

## Research Article

# Five-Year Mortality Trend Among Bushehr Nuclear Plant Workers Exposed to Ionizing Radiation: Does Sanctions Impact Mortality Rate?

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Received: November 15, 2021; Accepted: December 08, 2021; Published: December 15, 2021

## Abstract

**Background:** The investigation of potential adverse health effects of occupational exposures to ionizing radiation, on nuclear plant workers, is an important area of research. In this study, we aimed to calculate the incidence and risk of cancer development and mortality during last five years (2015-2019).

**Materials and Methods:** 660 nuclear industry workers were included into this study. For this cohort, the cancer mortality has been assessed by data obtained from national health registry excluded for the probability of known causes of death. The associations between cumulative occupational radiation exposures (radon, gamma radiation and long-lived radionuclides) and cancer mortality were calculated.

**Results:** Radon and Gamma exposure was significantly higher among workers who developed cancer [8.9 (0; 3,224.5) vs. 19.9 (0; 128.4),  $p=0.03$ ] and [15.0 (2.1; 110.0) vs. 24.5 (0; 470.1),  $p=0.02$ ]. However, no significant association was found between long-lived radionuclides and risk of cancer ( $p=0.07$ ). Considering economic sanction as a dependent variable, we found no significant effect on mortality rate among workers.

**Conclusion:** In conclusion, significant association has been observed between the risk of cancer development and radon and gamma exposure among nuclear industry workers, but no association was found between cancer and long-live nucleoids exposure.

**Keywords:** Ionizing radiation; Nuclear industry; Cancer; Mortality

## Introduction

Ionizing Radiation (IR) is a well-studied human carcinogen and has been revealed as a carcinogen in different reports from various population-based studies, mainly from nuclear workers occupationally exposed to IR [1].

IR has been shown to be associated with various health issues. Adverse effects mostly occur only after acute and high doses exposure of  $>0.1\text{Gy}$  and are considered by non-linear dose-responses, with a threshold dose below which the effect is not observed. Therefore, adverse effects are of most relevance in radiotherapy; normal tissue therapy doses are limited to avoid these effects. Adverse effects are thought to resulting from the destruction of substantial groups of cells in the tissues concerned, leading to functional decline in the affected organs [2].

The most recent study by Zablotska et al. [3] included post-1956 workers from three Canadian nuclear plants, all of which started monitoring after 1956. The study reported a substantial, although statistically non-significant, increased risk of solid cancer-related death among workers of nuclear plants (excess relative risk per sievert) = 2.80, 95% CI: -0.038, 7.13). Since, there is no similar report on cancer-related mortality among workers in Bushehr nuclear plant in a 5-year period, this cohort study was conducted.

## Materials and Methods

### Study design and setting

Our study included Bushehr nuclear plant workers visiting university affiliated clinics for screening. This retrospective study was performed from 21 March 2015 until 14 March 2019. Informed consent has been obtained from all patients. This study was approved by the Research Ethics Committee of the Baghiatallah University and received funding from the same university (Ref no. 92-21556).

### Participants

To be included to this cohort, participants had to be worked in nuclear facility in for at least 1-year or more and had to have a minimum of identifying information to ensure reliable linkage with the death records. The 1-year minimum monitoring was to avoid including individuals with very short-term employment, who often demonstrate irregular morbidity or mortality patterns. Monitoring data for exposure to ionizing radiation were available from company records for plant workers, providing individual annual quantitative estimates of whole-body dose attributable to external penetrating radiation.

### Cancer-related mortality

For cancer morbidity, incidence rates were estimated using the Iranian Health Insurance Claim Data registry and need more than one

week admission in a public hospital. National health insurance claim records include date of admission, and diagnosis made by physician at the time of admission. Diagnoses were classified according to the international Classification of Diseases and Causes of Death, (ICD).

Thus, Neoplasm (C00-D48); “total cancer” here means malignant neoplasms (C00-C96 of ICD-10), and “lung cancer” means malignant neoplasm of bronchus and lung (C34 of ICD-10). “Non-Hodgkins Lymphoma” (NHL) means follicular (C82), diffuse (C83) and other and unspecified types (C85) of NHL in ICD-10, and “Leukemia” means lymphoid (C91), myeloid (C92), monocytic (C93), other leukemias of specified cell types (C94) and unspecified (C95). Thus, leukemia also includes chronic lymphocytic leukemia (CLL) although there were no cases of CLL mortality and morbidity among radiation exposed workers in this study.

### Statistical analysis

A classification table for Poisson Regression analysis of mortality was calculated as described previously [4]. Statistical analyses were performed using SPSS Statistics software version 21 (IBM Corporation, Armonk, NY, USA). Chi-2 test was used for assessment of the association between categorical variables. The relationships between quantitative variables were evaluated using Fisher’s exact test. P-values less than 0.05 were considered significant.

## Results

456 plant workers had participated in this study (39 cancer patients and 417 healthy). The median duration of follow-up is 34.8 months, while the median age at the end of follow-up is 58.1 years old, respectively. The loss to follow-up or alive at the end of follow-up is 33.6 % for the (median age = 57.7 years old) cancer patients and 24.5% for the healthy cohort (median age = 51.2 years old). Further data is showed in Table 1.

The main characteristics of cumulative exposures and equivalent exposure doses among both cohorts are reported in Table 2. As it can be seen Radon and Gamma exposure was significantly higher among workers who developed cancer (8.4 (0; 3,224.5) vs. 19.7 (0; 128.4),  $p=0.03$ ) and (12.0 (2.1; 110.0) vs. 24.5 (0; 470.1),  $p=0.02$ ).

For workers who developed cancer, a nonzero cumulative radon exposure is significantly associated with an average increase in the instantaneous risk of death for all the aggregated causes other than cancer ( $r=0.877$ ,  $p=0.002$ ). Additionally, for workers who developed cancer, a nonzero cumulative gamma exposure is significantly associated with an average increase in the instantaneous risk of death for all the aggregated causes other than cancer ( $r=0.656$ ,  $p=0.04$ ).

## Discussion

We estimated associations for cancer mortality among nuclear workers from Iran and found that radon and gamma exposure play a more significant role in developing cancer among this population.

High doses of ionizing radiation can definitely produce deleterious consequences on human beings, including, but not only, cancer pathogenesis. At very low radiation doses the situation is much less clear, but the risks of low-dose radiation are of societal importance in relation to issues as varied as screening tests for cancer, the future of nuclear power, occupational radiation exposure, frequent-flyer risks,

**Table 1:** Demographics of study cohorts.

	Healthy (No Cancer)	Cancer
Age	50.9 (38-66)	58.1 (40-71)
Follow up	38 months (12-47)	32 months (11-37)
Death from solid cancer	0	11
Death from hematologic cancer	0	28

**Table 2:** Cumulative exposures of study cohorts.

	Healthy (No Cancer)	Cancer	P-value
Radon	8.4 (0; 3,224.5)	19.7 (0; 128.4)	0.03
Gamma	12.0 (2.1; 110.0)	24.5 (0; 470.1)	0.02
Long-live radionuclides	0.6 (0; 132.2)	0.9 (0; 10.4)	0.07

Data Presented as median (min, max).

manned space exploration, and radiological exposures [5].

Current evidence that support the hazard of cancers due to ionizing radiation are from the studies of survivors of the nuclear in Japan [6]. The study by Brenner and colleagues [6,7] revealed the odds of lifetime cancer mortality is substantially higher from pediatric CT-scan than from adult CT-scan which shows the importance of age in which an individual is being exposed. In another study by Pearce et al. [8], the cumulative radiation doses more than 50 milliSieverts (mSv) in children could triple the risk of leukemia and brain cancer, although the cumulative absolute risks were small and there was high possibility of reverse causation (explained below). The use of CT scans in pediatric populations could potentially produce small cancer risk and should be used only when absolutely necessary.

Studies of nuclear workers have the potential to increase our knowledge on health effects associated with low dose and low dose rate radiation exposure. Follow-up of large cohorts of nuclear industry workers has been ongoing for over four decades. Further work on the development of informative prior distributions could be useful in strengthening understanding of site dependent radiation and cancer associations [9].

## Conclusion

In conclusion, significant association has been observed between the risk of cancer development and radon and gamma exposure among nuclear industry workers, but no association was found between cancer and long-live nucleoids exposure.

## Declaration

**Acknowledgement:** This study was financially supported by Baghiatallah University of Medical Sciences.

**Author approval:** All authors have seen and approved the manuscript.

**Data availability statement:** Available based on a reasonable request from corresponding author.

**Funding:** Received from Baghiatallah University, faculty of medicine (Ref no. 92-21556).

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