exist today, and background radiation levels today are lower than at any time in the history of life on Earth. Since life first evolved, background radiation levels have decreased by a factor of about 10, although there has been a negligible reduction since the evolution of humans (Karam and Leslie, 1999; Karam et al., 2001). At present, natural background radiation levels on Earth vary by at least two orders of magnitude today, so humans and other organisms are subject to a wide range of background radiation levels. The annual background doses in some areas of the world are given in Table I. These do not include contributions from radon progeny in the lungs, which are estimated to be even greater than the absorbed doses shown if the radiation weighting factor of alpha particles is taken into account. Areas with unusually high background (high background radiation areas, or HBRAs) are found in Yangjiang, China; Kerala, India; Guarapari, Brazil; and Ramsar, Iran. Some areas of Ramsar, a city in northern Iran, have among the highest known background radiation levels in the world. For the purposes of this paper, "dose" will be used to mean absorbed beta/gamma radiation dose because the contribution of alpha emitters is not considered.

Table I: External exposure rates 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}): Outdoors	71
Average absorbed dose rate in air (nGy h^{-1}): Indoors	115
Indoors/outdoors ratio	1.6

Source: Survey of natural radiation exposure, UNSCEAR 2000.
Note: 1 nGy hr^{-1} gives an annual radiation dose of 8.8 μGy

The high background radiation in the "hot" areas of Ramsar is primarily due to the presence of very high amounts of ^{226}Ra and its decay products, which were brought to the earth’s surface by hot springs. Groundwater is heated by subsurface geologic activity and passes through relatively young and uraniferous igneous rock. Radium is dissolved from the rocks by hot ground water. Uranium is not dissolved because the groundwater is anoxic and uranium is insoluble in anoxic waters (Grandstaff 1976). When the groundwater reaches the surface at hot spring locations, travertine, a calcium carbonate mineral, precipitates out of solution with dissolved radium substituting for calcium in the mineral. A secondary cause of high local radiation levels is travertine deposits with a high thorium concentration. (Sohrabi 1990). The radioactivity in local soils and the food grown in them is also high because soils are derived from the weathering of local bedrock. Table II details the range of radioactivity levels measured in some local rocks and soil samples.

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

Country	**Area**	**Approximate population**	**Absorbed Dose rate in air[a] (nGy h^{-1})**
Brazil	Guarapari	73 000	90-170 (street) 90-90 000 (beaches)
Iran	Ramsar[b]	2 000	70-17 000
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

Source: UNSCEAR 2000.

Fig. 1 Location of Ramsar

There are at least 9 known hot springs with various concentrations of radioactivity around Ramsar. Residents and visitors use these springs as health spas. Residents of these “hot” areas have also used the residue of the hot springs as building materials to construct houses. The indoor and outdoor gamma radiation absorbed dose rates in some parts of Ramsar range from 50 to 900 μGy hr^{-1}, although other areas in the city have absorbed dose rates that are much lower. The annual dose to monitored individuals ranges up to 132 mGy, and Iranian researchers have calculated maximum credible annual radiation exposures of up to 260 mGy. The recommended dose limit for workers in Iran is 20 mSv yr^{-1}, so some residents in the Ramsar area receive a much higher annual radiation exposure than is permitted for radiation workers. Figures 1 and 2 show the location of Ramsar and the highest background radiation areas with respect to populated areas.

The people who live in high radiation areas of the world are of considerable interest because they and their ancestors have been exposed to abnormally high radiation levels over many generations. If an annual radiation exposure of a few hundred mSv is detrimental to health, causes genetic abnormalities or an increased risk of cancer, it should be evident in these people, given a large enough population to study.

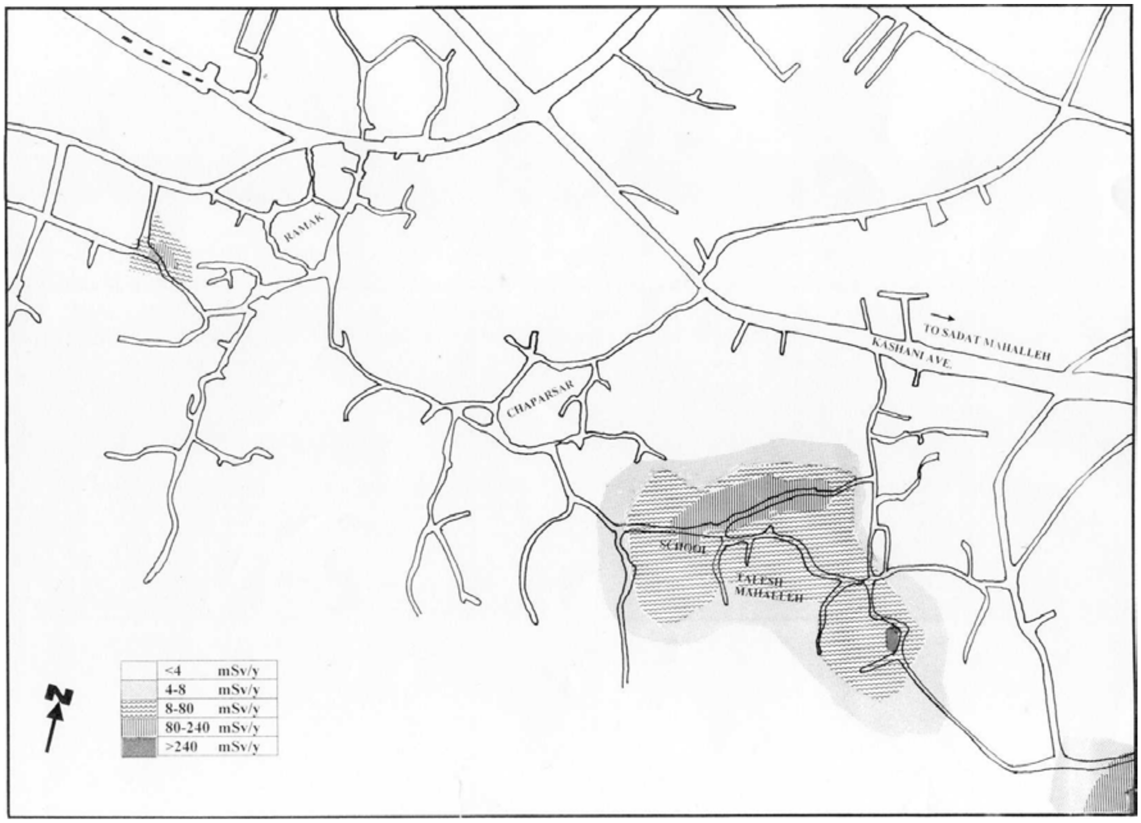

Fig. 2. Ramsar HBRAs

Ramsar Preliminary Findings

Preliminary studies (Ghiassi-nejad et al., 2002) show no significant differences between residents in high background radiation areas (HBRAs) compared to those in normal background radiation areas (NBRAs) in the areas of life span, cancer incidence, or background levels of chromosomal abnormalities. Further, when administered an *in vitro* challenge dose of 1.5 Gy of gamma rays, donor lymphocytes showed significantly *reduced* sensitivity to radiation as evidenced by their experiencing *fewer* induced chromosome aberrations among residents of HBRAs compared to those in NBRAs. Specifically, HBRA inhabitants had 44% fewer induced chromosomal abnormalities compared to lymphocytes of NBRA residents following this exposure. These results are shown in Figures 3 and 4.

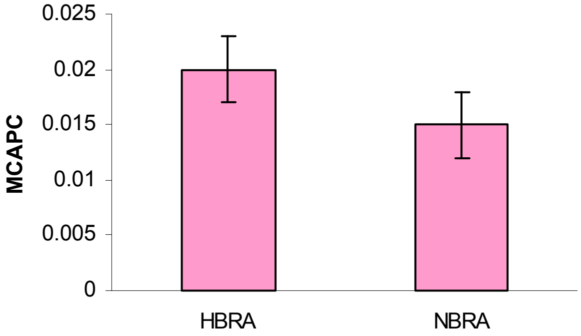

Fig. 3. Mean chromosome aberrations per cell (MCAPC) among 35 inhabitants of high background radiation areas (HBRA) and 14 living in normal background radiation areas (NBRA). Note that the 95% confidence intervals for these two populations overlap, indicating there is no statistically significant difference in the level of background chromosomal abnormalities in these two populations (from Ghiassinejad et al., 2002).

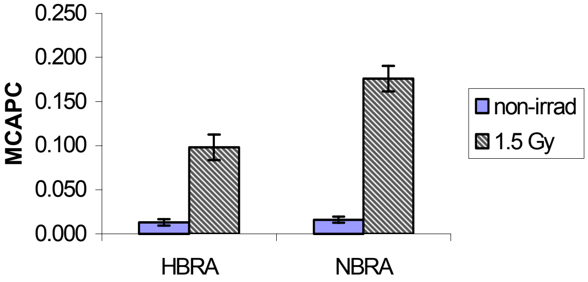

Fig. 4. MCAPC in irradiated and non-irradiated cells from inhabitants of HBRAs and NBRAs. Samples from inhabitants of both areas were examined for chromosomal abnormalities before and after irradiation with 1.5 Gy. Although there is no statistically significant difference in chromosomal abnormalities in both populations before irradiation, there is a statistically significant difference in post irradiation abnormalities. In this case, cells from inhabitants of the HBRAs have fewer chromosomal abnormalities than those of inhabitants of NBRAs. Adaptive response has previously been noted in organisms exposed to acute conditioning doses at relatively high exposure rates; these results suggest that chronic exposure to lower exposure rates may stimulate adaptive response as well (from Ghiassi-nejad et al., 2002).

Similarly, data obtained from studies on HBRA inhabitants of Yangjiang, China (Zha et al. 1996; Chen and Wei 1991) and Kerala, India (Nair et al. 1999) show no harmful impact induced by regional natural radiation, although one study (Sugahara et al., 2000) suggests that the incidence of dicentric and ring chromosomes increases with increasing age in some HBRAs[1]. In these studies, cancer mortality from 1,008,769 person-years in HBRA and 995,070 person-years in the control area, hereditary diseases and congenital malformations from 13,425 subjects in HBRA and 13,087 subjects in the control area; human chromosome aberrations, and immune function of the inhabitants, are statistically identical (Zha et al. 1996). These results suggest that exposure to elevated levels of natural radiation in these areas does not result in increased chromosomal damage and is not detrimental to the health of residents of these HBRAs.

One of the arguments used in support of increasingly strict radiation dose limits is that every incremental reduction in radiation exposure carries with it a net benefit to the public health. This hypothesis is also frequently cited by those with a seemingly irrational fear of radiation as justifying their fears, and the continued use of the linear, no-threshold (LNT) hypothesis helps to feed radiation phobia. Abandoning this hypothesis or explaining that it over-predicts risks at low levels of radiation exposure, *if supported by appropriate scientific studies*, may help alleviate radiation phobia.

Recently-published data suggest that there is *no* detectable chromsomal damage from the high levels of natural background radiation found in Ramsar and other HBRAs, contrary to the predictions of linear, no-threshold or supra-linear models of radiation dose-response (Ghiassi-nejad et al. 2001; Mortazvi 2000). This suggests that the linear extrapolation of radiation risk from very high dose at high dose rates (e.g., to A-bomb , many animal studies) to moderate doses at natural low dose rates is scientifically invalid. Given the apparent lack of ill effects to the populations of HBRAs, these data further suggest that current dose limits are overly conservative. However, the available data do not yet seem sufficient to cause national or international advisory bodies to change their current conservative radiation protection recommendations; for this to happen more definitive data are needed (Roth et al, 1996). Iranian scientists are currently conducting an epidemiological study of the inhabitants of both high and normal background radiation areas. This study complements another research project examining the cellular biology and cellular radiation response of Ramsar inhabitants; again looking at inhabitants of high and normal background radiation areas. It is hoped that these projects will provide data of sufficient quality to assist in resolving the current controversy.

Dose Limits for Natural Radiation

ICRP report 36 recommended dose limits for the public that only applied to artificial radiation exposure and have no relevance to natural radiation exposure (ICRP 1983). However, ICRP 39 confirmed that there might be levels of natural radiation, which might have to be controlled, to the extent practicable, in much the same way as for artificial sources (ICRP 1984). Currently, radiological authorities in many countries have recommended radon action levels to limit the indoor radon concentrations and hence the annual doses to the general public (Leung et al. 1999), based on recommendations found in ICRP reports 65 and 82 (ICRP 1993 and 1999, respectively). This is due to the recognition that radon and its progeny are the major contributors to the natural radiation. The US Environmental Protection Agency (EPA) recommends homes be fixed if an occupant's long term exposure will average 4 pCi/L (148 Bq/m^3) or higher (Evdokimoff and Ozonoff 1992, Wang et.al. 1999). The EPA recommends testing all homes below the third floor for radon. The average cost to install radon-resistant features in an existing home is estimated to be from $800 to $2,500. In Ramsar, Iran, the levels of ^{222}Rn were determined in 437 rooms located in 350 houses, and in 16 schools located in high background and normal background radiation areas (Sohrabi 1990). Thus, as shown in Table III the mean radon levels in some of the regions in Ramsar are much higher than the recommended acceptable limit of exposure to radon. Therefore if Iranian regulatory authorities accept recommendations similar to those of US EPA, new construction would not be permitted in many regions of Ramasar and immediate remedial action would be required for many houses. In addition, radiation exposure of many Ramsar inhabitants exceeds international recommendations for radiation exposure to radiation workers of 20 mSv per year (ICRP 1991)

Table III: Mean and Maximum Radon levels in different regions of Ramsar, Iran and comparison to US and Swedish regulatory recommendation levels.

Regions	**No. of Rooms Tested**	**Mean (Bq/m^3)**	**Maximum (Bq/m^3)***
Talesh Mahelleh	137	615	3700
Chaparsar	65	326	1983
Ramak	49	246	1459
Ramsar Schools and HBRAs	63	258	1572
USA, EPA Level	N/A	148	N/A
Sweden Level	N/A		N/A
New Houses		70	
Renovated Houses		200	
Existing Buildings		400	

* 37 Bq/m^3 = 1 pCi/L

IMPLICATIONS FOR PUBLIC HEALTH POLICY

If, indeed, low levels of radiation exposure are confirmed to be harmless or even beneficial, then it is possible that current public health policies regarding the control of low levels of radiation exposure are overly conservative. In fact, it is probable that these policies could be relaxed to some extent, while still maintaining a safety margin to ensure that the public is not exposed to levels of radiation that are harmful. In addition, governmental recommendations regarding radon mitigation could be relaxed, offering financial relief to residents in areas with high radon levels. It is also possible that governments would find it is unnecessary to consider relocation of residents in HBRAs such as Ramsar.

These policy changes, in aggregate, would result in considerable cost savings to governments and affected members of the public. These savings, in turn, could be designated for mitigation of other risks that can be addressed more cost-effectively. The net result should be an effective reduction in societal risk at little or no extra cost. In fact, using the LNT model it has been shown that reducing radiation dose is a far more expensive way of saving lives than virtually all other life-saving measures (Tengs et al 1995). If the LNT model is shown to be incorrect, the money spent on low-dose radiological risk abatement becomes even less effective than previously thought. It is an irony that monies spent to address the perceived health risks from natural radiation are currently taken from other, more effective risk reduction strategies, with the net result that such funds are making society *less* safe. In particular, I note a publication by Keeney (1995) suggesting that every $7 to $12 million in cost distributed across society may cost one life because that money is not available for other risk-reduction activities.

The US Nuclear Regulatory Commission recommends spending up to $2000 to avert one person-rem (10 person-mSv) of radiation exposure. According to the National Academy of Science’s BEIR V report, the hypothetical LNT risk of developing a fatal cancer from this level of exposure is about 5 in 10,000 (NAS 1991). Currently, over 1 million residents in the Denver area annually receive about 1 mSv (100 mrem) higher radiation dose than their counterparts along the coast of the Gulf of Mexico. Using NRC guidelines, then, the US could justify spending up to $200 per person per year to reduce their radiation exposure for a total expenditure of roughly $200 million annually. Using the LNT hypothesis and assuming the average person lives about 70 years, this would result in a total reduction of about 7 million person-rem (70,000 person-Sv) over the combined lifetimes of the currently living residents, and would save about 3500 lives. Using Keeney’s relationship, this would cost upwards of 1400 lives, simply by distributing this cost among society in the form of higher taxes. The actual public health cost might be higher, indeed, if this money came from very cost-effective interventions such as immunization programs or highway safety programs, which Tengs (1995) showed are much more efficient at saving lives. This suggests that, even under the most conservative LNT conditions, spending money to relocate residents of high background radiation areas would not generate the highest net benefit to society. The fact that the cancer rate in Denver is actually lower than in the Gulf Coast states further suggests that such measures would be a counterproductive way of reducing public risk.

Further, it should be noted that the Health Physics Society (1995) has recommended against calculating risk at cumulative radiation doses of less than about 10 rem (0.1 Sv) because of the uncertainty of radiation effects at such low doses. In addition, the HPS also recommended against calculating risks based on low levels of radiation exposure to large populations for similar reasons (1996) because of a recognition that the LNT may not be applicable at low doses and that, accordingly, it is simply not possible to determine the existence of a benefit from averting such low doses. Finally, the preliminary results presented here, along with the apparent good health of residents in HBRAs further suggest that it is not in the public’s interest to spend societal resources to relocate populations exposed to even the relatively high levels of radiation found in Ramsar and other HBRAs.

CONCLUSIONS

Preliminary results of some studies (mentioned above) suggest that there would be no public health advantage from relocating Ramsar’s inhabitants, and studies performed on the inhabitants of other HBRAs, like Yangjiang, China indicated that there is no harmful impact induced by natural radiation. Furthermore, after the Chernobyl accident there were widespread psychological reactions to the accident that were due to fear of the radiation, not due to the radiation doses. Considering the ill effects of relocating residents of areas contaminated after the Chernobyl accident, it can be concluded that relocation of inhabitants of high background radiation areas of Ramsar not only is not necessary, it could lead to considerable social, economic and psychological problems. In addition, if future studies show that low levels of radiation exposure are, indeed harmless or beneficial, governments and their citizens may allocate considerable sums of money to measures that reduce actual risks. This, in turn, would have a significant positive impact on overall public health while simultaneously reducing the irrational fear of radiation that drives many public policies.

FOOTNOTES

[1] The levels of cumulative radiation exposure among the members of this study is much less than those of the people studied in Ramsar; 31-360 mSv cumulative exposure as compared to lifetime doses of 300 to over 10,000 mSv among those studied in Ramsar.

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