The Impact of Nuclear Radiation Exposure on Humans and Ecosystems: The Urgency of Iodine Pills in Emergency Management

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Abstract

Background: Nuclear disasters and radioactive contamination pose severe health and environmental risks, with both immediate and long-term effects. Beyond acute radiation sickness, exposure increases the risk of genetic mutations, thyroid cancer, cardiovascular diseases, and immune suppression. Radioactive isotopes like iodine-131 (I-131), cesium-137 (Cs-137), and strontium-90 (Sr-90) persist in ecosystems, bioaccumulate, and contaminate food chains. Iodine pills play a crucial role in blocking I-131 absorption by the thyroid, reducing thyroid cancer risk.

Objective: This study evaluates iodine prophylaxis as a primary intervention in nuclear disasters and examines the cascading effects of environmental contamination. **Methods:** A systematic review was conducted using PubMed, Scopus, and Google Scholar with keywords like “nuclear disaster,” “radiation exposure,” and “potassium iodide pills.” Seven Scopus-indexed journals were analyzed, focusing on nuclear disaster preparedness, radiation effects, and iodine pill efficacy.

Discussion: Elevated I-131 levels heighten thyroid cancer risks, making iodine pills essential. Rapid distribution and public awareness are critical, especially for vulnerable populations. Contaminated food chains pose long-term health risks, necessitating decontamination, radiation surveillance, and bioremediation to mitigate environmental damage.

Conclusion: Immediate iodine prophylaxis, environmental remediation, and continuous health monitoring are vital for reducing nuclear disaster risks. A multidisciplinary approach involving

governments, healthcare professionals, and environmental experts is essential for effective preparedness and response strategies.

Keywords: Nuclear Disasters, Radiation exposure, Human Health, Potassium Iodide Pills, Radioactive iodine.

Introduction

Nuclear disasters have become a global concern with far-reaching impacts on public health and the environment. According to Indonesia's National Disaster Management Agency (BNPB), a disaster is defined as an event or series of events that threaten and disrupt people's lives, caused by natural, non-natural, or human factors, leading to loss of life, environmental damage, and economic disruption.[21] Nuclear disasters fall under non-natural disasters, where radiation exposure can have severe health and environmental impacts.

The Sustainable Development Goals (SDGs) highlight the need for clean and affordable energy. SDG 7 focuses on ensuring access to reliable, sustainable, and modern energy for all, promoting nuclear energy as an alternative source while addressing its potential hazards.[22] While nuclear energy offers benefits, past accidents have shown the devastating consequences of radioactive contamination. The balance between nuclear energy's promise and its potential risks makes nuclear safety measures and emergency preparedness essential components of energy policies worldwide.

Major nuclear accidents, such as the Chernobyl disaster in 1986 and the Fukushima Daiichi disaster in 2011, underscore the severe threat posed by radiation exposure. The Chernobyl accident resulted in widespread radiation contamination, increased cancer rates, and long-term ecological damage.[24] Similarly, the Fukushima disaster led to large-scale evacuations and environmental degradation due to radioactive material release.[19] These incidents emphasize the necessity of robust emergency preparedness, including the deployment of iodine pills to mitigate radiation risks.

The impact of nuclear radiation on humans and the environment can be analyzed through several grand theories in environmental science and public health. One of the most widely recognized models is the Linear No-Threshold (LNT) Model, which asserts that no level of ionizing radiation exposure is completely safe; even low doses can increase the probability of cancer and genetic mutations.[13] This theory serves as the foundation for global radiation protection policies and has been adopted by international organizations such as the International Commission on Radiological Protection (ICRP) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

Additionally, the Ecological Resilience Theory is relevant in discussing the impact of radiation on ecosystems. This theory suggests that ecosystems have a certain capacity to adapt to disturbances, including radiation exposure.[11] Research on Chernobyl and Fukushima has shown some adaptation in plant and animal populations, such as genetic resistance to mutations and changes in population structures.[12] However, despite these adaptations, the overall negative impact of radiation remains significant, as many species experience population declines due to radionuclide accumulation in the food chain.

From a human health perspective, the Stochastic Effects Theory in radiobiology explains that the health effects of radiation, such as cancer and genetic mutations, occur probabilistically, meaning that the risk increases in proportion to the radiation dose without a clear threshold.[10] These effects can manifest years after radiation exposure, making risk management and preventive policies—such as iodine tablet distribution—crucial in mitigating radiation-related health hazards.

The biological effects of radiation exposure depend on several factors, including radiation dose, duration of exposure, and the type of radioactive isotopes released. Exposure to ionizing radiation can trigger an array of medical conditions, ranging from acute radiation syndrome to long-term risks such as cancer and genetic damage.[10] Among these concerns, the thyroid gland is particularly susceptible due to its affinity for radioactive iodine (I-131),[24] substantially increasing the likelihood of thyroid cancer (Klein & Schwartz, 2020). In response, the use of iodine pills (potassium iodide/KI) has been recognized as an effective countermeasure, preventing the thyroid's uptake of radioactive iodine and reducing malignancy risks.[14] The swift administration of iodine pills following exposure—particularly for vulnerable populations—is a critical component of nuclear emergency management.[26]

However, iodine prophylaxis alone is not sufficient. Long-term health management includes continuous surveillance for radiation-induced illnesses, mental health support for affected populations, and strict monitoring of food contamination pathways to minimize secondary exposure.[27] Additionally, environmental decontamination and frequent radiation assessments are essential in reducing long-term risks.[19] Past nuclear disasters have demonstrated the persistence of radioactive contaminants in soil and water, necessitating ongoing remediation efforts. Several decontamination strategies, such as soil excavation, chemical treatments, and phytoremediation, have been explored to mitigate environmental contamination and reduce radiation levels in affected areas.[20]

Problem Formulation

1. Why are iodine pills the primary emergency response for nuclear radiation disasters?

2. How does nuclear radiation impact the environment?

Objectives

1. To explain that iodine pills are one of the primary emergency responses in nuclear disasters.
2. To describe the environmental impact of nuclear radiation.

Given the complexity of nuclear disasters, a multidisciplinary approach that integrates medical, environmental, and policy-based solutions is necessary to enhance disaster preparedness and protect public health.[28] Governments and international organizations must establish clear nuclear safety protocols, strengthen early warning systems, and ensure the availability of protective measures such as iodine pills. Additionally, public education campaigns on radiation risks and emergency response procedures are essential for minimizing casualties and improving community resilience. Collaborative efforts between policymakers, healthcare professionals, environmental scientists, and nuclear safety experts will be key to refining existing strategies and ensuring sustainable disaster preparedness.

This review explores the impact of nuclear radiation exposure on humans and ecosystems, emphasizing the urgency of iodine pills in emergency management. By assessing nuclear disaster preparedness, health impacts, and environmental consequences, this study aims to provide insights into improving emergency response strategies and ensuring long-term public safety.

Methods

This review employed a systematic literature analysis approach, guided by clearly defined inclusion and exclusion criteria, to examine the dual threat posed by nuclear catastrophes and radioactive contaminants to ecosystems and human health. The methodology encompassed three primary steps: searching, selecting, and critically reviewing relevant scholarly articles. Systematic searches were conducted on databases such as Google Scholar, PubMed, and reputable international journal platforms such as Scopus. Search terms included “nuclear disaster,” “radioactive contamination,” “iodine-131,” “nuclear radiation,” and “nuclear,” along with relevant variations in English.

The initial search across all databases yielded 3,752 results. To refine the selection, screening was performed based on relevance to the core topic, reducing the number to 229 articles. A further in-depth review of abstracts and methodological quality narrowed the selection to 11 articles, which were then subjected to full-text examination. After applying the final inclusion criteria, seven articles were identified as meeting the required standards for this

review. During the search process, duplicate articles were found in PubMed and subsequently excluded. Additionally, no relevant results were retrieved from PubMed, Google Scholar, or SINTA that met the study's inclusion criteria.

The time frame for publication was limited to 2015–2025, ensuring a focus on recent empirical studies and excluding purely theoretical or technical papers. Titles and abstracts of identified articles were initially screened for relevance to the core topic, focusing on the direct impacts of radioactive contamination on health (e.g., acute radiation sickness, thyroid cancer risk) and ecological well-being (e.g., pollution of food chains, biodiversity loss). Articles had to be original research, available in full text, and written in either English or Indonesian to be considered for full review.

Exclusion criteria included studies discussing only technical aspects of nuclear reactors without addressing health or environmental effects, as well as review or meta-analysis papers lacking primary data. A thorough full-text examination was then undertaken to assess methodological rigor, relevance of findings, and the depth of discussion on mitigative strategies—such as iodine prophylaxis and environmental remediation. Through this process, the final pool of selected articles provided a comprehensive overview of acute and long-term health risks associated with nuclear disasters, potential ecological harm, and possible intervention strategies for minimizing the dual impacts of radioactive contamination.

Result and Discussion

Table 1. Table of literature review

AUTHOR AND PUBLICATION	TITLE	OBJECTIVE	METHODS	RESULT
Uchiyama K, Miyashita M, Tanishima Y, Maeda S, Sato H, Yoshikawa J, Watanabe S, Shibata M, Ohhira S, Kobashi G. Year 2018	Use of Iodine-131 to Tellurium-132 Ratios for Assessing the Relationships between Human Inhaled Radioactivity and	To assess the relationships between human inhaled radioactivity and dietary iodine intake.	Physiological biokinetic approach	1. **Iodine's Role in Thyroid Function**: Iodine is essential for the synthesis of thyroid hormones, which regulate metabolism and overall health. The sodium-iodide symporter (NIS) mediates iodine uptake

	Environmental Monitoring after the Accident in Fukushima	in the thyroid, and its expression is influenced by dietary iodine levels. In populations with sufficient iodine intake, such as in Japan, the thyroid can effectively manage excess iodine, which may help mitigate the effects of radioactive iodine exposure from environmental sources, such as nuclear accidents 2. **Impact of Radioactive Iodine**: Following nuclear incidents, such as the Fukushima disaster, radioactive isotopes like iodine-131 (131I) can be released into the environment. The uptake of these isotopes by the thyroid can lead to increased radiation exposure, which poses health risks, particularly thyroid cancer. The protective effect of stable iodine pills is estimated to be around

				70%, but this can be reduced to about 10% if the thyroid's autoregulation affects iodine uptake 3. **Environmental Monitoring**: The release of radioactive materials into the environment can be monitored through air dose rates and soil contamination assessments. These measurements help estimate the potential exposure to populations living near affected areas. The study of iodine-131 and tellurium-132 ratios provides insights into inhaled radioactivity and its relationship with environmental monitoring data
IGOR OGOREVC,YASI HIROO SHIMOTSUURA ,IRMA	Natural Protection from Nuclear Accidents in the Environment	To explore and highlight natural methods for radiation	Supplementation with cold-pressed oils and	1. **Effectiveness of Cold-Pressed Oils**: Certain cold-pressed oils, specifically walnut and bay oil,

OGOREVC, SLAVISA STANISIC Year 2024	Radiation Protection for Everyone	protection, particularly in the context of nuclear accidents such as the Fukushima Daiichi disaster	conducted a study.	have been shown to effectively eliminate radioactive materials from the body, including radioactive iodine, cesium, and strontium. 2. **Natural Therapies**: In addition to oils, the study highlights the benefits of other natural therapies, such as cilantro tablets and hydroxyl ion water, in managing radiation exposure. 3. **Preventive and Therapeutic Use**: The research indicates that these natural methods can be employed both preventively and therapeutically, providing a practical and cost-effective alternative to conventional treatments, which may carry adverse side effects.

S. Oliver, J. Cases, B. Juste, R. Mir´ o, G. Verdú Year 2024	Determination of organ doses in thyroid treatments with radioactive iodine by Monte Carlo simulation	To assess the precision of I-131 activity quantification and patient-specific absorbed dose calculation using Monte Carlo simulation techniques.	Monte Carlo simulation method to evaluate organ doses in thyroid treatments using radioactive iodine (I-131)	1. **Dosimetry Techniques**: The use of Monte Carlo simulations, particularly with the MCNP6.2 code, is highlighted as an effective method for analyzing radiation transport and dose distribution in various organs during I-131 treatment. 2. **Dose Distribution**: The study found that the thyroid gland received the highest absorbed dose during I-131 treatment, with notable contributions from the bladder and stomach shortly after ingestion. This emphasizes the need to consider organ-specific doses when evaluating treatment efficacy and safety.
Koji Uchiyama,Masami Miyashita,Hitoshi	A Study Of Thyroid-131 Activity Of Five Human Subjects	To investigate the thyroid activity of members of the	Observational Study	1. **Preparation and Protective Measures**: o DMAT members ingested stable iodine

Sato,Yoshinobu Tanishima,Shigenobu Maeda,Jun Yoshikawa, and Shinzo Kimura Year 2015	Exposed To a Radioactive Plume At Tamura City in Fukushima	Disaster Medical Assistance Team (DMAT) who were exposed to radioactive iodine-131 (131 I) during the Fukushima Daiichi nuclear disaster	pills to mitigate the risk of radioactive iodine exposure. 2. **Thyroid Activity and Age Correlation**: o The study measured thyroid activity in five DMAT members exposed to radioactive iodine. o Results indicated an inverse relationship between age and thyroid activity, with younger individuals showing higher levels of radioactive iodine uptake. 3. **Impact of Stable Iodine**: o The oldest participant exhibited a 70% reduction in thyroid activity, suggesting that stable iodine administration effectively reduces radioactive iodine uptake. o The findings underscore the importance of stable iodine as a

				prophylactic measure during nuclear accidents and highlight the need for assessing internal doses from radioactive exposure.
Mayo Ojino; Sumito Yoshida; Takashi Nagata, MD, PhD; Masami Ishii, MD, PhD; Makoto Akashi, MD, PhD Year 2017	First Successful Pre-Distribution of Stable Iodine Tablets Under Japan's New Policy After the Fukushima Daiichi Nuclear Accident	To evaluate the effectiveness of this proactive approach in mitigating risks associated with radioactive iodine exposure	Observational Health Survey	1. **Proactive Approach**: Japan shifted to a pre-distribution model for stable iodine tablets to prepare residents for potential radioactive iodine exposure, moving away from post-incident distribution practices used previously after the Fukushima Daiichi nuclear accident 2. **Health Screening**: A health survey was conducted to identify individuals at risk for side effects from the tablets. Approximately 4.8% of those surveyed required medical evaluation before receiving the tablets

Spatola, G. J., Buckley, R. M., Dillon, M., Dutrow, E. V., Betz, J. A., Pilot, M., Parker, H. G., Bogdanowicz, W., Thomas, R., Chyzhevskyi, I., Milinevsky, G., Kleiman, N., Breen, M., Ostrander, E. A., & Mousseau, T. A. Year 2023	The dogs of Chernobyl : Demographic insights into population inhabiting the nuclear exclusion zone	To investigate the genetic structure, diversity, and ancestry of dog populations in the Chernobyl Exclusion Zone (CEZ) following the 1986 nuclear disaster	Sample and Analysis Collection	**1. Ecological Consequences:** The Chernobyl disaster in 1986 resulted in the release of vast quantities of radioactive materials, including cesium-137 and iodine-131, which significantly altered the ecological landscape of the region. The CEZ, covering approximately 2,600 km², experienced severe ecological disruption, leading to a substantial reduction in wildlife populations immediately following the accident **2. Genetic Health Effects:** Studies indicate that chronic exposure to low-dose radiation can influence the genetic health of wildlife. For instance, adaptations to oxidative stress have been observed in some species, suggesting a complex interplay between radiation exposure and

				evolutionary pressures. The genetic analysis of domestic dogs in the CEZ revealed unique adaptations and high genetic diversity, indicating resilience in the face of harsh environmental conditions
R. A. Yakymchuk, V. V. Morgun, I. V. Chyzhevskyi Year 2024	Chromosomal disorders in Triticum aestivum subject to prolonged radionuclide pollution of soil from the Exclusion Zone of the Chornobyl Nuclear Power Plant	to investigate and document the long-term effects of radiation exposure, particularly in the context of the Chornobyl nuclear disaster.	Observational and Comparative Studies	1. **Chromosomal Aberrations in Winter Wheat:** 35 years post-Chernobyl disaster. 2. **Radionuclide Levels**: Soil samples showed specific activities of Cs-137 and Sr-90 ranging from 4.5 to 28.2 kBq/kg. 3. **Aberration Frequency**: The frequency of chromosomal aberrations in wheat cells was found to be **3.53 to 7.55 times** higher than the spontaneous level.

4. **Common Disorders**: Types of chromosomal disorders included paired fragments, bridges, and acentric rings.
5. **Pollution Impact**: Interestingly, the highest rates of chromosomal abnormalities were observed in areas with lower radionuclide pollution, indicating complex interactions between radiation exposure and genetic effects.

Discussion

The study conducted by Uchiyama et al., 2018 evaluates the relationship between human inhaled radioactivity and environmental monitoring data following the Fukushima accident. This research measured the iodine-131 and tellurium-132 body burdens of five subjects exposed to a radioactive plume, who underwent whole-body counter measurements for 21.5 hours. The results showed that the iodine-131 to tellurium-132 ratios ranged from 0.96 ± 0.05 to 2.29 ± 0.38, which were consistent with environmental monitoring results. The 24-hour iodine uptake values ranged from 12.1% to 16.0%, which were within the normal range for the Japanese population. These findings suggest that environmental monitoring data can be used to estimate the amount of inhaled radioactivity in areas surrounding nuclear accidents.[1] This study highlights the importance of accurate intake scenarios in estimating inhaled

radioactivity and the effectiveness of environmental monitoring in assessing radiation exposure in the population.

The study conducted by Ogorevc et al., 2025 evaluates the effectiveness of natural therapies in eliminating radioactive substances from the human body following nuclear accidents. The research focused on patients exposed to radiation, measuring the levels of radioactivity in their thyroid glands, kidneys, and reproductive organs before and after therapy. The study found that oils containing organic potassium iodide, such as walnut oil and bay leaf oil, were highly effective in removing radioactive iodine, cesium, and strontium. The therapy using bay leaf essential oil achieved 100% efficiency, while walnut oil therapy showed an 83.3% effectiveness rate. Compared to other treatments, these natural therapies demonstrated superior efficacy in detoxifying radiation-exposed individuals.[2] This study highlights the potential of natural supplementation as a preventive and therapeutic approach in radiation protection, offering a practical, affordable, and side-effect-free alternative for mitigating nuclear exposure risks.

The study conducted by Oliver et al., 2024 evaluates organ doses in thyroid treatments using radioactive iodine (I-131) through Monte Carlo simulations. The research utilizes a high-resolution computational phantom and a biokinetic model to analyze iodine distribution and radiation dose absorption in various organs. Results indicate that the thyroid gland absorbs the highest radiation dose following I-131 administration, while other organs such as the bladder, stomach, kidneys, and trachea receive significantly lower doses. The peak thyroid dose occurs 1.5 days post-ingestion, gradually decreasing over time. The study confirms that Monte Carlo simulations provide accurate dosimetric data, supporting their use in optimizing nuclear medicine treatments and minimizing risks to non-targeted organs.[3] This research highlights the importance of precise dose estimation in thyroid treatments to balance therapeutic benefits and potential side effects.

The study conducted by Uchiyama et al., 2015 evaluates thyroid I-131 activity in five human subjects exposed to a radioactive plume in Tamura City, Fukushima, following the Fukushima nuclear accident. The research measured thyroid I-131 activity using a thyroid counter approximately 17 hours after exposure. Results showed that a 53-year-old subject who did not receive stable iodine had a thyroid activity of 268 ± 38 Bq, whereas four younger subjects who ingested potassium iodide before exposure had varying levels of thyroid activity, ranging from 249 ± 86 Bq to 1,082 ± 119 Bq. An inverse relationship between age and thyroid activity was observed, suggesting that stable iodine administration was more effective in reducing I-131 absorption in older individuals. The study highlights the importance of stable

iodine prophylaxis and thyroid metabolism differences across age groups in radiation exposure scenarios.[4]

The study conducted by Ojino et al., 2017 evaluates Japan's first successful pre-distribution of stable iodine tablets under a new policy following the Fukushima Daiichi nuclear accident. The research focuses on the implementation of stable iodine tablet distribution to 4,715 residents within a 5-km radius of a nuclear facility in Kagoshima Prefecture. Health surveys were conducted to assess potential risks, identifying 132 individuals requiring physician evaluation. Of these, 76 were approved for tablet distribution, 47 were recommended for further consultation, and 9 were deemed ineligible. A total of 2,420 individuals ultimately received stable iodine tablets. The study highlights the importance of physician involvement and risk communication in nuclear disaster preparedness, ensuring safe and effective distribution while preventing misuse.[5] This research underscores the need for continuous medical education on stable iodine administration and structured public health interventions in radiation emergency preparedness.

The study conducted by Spatola et al., 2023 examines the genetic structure and demographics of free-roaming dog populations living within the Chernobyl Exclusion Zone (CEZ). The research analyzed the genome-wide profiles of 302 dogs from three distinct populations: those within the Chernobyl Nuclear Power Plant (CNPP), those in Chernobyl City (15 km away), and those in Slavutych (45 km away). The findings revealed that the CNPP and Chernobyl City dogs are genetically distinct, with CNPP dogs showing higher genetic similarity within their population. The study also identified 15 family lineages, indicating migration between populations. This research marks the first genetic characterization of a domestic species in Chernobyl, providing insights into the effects of long-term, low-dose radiation exposure on large mammals.[6] The study highlights the importance of understanding genetic adaptation to radiation exposure and its implications for both wildlife and human health.

The study conducted by Yakymchuk et al., 2024 evaluates chromosomal disorders in *Triticum aestivum* (soft winter wheat) subjected to prolonged radionuclide soil pollution from the Chernobyl Exclusion Zone. The research analyzed the mutagenic activity of cesium-137 and strontium-90 in soil samples collected 35 years after the disaster. Using the anaphase-telophase method, the study found that the frequency of chromosomal aberrations in wheat root meristem cells was 3.53–7.55 times higher than spontaneous levels. The most common aberrations included paired fragments, chromosomal bridges, acentric rings, and lagging chromosomes. Interestingly, high mutagenic activity persisted even in areas with the lowest

radionuclide contamination, suggesting a complex dose-response relationship. The study underscores the long-term genetic risks of nuclear accidents and highlights the necessity for systematic genetic monitoring in radionuclide-contaminated areas.[7]

Nuclear radiation exposure has been a significant concern due to its potential impact on human health, ecosystems, and genetic stability. Accidents such as those at Chernobyl and Fukushima have highlighted the long-term consequences of radioactive contamination, prompting extensive research into its biological effects and mitigation strategies. Various studies have explored different aspects of radiation exposure, including its direct effects on human health, genetic mutations in living organisms, and possible protective measures. Some research focuses on the effectiveness of stable iodine in preventing radioactive iodine absorption, while others investigate environmental monitoring, genetic adaptation, and potential detoxification methods. By analyzing these studies collectively, it is possible to identify correlations, supporting evidence, and contrasting findings that contribute to a deeper understanding of radiation exposure and its long-term consequences.

The studies provided show a strong correlation in assessing the impact of nuclear radiation exposure on various aspects of life, including humans, the environment, and other organisms. Several studies highlight the importance of iodine tablets as a mitigation measure against radioactive exposure, such as the research by Ojino et al. (2017), which discusses the pre-distribution of stable iodine tablets in Japan, and the study by Uchiyama et al. (2015), which demonstrates the effectiveness of stable iodine in reducing iodine-131 absorption in the thyroid gland. These findings align with Oliver et al. (2024), which shows that Monte Carlo simulations of organ radiation doses can help optimize iodine-131 therapy while minimizing risks to non-target organs. Thus, there is continuity among studies that assess the direct impact of radiation exposure on humans and the mitigation strategies that can be applied to reduce its risks.Beyond human health, several studies explore the effects of radiation on ecosystems and other organisms.

Yakymchuk et al. (2024) found that radionuclide pollution in Chernobyl soil led to significant chromosomal mutations in *Triticum aestivum*, even 35 years after the disaster. This finding supports the study by Spatola et al. (2023), which identified genetic alterations in free-roaming dog populations in the Chernobyl Exclusion Zone, suggesting that long-term radiation exposure affects the genetic structure of large mammals. Meanwhile, Ogorevc et al. (2025) presents a different perspective by proposing natural oil-based therapies as a method for detoxifying radioactive substances from the human body. This opens possibilities for further

exploration of how organisms, including humans, may develop natural protective mechanisms against radiation effects.

While many studies support each other in highlighting radiation's impact, there are also differences in the interpretation of long-term effects. Uchiyama et al. (2018) suggest that environmental monitoring data can be used to estimate the amount of inhaled radioactivity in humans, whereas Ojino et al. (2017) highlights the challenges of effectively distributing iodine tablets to at-risk populations. On the other hand, Yakymchuk et al. (2024) argues that even low-dose radiation exposure over time causes significant genetic mutations, while Spatola et al. (2023) focuses on genetic changes in dogs without confirming their biological health effects. These differences reflect the need for further research to understand the relationship between radiation exposure levels, biological adaptation, and the most effective mitigation strategies in addressing nuclear radiation hazards.

Iodine pills serve as a first-line measure in both post-nuclear disaster response and as a preventive strategy against nuclear radiation exposure. Several studies have demonstrated the effectiveness of stable iodine in reducing the absorption of radioactive iodine by the thyroid gland, thereby mitigating the risk of radiation-induced thyroid disorders. The pre-distribution of iodine tablets, as highlighted in various studies, plays a crucial role in ensuring rapid and effective protection for at-risk populations. Given the unpredictability of nuclear accidents, the availability of iodine pills should be regarded as a fundamental component of nuclear emergency preparedness and radiation protection protocols.

The hazards of nuclear radiation can be further understood through established grand theories in radiobiology and environmental science. One of the most widely accepted models, the Linear No-Threshold (LNT) Model, posits that no level of ionizing radiation exposure is completely safe; even low doses can increase the probability of cancer and genetic mutations.[13] This model serves as a fundamental basis for global radiation protection policies and has been adopted by international regulatory bodies such as the International Commission on Radiological Protection (ICRP) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). The Stochastic Effects Theory in radiobiology further supports this perspective, emphasizing that the health risks associated with radiation, including cancer and genetic mutations, occur probabilistically, with an increasing dose correlating to a heightened risk.[23] These findings underscore the necessity of proactive mitigation strategies in nuclear emergency management.

While some research suggests that nuclear radiation may contribute to genetic diversity within ecosystems, its overall detrimental effects on the environment cannot be overlooked.

The Ecological Resilience Theory suggests that ecosystems possess a degree of adaptability to environmental disturbances, including radiation exposure.[8] Studies conducted in Chernobyl and Fukushima have identified certain adaptive responses among wildlife, such as genetic resistance to mutations and shifts in population dynamics.[9] However, the broader scientific consensus remains that the negative consequences of radiation exposure outweigh any potential adaptive advantages. Prolonged exposure to radionuclides has been linked to chromosomal mutations, elevated cancer rates, and long-term environmental contamination. These findings emphasize the need for stringent radiation control measures and preventive strategies to mitigate harm to biodiversity and ecosystem stability.

Despite the insights provided in this review, its scope remains limited by the availability of relevant journal references and the breadth of nuclear-related discussions. The complexity of nuclear radiation and its multifaceted effects necessitate further research and a broader range of scientific literature. Future studies should aim to provide a more comprehensive analysis of nuclear risks, mitigation strategies, and emerging technologies in radiation protection. Expanding the scope of this review with additional high-quality references would enhance its accuracy and applicability in addressing nuclear disaster preparedness and management.

Conclusion:

Nuclear radiation exposure poses significant risks to human health and the environment. The use of iodine pills (potassium iodide/KI) is a crucial emergency measure to prevent thyroid absorption of radioactive iodine, reducing the risk of thyroid cancer. Studies emphasize the importance of pre-distribution of iodine tablets, environmental monitoring, and accurate radiation dose estimation to minimize health impacts. Beyond human health, radiation exposure also leads to genetic mutations in plants and animals, raising concerns about biodiversity loss and ecosystem disruption. While natural detoxification therapies show promise, further research is needed to validate their effectiveness. A multidisciplinary approach integrating early warning systems, radiation safety protocols, and public education is essential for nuclear disaster preparedness. Strengthening global policies, research, and technological advancements will ensure better radiation protection and long-term sustainability.

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