ANALYSIS OF CHEMICAL AND BIOLOGICAL RISK EFFECTS TO PERSONNEL EXPOSED TO IONIZING RADIATION
Hospital Example

by

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The universe of this study are the doctors, technicians and assistants working in two state and two private hospitals operating in Van and exposed to the risk of ionizing radiation. After the difference analysis, it was determined that there is a cause-effect relationship between the ventilation status in the workplace regarding radiation and the occupation health and safety performance of the businesses according to the radiation knowledge of the employees. The purpose of this article is to analyze the effects of ventilation systems and radiation knowledge of employees on the performance of occupation health and safety activities implemented in businesses, regarding radiation risk in hospitals in the relevant region. In this context, it has been determined that having ventilation facilities for employees in businesses and having employees informed about radiation increases occupation health and safety performance.

Key words: *ionizing radiation, electromagnetic waves, health risk, rays, air pollutant*

Introduction

While the effects of radiation on human health are an important research topic, people are exposed to radiation from many sources in almost every aspect of life. After the discovery of X-rays, important developments such as nuclear accidents (Chernobyl) and nuclear war (atomic bombs dropped on Hiroshima and Nagasaki) accelerated research in this field. It is known that radiation exposure dose, type and duration of exposure are the main factors. Ionizing radiation is proven to have more dangerous effects than non-ionizing radiation. Ionizing radiation can cause cancer, but non-ionizing radiation has no proven carcinogenic effects in long-term studies [1].

The basis for protection against radiation as a form of energy is to correctly understand radiation. As technology advances, the use of ionizing radiation in medical imaging and treatment is becoming more common. However, frequent use of radiation increases radiation exposure for both radiation workers, patients and society. Therefore, the correct application of radiological protection principles is important for public and environmental health. Radiation is defined as the transfer of energy through particles or electromagnetic waves. The energy, source and type of radiation are the basic parameters of radiological classification. If the ener-

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gy packet of the radiation is at a level that can remove atoms, it is classified as ionizing radiation. If the energy packet is not at a level that can remove electrons from atoms in the interacting medium, it is classified as non-ionizing radiation. Non-ionizing radiation includes the frequency ranges of radio waves and low-energy ultraviolet radiation. Ionizing radiation includes X-rays, high-energy ultraviolet radiation, gamma rays, cosmic rays, which have wave properties, and beta, alpha, and neutron particles, which have particle properties [2].

Ionizing radiation is considered a type of energy used in different sectors such as industry, research, and medicine. Healthcare workers, whose professional lives inevitably result in regular exposure to ionizing radiation, face significant health risks. Healthcare workers in particular are exposed to radiation during medical procedures such as radiotherapy, nuclear medicine applications, and imaging tests. Therefore, it is very important for medical professionals to have knowledge about radiation protection to ensure safety and minimize the risk of exposure [3]. Various national and international organizations develop guidelines and regulations regarding rules to be followed, radiation protection, precautions to be taken by workers exposed to radiation, and related regulations. On the other hand, many studies are being conducted to determine the awareness and knowledge levels of healthcare professionals and candidates regarding radiation protection [4]. In this context, it is of great importance to have a good scientific understanding of the biological effects of radiation, to establish appropriate protective standards and, in a broader sense, to use nuclear technologies in the fields of industry, medicine and energy in a controlled manner [5].

The main material of nuclear medicine is ionizing radiation, therefore, it is important for its users to have knowledge of its biological effects and pathophysiological basis. Ionization occurs when electrons are removed from atoms and molecules after exposure to high temperatures, electrical discharges, or electromagnetic and nuclear radiation [6]. Radiation is defined as the type of energy created by moving atoms due to particles (neutrons, beta or alpha) or electromagnetic waves (gamma or X-rays). This spontaneous disintegration of atoms is called radioactivity, and the excess energy emitted is described as a type of ionizing radiation [7]. Indirect and direct damage from radiation causes permanent physiological changes by activating biochemical and molecular signaling pathways and leads to cell death [8]. Background radiation is invisible and harms human health. Moreover, a fact stated by the National Council on Radiation Protection and Measurements (NCRP) in 2009 shows that the largest source of human-induced exposure or dose is from medical testing and treatment. However, a 2012 study by the United States Environmental Protection Agency (US EPA) states that radon (naturally occurring radioactive substances) causes an estimated 20000 lung cancer deaths each year. This finding is consistent with Mishra *et al.* [9]. It is also supported by the results of the study, which concludes that the increasing mortality rates are closely related to the high background radiation field [10].

Electromagnetic waves, which cover about 15 wavelength (or frequency or energy) ranges from radio waves to microwaves, infrared radiation, visible light, ultraviolet radiation, and X-rays to high-energy γ-rays, are used in different businesses. Understanding the attenuation of electromagnetic radiation in matter requires knowledge of the particle properties of electromagnetic waves. In this context, it is necessary to know the microscopic structure of matter in the form of atoms, molecules and nuclei, and to understand the formation of electromagnetic radiation and its interaction with matter [11]. Ionizing radiations such as alpha particles, beta particles, X-rays, gamma rays, and neutrons ionize atoms and molecules at the molecular level in cells, transferring energy to the molecules and causing them to disperse to the ground surface. The energy release caused by ionizing radiation is called linear energy transfer (LET). As the speed of ionizing radiation decreases and its charge increases, its LET increases, and as LET increases, the lethal effects of radiation also increase [12]. High energy electromagnetic radiation, such as γ-rays and X-rays, have the effect of breaking chemical bonds in the environment in which they come together. Although this type of ionizing radiation has a negative effect on living beings, γ- and X-rays are generally used in the treatment and diagnosis of diseases. In all living things exposed to ionizing radiation, different cell and tissue types can be affected in different ways. Specific treatments can be developed based on the cellular mechanisms affected by the molecules identified through research on this subject. These treatments can be applied to minimize the effects that may occur in patients after medical radiation, and can also be used for people exposed to radiation after accidents [13]. The effects of radiation are expressed as the effective equivalent dose (H), the conventional unit of effective equivalent dose is the Rem, the SI unit is the Sievert [Sv] and the absorbed dose, D. The effective equivalent dose, H, is expressed by a quality factor, Q, that describes the damage caused by radiation. The $Q = 1$ in X-rays, γ-rays, and electrons, $Q = 2$ to 20 in neutrons of various energies, and $Q = 20$ in alpha particles or fission products. The H (effective equivalent dose) = D (absorbed dose) × Q (quality factor) Sievert [Sv] = Gray [Gy] × Q It is calculated with the formula [14].

Effects of ionizing radiation, such as cell death, chromosomal aberrations, DNA damage, mutagenesis, and carcinogenesis, occur either directly from the ionization of cell structures, especially DNA, or indirectly from reactive oxygen produced by radiolysis of water. Using the linear threshold-free model (LNT), possible risks from exposure to low doses of ionizing radiation (below 100 mSv) are estimated by extrapolating from data obtained after exposure to higher doses of radiation. This model shows that cells that are not directly exposed to ionizing radiation exhibit responses similar to those of cells that are directly irradiated. In general, many studies indicate that the significant biological effects of ionizing radiation result from DNA damage induced by direct interaction of the radiation trace with the cell nucleus. This paradigm suggests that irradiated and non-irradiated cells interact and that oxidative metabolism and intercellular communication play an important role in the signaling events that lead to radiation-induced bystander effects [15].

Environmental pollution and degradation are a global concern due to their adverse effects on health. Ionization radiation is considered environmental contamination, especially when it exceeds safe occupational and public limits [16]. Ionizing radiation is high energy particles with high penetrating power [17]. Exposure to high levels of gamma radiation causes a number of harmful effects in humans, including mutation, various cancers, and different types of diseases [18]. One of the biggest consequences of radiation exposure is DNA damage. Damaged DNA can be completely healed. It can also be harmless or cause dysfunction and cell death. The effect of radiation exposure depends, as noted, on the type of exposure, as well as on the type of radiation (γ or β) and the dose of radiation absorbed and the rate of absorption. A single radiation dose greater than 1 Gy, equivalent to one joule of radiation energy per kilogram of body mass, can cause acute radiation syndrome [19].

According to Kara [20], radiation is one of the biggest physical risk factors in diagnostic and treatment hospitals. It is observed that not only healthcare personnel working in radiation areas but also those caring for patients in other departments are at significant risk. Radiobiology is concerned with the optimization of methods and techniques for the benefit of humans and the assessment of risks to human health following exposure of technical personnel in diagnostic and nuclear medicine procedures. These radiation exposures are in the low dose ranges. On the other hand, in unintended nuclear accidents and emergencies, radiation exposures are usually in the high dose ranges affecting the on-duty workforce, rescuers, early responders and the general public. According to Kumar *et al.* [21], cellular responses to ionizing radiation such as X-ray, alpha, beta, γ-rays and neutrons are the focus of intense radiobiology studies. Extensive studies show that exposure of cells/tissues to ionizing radiation causes damage through direct or indirect effects on vital cellular molecules such as DNA, proteins, and lipids. Indirect radiation damage to cellular molecules is caused by free radicals formed by the effect of radiation on water molecules in the irradiated body.

Especially in closed living spaces, if electromagnetic waves cannot be reduced from their source, shielding largely prevents electromagnetic energy from entering the relevant area. Shielding is typically made of metallic materials with suitable electrical conductivity. In this context, there are studies in the literature indicating that many advanced materials can be used for next-generation shielding platforms [22].The main purpose of radiation protection is to benefit from the benefits of using radiation in various areas and to reduce the risks arising from its effects on employees, people, the environment and future generations as much as possible [23].

Experimental procedure

In this research, the qualitative deductive method was used in literature writing and the *relational screening* model, which is a quantitative method to analyze cause and effect relationships, was used in the application part.

Measurement item

In the study, in order to determine demographic characteristics, questions regarding personal information such as gender, age, marital status were also used, using the *Scale for Assessing the Situation of Healthcare Workers Working with Ionizing Radiation Sources* [24] and *Occupational Health and Safety (OHS).* Two scales were used, namely [25].

Statistical analysis

Survey participants were determined by simple random sampling method. The *T*-test and one-way variance analysis were applied to the data obtained from the surveys *via* the SPSS statistics program. The mean difference and 95% confidence interval are provided where applicable. All comparisons, significance was set at $p < 0.05$. Findings obtained from the analysis.

Differences in OHS performance of businesses according to ventilation status against radiation in the workplace

H1a: In terms of the ventilation variable for radiation, the *T*-test results related to the hypothesis that there is a statistical difference between the enterprises in terms of OHS practices performance (*Managerial Measures and Precautions on Occupational Health and Safety, Employees' Working According to Occupational Health and Safety Criteria, Employees' Awareness and Consciousness Levels on Occupational Health and Safety, Occupational Health and Safety Training Practices, Cooperation and Communication between Management and Employees on Occupational Health and Safety*) are given in tab. 1.

With regard to ventilation status regarding radiation in the workplace differences between the OSH performance of the enterprises were tested with the help of *T*-test. As a result of the test, it was determined that the relevant hypotheses for *Administrative Measures and Precautions on Occupational Health and Safety* (H1a1, $p = 0.000$), employees working according to occupational health and safety criteria (H1a2, $p = 0.000$), employees' awareness and

Table 1. The *T*-test findings for the relationship between radiation ventilation and OHS performance of enterprises

Levels	Radiation-related ventilation	N	Average	*T*-value	*p*-value	Hypothesis
Administrative Measures and Precautions on Occupational Health and Safety	No	46	28859	–6832	0.000	H1a1 Accepted
	Yes	95	40882			
Employees Working According to Occupational Health and Safety Criteria	No	46	28125	–7865	0.000	H1a2 Red
	Yes	95	39684			
Awareness and Consciousness Levels of Employees on Occupational Health and Safety	No	46	25507	–6811	0.000	H1a3 Accepted
	Yes	95	35702			
Occupational Health and Safety Training Practices	No	46	25652	–6885	0.000	H1a4 Accepted
	Yes	95	38779			
Cooperation and Communication between Management and Employees on Occupational Health and Safety	No	46	28641	–3931	0.000	H1a5 Accepted
	Yes	95	36658			

consciousness levels on occupational health and safety (H1a3, $p = 0.000$), *Occupational Health and Safety Training Practices* (H1a4, $p = 0.000$) and *Cooperation and Communication between Management and Employees on Occupational Health and Safety* (H1a5, $p = 0.000$) were supported, in other words, in the case of ventilation for radiation in the working area, there was a difference in the OHS performance of the enterprises ($p < 0.05$).

When the averages were examined to determine the group from which the differences that emerged as a result of the analysis originated; it was determined that the average of the businesses with ventilation against radiation in the area of work was higher than the average of the businesses without ventilation in terms of the variables of *Administrative Measures and Precautions on Occupational Health and Safety*, *Employees working according to occupational health and safety criteria, Awareness and Consciousness Levels of Employees on Occupational Health and Safety, Occupational Health and Safety Training Practices* and *Cooperation and Communication between Management and Employees on Occupational Health and Safety*.

Differences in OHS Performance of businesses according to radiation knowledge of employees

H1b: The *f*-test results related to the hypothesis that there is a statistical difference between the enterprises in terms of employees' knowledge of radiation and the performance of OHS practices (*Managerial Measures and Precautions on Occupational Health and Safety, Employees' Work According to Occupational Health and Safety Criteria, Employees' Awareness and Consciousness Levels on Occupational Health and Safety, Occupational Health and Safety Training Practices, Cooperation and Communication between Management and Employees on Occupational Health and Safety*) are given in tab. 2.

The differences between the radiation knowledge of the employees and the OHS performance of the enterprises were tested with the help of *f*-test. As a result of the test, it was determined that the relevant hypothesis was supported for the factors of *Administrative*

Table 2. The *f*-Test findings for the relatinship between employees' radiation knowledge and businesses' OHS performance

	Radiation information	N	Average	*f*-value	*p*-value	Hypothesis
Administrative Measures and Precautions on Occupational Health and Safety	During my pre-graduation education from school	91	3.8255	15.448	0.000	H1b1 Accepted
	After starting work, in-service training	25	3.7700			
	From my colleagues	20	2.2500			
	From media and the internet	14	4.5000			
	Other	6	3.8750			
Employees Working According to Occupational Health and Safety Criteria	During my pre-graduation education from school	91	3.6497	12.604	0.000	H1b2 Accepted
	After starting work, in-service training	25	4.0500			
	From my colleagues	20	2.4250			
	From media and the internet	14	3.8125			
	Other	6	3.8750			
Awareness and Consciousness Levels of Employees on Occupational Health and Safety	During my pre-graduation education from school	91	3.4579	20.276	0.000	H1b3 Accepted
	After starting work, in-service training	25	3.8533			
	From my colleagues	20	2.1167			
	From media and the internet	14	2.5833			
	Other	6	3.,6667			
Occupational Health and Safety Training Practices	During my pre-graduation education from school	91	3.6681	12.259	0.000	H1b4 Accepted
	In-service training after starting work	25	3.6080			
	From my colleagues	20	2.0400			
	From media and the internet	14	2.7000			
	Other	6	4.,0000			
Cooperation and Communication between Management and Employees on Occupational Health and Safety	During my pre-graduation education from school	91	3.6071	13.776	0.000	H1b5 Accepted
	After starting work, in-service training	25	3.5200			
	From my colleagues	20	1.9125			
	From media and the internet	14	2.6250			
	Other	6	4.0000			

Measures and Precautions on Occupational Health and Safety (H1b1, $p = 0.000$), employees working according to occupational health and safety criteria (H1b2, $p = 0.000$), employees' awareness and consciousness levels on occupational health and safety (H1b3, $p = 0.000$), Occupational Health and Safety Training Practices (H1b4, $p = 0.000$) and Cooperation and Communication between Management and Employees on Occupational Health and Safety (H1b5, $p = 0.001$), in other words, in the presence of radiation information, there was a difference in the OHS performance of the enterprises ($p < 0.05$).

When the averages were examined to determine the group from which the differences resulting from the analysis originated; it was determined that the averages of the businesses with radiation information on *Administrative Measures and Precautions on Occupational Health and Safety, Employees working according to occupational health and safety criteria, Awareness and Consciousness Levels of Employees on Occupational Health and Safety, Occupational Health and Safety Training Practices,* and *Cooperation and Communication between Management and Employees on Occupational Health and Safety* were higher than the averages of the businesses without radiation information.

Results

It has been determined that there are differences between the ventilation status regarding radiation in the workplace and the OHS performance of the enterprises ($p < 0.05$). Additionally, it was determined that there was a difference in the performance of employees' radiation knowledge and the OHS performance of the enterprises ($p < 0.05$).

Discussion

The harmful effects of ionizing radiation are more numerous and more serious, and especially its carcinogenic potential is a significant threat to human health. Conflicting results have been reached in the long-term studies on the effects of non-ionizing radiation emitted from sources such as television, radio, and telephone used in the health field. For this reason, it is beneficial to stay as far away from radiation sources as possible in order to prevent negative effects. Those who have to be exposed to radiation professionally should also carry out their work after taking the necessary precautions, thus minimizing the risk [1]. The effect of temperature on performance was studied through numerical results along with graphs showing methanemol distribution and electrolyte current density. It has been observed that the increase in temperature leads to an increase in the methane consumption rate due to the increasing effects of factors such as reaction kinetics, diffusion, conductivity and thermokinetic factors and at the same time this increase in temperature causes a rapid increase in the electrolyte current density [26].

The heat factor can be a more significant problem, especially in terms of the intense development of the spread. There is a relationship between radiation and heat production, and this situation can continue on the negative effects of diseases on health. High temperatures can affect the comfort of employees in areas exposed to radiation, and it is possible to experience long-term exposure biologically under these conditions. In addition, excessive heat can cause problems, stress, dehydration and even heat stroke. Radiant heat can be found on hot surfaces in the workplace due to the nature of the work and heat radiation can occur from these surfaces. Thermal radiation, *i.e.* radiant heat, is an electromagnetic energy that does not produce heat unless it hits a surface where it will be absorbed. Therefore, air currents cannot affect radiant heat. However, air currents in the environment can provide some comfort to the employee. The only way to protect from thermal radiation is to place a heat-proof curtain between the employee and the source. However, if the curtain does not reflect the heat, it can absorb the heat and become a heat source. Therefore, both ventilation and temperature regulation in areas exposed to emissions are of great importance for the safety of employees in hospitals and other healthcare facilities. Adequate ventilation and appropriate temperature levels not only reduce employee exposure to emissions, but also increase occupational health and safety.

Minimizing the negative effects of radiation on employee health can be achieved by simultaneously implementing source-based control methods and collective protection measures. For this purpose, first of all, necessary protocols should be established in radiologic applications and personnel who will work in this field should be trained. Proactive measures should be taken such as ensuring the use of individual dosimeters for relevant healthcare workers, carrying out regular health and OHS follow-ups, monitoring and evaluating dosimeter results, planning annual training for relevant personnel, using appropriate armor in radiation areas, isolating waiting rooms, resting relevant healthcare personnel, and using personal protective equipment. Radiation protection aprons, gonadal and thyroid protection and lead glasses of different sizes should be made available, especially for healthcare workers and patients, and their use should be monitored. With these OHS approaches, the work-life balance of employees will be ensured [27].

Conclusion

Today, it is claimed that the negative effects of radiation on human life are high. In this context, it does not seem possible to get rid of the effects of radiation. Therefore, it is necessary to ensure that especially those working in the health field and the society are kept away from different types of radiation for a longer period of time, with lower doses and more permanent measures. Treatment after exposure to radiation causes huge costs, therefore, it is of great importance for humanity to implement radiation prevention practices supported by scientific research in order to be protected from the effects of radiation to the maximum extent.

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Nomenclature

D – Absorbed dose
H – effective equivalent dose
LNT – linear thresholdless model
Q – a quality factor that describes the damage caused by the type of radiation
Rem – effective equivalent dose unit
Sv – SI unit Sievert

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