Review Article

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Natural Background Radiations, Radioadaptive Response and Radiation Hormesis

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ABSTRACT

Natural background radiation has been an interesting subject among scientific studies for many years. The effective radiation dose of human from natural sources is about 2.5 mSv/y yet it is higher in certain regions around the world. The city of Ramsar, located in the province of Mazandaran, is one of the most important areas with the highest rate of natural background radiation in the residential areas of the world.

Background radiation is an ionizing radiation in the environment the source of which could be either natural or man-made. Its natural sources are cosmic radiations, terrestrial radiations, internal radiations and radon. As for the man-made sources, natural radiation could come from nuclear power plants and the scatter radiations of atomic bomb tests. There are numerous studies on the effects of natural background radiation on biological systems and humans. Most of these studies confirm the harmless and even useful impacts of certain dosages of natural background radiation. In this regard, there are reports on the decrease, increase or even equality in the risk of some types of cancer with low and high dosages of radiation. Nevertheless, extensive epidemiological studies are required in order to confirm the effects of low-dose radiation on carcinogenesis and other factors. Additional decrease or increase in the risk of different types of cancer is also a possibility.

KEY WORDS: Ramsar, Natural Background Radiations, Radioadaptive Response, Radiation Hormesis.

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Introduction

Natural Background Radiations have been studied for many years (1). Everyone in their life are under different natural radiations and it seems that these types of radiation cannot be removed completely (2). Natural radiations come from different sources in the space and the earth's crust (3). For instance, they could originate from the cosmic radiation, terrestrial radiation, internal radiation and radon (4,5). The studies conducted in the United States claimed that radon is responsible for 37% of the human exposures. According to these reports, the dose of cosmic, terrestrial and internal exposures received by local residents is 5%, 3% and 5% respectively (6,4). In this review, the situation and the sources of natural radioactivity in different parts of the world, especially in Ramsar, also the latest reports on the effects of low doses of ionizing radiation on the inhabitants of Ramsar have been reviewed. Therefore, we classified

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these findings based on the effects of radiation as well as the recent debates raised by the scientific community on the harmless doses which are several times higher than the harmful ones. We additionally reviewed the reasons behind these opinions as well as the arguments against them.

Areas with High Natural Radioactivity: Such areas as Yangjiang in China, Kerala in India, Guarapari in Brazil and Ramsar in the north of Iran enjoy the natural radiation level above usual (8). In nearly half a century, Ramsar has been recognized as one of the regions with high background radiation. According to the report of the United Nations Scientific Committee on Atomic Radiation in the year 2000, the coastal city of Ramsar enjoys the highest levels of natural radioactivity compared to the rest of the important regions around the globe (9-7). In addition, the levels of the radioactive gas "radon" in some areas of Ramsar is above the action level recommended by the Environmental Protection Agency of the United States of America (2).The annual radiation dose received by the residents in some areas with high background radiation in the world is compared to other parts of the world (fig 1).

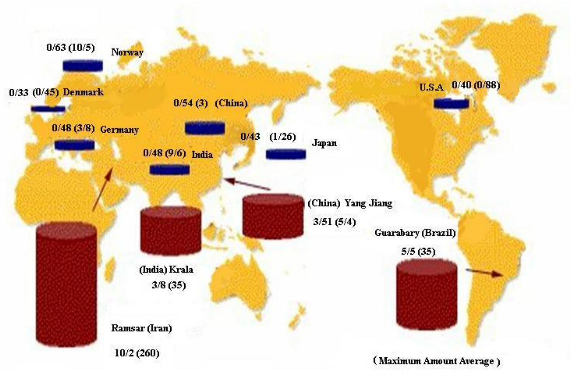

Figure 1. shows the level of background radiation compared to other areas in the world which are known to have high levels of natural radioactivity. It also illustrates the background radiation levels in some countries. The numbers listed represent the average annual dose rate (in mSv). Numbers in parentheses indicate the maximum annual dose rate (2).

The Origin of Natural Radioactivity in Ramsar: High levels of natural radiation in some areas of Ramsar originate from the high density Radio Nuclides radium-226 and radioactive substances coming from the its subsequent decay (9). After entering the body, the radium accumulates in the bone and thus, leads to the next internal exposures.

For another thing, travertine with its varying amounts of radioactive thorium has also caused the high level of natural radiation exposure in Ramsar (2). Figure 2 illustrates the igneous rocks' ferrous afferents which are rich in uranium (10). Although uranium is not dissolved in ground waters without oxygen, after its dissection into radium-226, radium can be dissolved in water and so it flows in underground slots.

Finally, when radium brings onto the surface of the earth carrying oxygen, calcium carbonate (CaCO3) precipitates and radium -226 is replaced with calcium atoms and radium carbonate (RaCO3) is produced. High levels of radium carbonate are detected in the sediments of areas with hot-water springs (2). In some cases, the residents use these sediments in the form of travertine stone to build their houses (2).

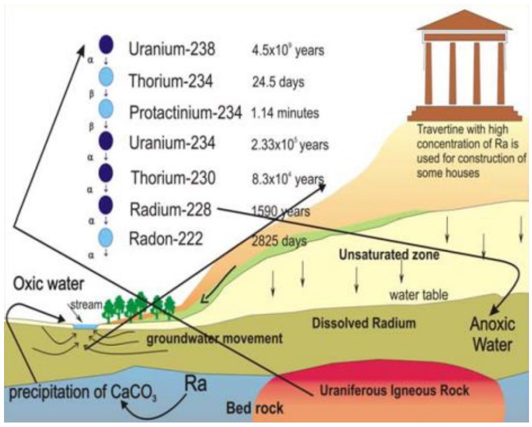

Figure 2. The Origin of High Levels of Natural Radioactivity in Ramsar (2)

Adaptive Radiation (Radioadaptive Response):

Studies show that the average annual dose of natural radiation found in Ramsar inhabitants is about 10 mSv. However, this amount appears to be relatively higher in some residents of these areas (11). The current radiation protection legislation is based on the assumption of a linear, non-threshold relationship between the radiation dose and cancer induction (13, 12). Thus, simple, scientific estimations indicate that some residents of Ramsar who have been under a radiation dose excessively higher than normal are likely to develop some kind of cancer. Nevertheless, the majority of the residents seemed to be in good health and the preliminary studies conducted so far have not revealed any harmful effects in particular. As a result, the need for any intervention of policy makers has yet not been identified (16-14).

Studies from other areas with high natural radioactivity in the world represent a lack of proof for any deleterious effects on the residents of those areas (8). Also some studies reported the adaptation after the medical and occupational radiation tooexposures (17, 18). However, it seems that this adaptation after natural exposure has the higher extent compared to other types of exposure (18).

It can be concluded that despite the fact that the residents of these areas recieved far higher radiation doses than radiologists and radiologic technologists [8], studies have shown that the exposure to natural radiation above the normal rate will eventually result in comparative effects of radioadaptive response and radiation hormesis in these residents (18, 19). The radioadaptive response are defined as the increasing resistance of the organisms or cells in the culture to a significant dose of radiation upon receiving a lower dose (18-20).

This type of exposure which is primarily induced by lower doses and is done via increasing the activity of the immune system (8, 9, 11, 20-22) or enhancing the efficiency of the repairing systems of the damaged DNA (23, 24), ultimately increases the resistance of the organism against later irradiations by higher doses. Radioadaptive response of exposure to natural radiation have been considered important by the scientific world (2) in a way that upon the publication of the initial reports on the subject, hundreds of more articles were instantly published. Some researchers have ventured further and stated that lower doses of radiation not only reduce the mortality of many causes and cancer, but they also can provide protection against accidental exposures to higher doses (25). In some reports, the results of Ramsar inhabitants are validated as evidence for the assessment of different biological effects of lower doses compared with higher doses (26).

Radiation Hormesis: Hormesis of Greek origin, which has been defined as the desire to move quickly, is usually used to assess biological responses to lower doses of toxins and other stressful stimuli (27). Hormesis is used for those toxins and irritants which their effects is diverse between lower and higher doses (28,29). The term was first applied in 1888 by a German Pharmacologist (30). Radiation Hormesis or radiation homeostasi is as theory verifying the usefulness of the lower doses of ionizing radiation compared to the slightly higher ones. According to this theory, healing against the diseases which are inactive in the absence of ionizing radiation is activated at doses of 3 to 10 times the normal value (31).

This theory, which was initially skeptical (32), also claims that the reverse-repair mechanism is enabled not only to cancel the harmful effects of radiation but to also prevent unrelated diseases to the radiation (33, 34).The decreased mortality rate of cancer as a result of living in the increasing radiation field (35), cases of no reduction in telomere length in infants and adults living in areas with high natural radioactivity in Kerala, India (37, 36) as well as many other examples (38,39) validate the theory of Hormesis.

On the other hand, a number of credible reports reject the Hormesis theory in case of some specific types of cancers. One example is a 26-year relationship between childhood leukemia and the amount of exposures in mothers during pregnancy in England. The results indicate that there is a linear relationship between this kind of exposure and childhood leukemia (40). We can also refer to the study of thyroid cancer associated with the exposure field of atomic bomb survivors in Japan (41).It is noteworthy that in some cases, the examination of the epidemiological link between cancer and radiation exposure has been known invalid and defected and the accuracy of the results remains uncertain (42). However, due to the large number of articles and reports on this subject, hardly any doubt is cast on the harmony and Hormesis. In this regard, different modes have been suggested for assessing the relationship between the amount of dose and the specific effects of the lower doses (fig 3). Radiation protection laws have currently been passed on the linear model without a threshold (B); but in the past 15 years, many scientific findings have agreed the effectiveness of Hormesis model (D). Apart from the Hormesis model, three other models of low and very low doses of radiation have been designated:

1-**Supra-linearity model** associates the rate of the low doses of radiation with a higher risk than the higher doses (43).

2-**Linear model** suggests that lower doses pose as much a risk as higher doses (44).

3-**Linear Quadratic model** proves that lower doses involve lower risks than higher doses. In other words, despite the fact that lower doses of radiation are potent, as the exposure increase, the risk is heightened with higher rate (45).

In contrast with these three models, in the Hormesis model exposures to about 10 times higher than the background levels are not only harmless, but they can also reduce the natural harmful effects as well (37, 46, 47).

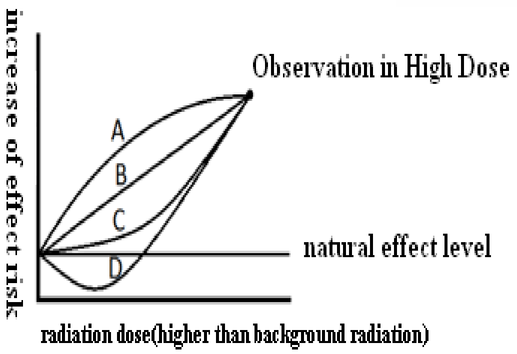

Figure 3. hypothesis on the relationship between the effect of lower doses of radiation. (A) (supra-linearity), (B) (linear), (C) (linear quadratic) and (D) (Hormesis)

It is acknowledged that the public aspect of the matter makes it a sensitive subject and thus, it might induce fear in the individuals of the society. However, it is a matter of less concern in the scientific community because of the attention which has been given to the effects such as radiation hormesis and radioadaptive response (48).

Of course, some concern remains particularly in the diagnostic departments mainly in nuclear medicine. (48), While in imaging, patients are often under the effect of low doses too. For instance, the approximate effective dose of medical imaging and nuclear medicine in the north of Iran is reported to be approximately 1.5 mSv per test (49, 50). Although the intermediate dose from the medical imaging in the north of Iran has been reported to be 0.33 mSv per year (48), only their background gamma ray dose is 0.53 mSv per year on average (51). Moreover, despite more chromosomal breakage even at lower and chronic exposures (52), the reports show an inverse relationship between the amount of background exposure and cancer in parts of the north (53). It should be noted that as well as the aforementioned findings in the context of chronic background radiation, there are also reports rejecting the whole theory. For instance, in a study done in Iran, thyroid cancer in the region of Chaharmahal Bakhtiary has been proven to be directly related to the height and location with an increasing altitude which results in an increasing exposure (54).

One of the most interesting experiments in recent decades has been the study which was conducted on the effects of low radiation doses on the immune system and the necessity of Hormesis.

Similarly, many other reports have been published on the subject and based on their conclusion, low and chronic radiation exposure leads to certain changes in the immune system which makes it one of the primary candidates for the hormesis beam.

Of the subjects of these reports, fields like the increasing percentage of cells in $CD4^+$ and $CD8^+$ (8), decreasing cells of $CD107a^+$ (55), the decreasing activity of natural killer cells and cytotoxic in areas with natural radiation (9), increased production of interlokin-4 and 10, decreased production of interlokin-2 and interferon-gamma (56) and finally, hormone-related changes in hormons of the immune system have been investigated (57) many of which have helped to confirm the connection between the immune system and hormesis. It should also be taken into account that other factors have been proposed for hormesis and among them, comparative radiation and repair process are the most prominent candidates (23).

Conclusion

A large number of reports on the effects of natural and man-made Radiation fields on biological systems and humans have been published so far. For the most part, the harmless and even beneficial effects in certain doses of radiation are being discussed. In some cases, the increase, decrease and even the equality of in the rate of cancer risk at lower doses have been reported compared to high doses. Nevertheless, extensive epidemiological studies seem to be required to confirm the actual effects of low and very low exposure on diseases. With respect to that, any of the described theories for cancer or any other disease in general might be proven to be true in the future.

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