



Dispersion Study of Radioactive Pollutants from nuclear facility and Regulatory Responsibility for Radiation Protection: A Review

O.S. Ahmed*

Department of Physics, College of Sciences, Qassim University, Saudi Arabia

Received 01 Feb 2026, Accepted 08 March 2026, Available online 09 Mar 2026, Vol.14, No.2 (Mar/Apr 2026)

Abstract

Safeguarding the environment and public health and ensuring nuclear safety depend heavily on regulatory authority to regulate the discharge of radioactive pollutants into the environment around nuclear installations. With an emphasis on the role of regulatory bodies in supervising the operations of nuclear facilities and guaranteeing their adherence to established standards, this reference study examines the national and international regulatory frameworks controlling the prevention, monitoring, and environmental impact assessment of radioactive emissions. The study examines the guidelines and standards published by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the International Atomic Energy Agency (IAEA), and the International Commission on Radiological Protection (ICRP). It also shows how these standards can be incorporated into national laws, licensing, inspection, and oversight systems. Additionally covered are emergency response plans, continuous environmental monitoring programs, modeling of air contamination releases, and environmental impact assessments.

Keywords: Regulatory Responsibility, Atmospheric Dispersion Models, Radiological Risk Assessment

Introduction

Ensuring environmental and health safety in nations that use nuclear technology for peaceful reasons requires effective regulation of nuclear and radiological activities. In compliance with globally accepted radiation safety standards, this regulation is founded on legal and technical frameworks designed to stop the spread of radioactive contaminants and reduce their possible impacts on people and the environment. National authorities have an essential regulatory role in this situation. To ensure complete conformity to appropriate radiation dose levels, these bodies create regulations, issue licenses, oversee adherence to regulatory standards, and carry out monitoring and audit programs. The Kingdom of Saudi Arabia is one of the nations that has enacted a thorough regulatory system for this reason. In order to regulate and oversee all nuclear and radiation-related activities and practices in the Kingdom, including safeguarding the environment from potential radioactive effects, the Nuclear and Radiological Regulatory Commission was established as an independent body with administrative, financial, and legal autonomy. In addition to meeting the Kingdom's responsibilities under pertinent international treaties and agreements, the Nuclear and Radiological Uses Control System was established by Royal Decree No. (M/82), which serves as the primary legal framework for this control.

Its goals are to achieve the highest standards of nuclear safety and to appropriately protect people and the environment from any harmful effects of ionizing radiation [1-8]. The utilization of atmospheric diffusion models of radioactive contaminants is essential in accomplishing these regulatory goals and guaranteeing the successful application of radiation safety regulations. These models are crucial for helping regulatory agencies evaluate the possible effects of radioactive emissions on the environment during regular operations as well as during nuclear crises and accidents. With the use of atmospheric diffusion models, it is possible to forecast the movement of radioactive contaminants in the atmosphere, estimate their concentrations and modes of transport, and determine the radiation dosage levels to which the local population and environment may be exposed.

Atmospheric Dispersion Models:

An essential technique for evaluating the environmental impact and guaranteeing the security of industrial and nuclear activities is modeling the dispersion of contaminants in the air. To forecast how gases or dangerous compounds will move through the atmosphere following a spill, it uses computer simulations [9-12]. By calculating pollutant concentrations, exposure levels, and windward hazard zones, these models support risk management, public safety, and regulatory compliance.

*Correspondant Author's ORCID ID: 0000-0000-0000-0000

DOI: <https://doi.org/10.14741/ijmcr/v.14.2.4>

Dispersion models are a vital tool for government organizations in creating air quality regulations and organizing emergency responses, such as chemical or radioactive accidents, and are widely utilized in a variety of industries, including oil and gas, energy, and chemicals [13-21]. Estimates of impacted areas and suitable preventive actions, such as evacuation or staying put, are provided by their findings, particularly when employing worst-case scenarios. Traditional Gaussian column models, Lagrangian models, and the more sophisticated computational fluid dynamics (CFD) models are the three primary generations of dispersion modeling methodologies. Depending on whether these models are used for emergency response with programs like RASCAL and HOTSPOT or for probabilistic risk assessment with tools like MACCS and COSYMA, their complexity varies [22-28].

Gaussian Dispersion Model

The Gaussian Dispersion Model (GDM) is a type of air quality model that is derived from the Gaussian distribution equation, is given by equation [1][2]., often known as the normal distribution. When simulating inert or stable air contaminants distributed throughout the atmosphere, GDM works well. It is predicated on the idea that the pollution source's puff or plume will disperse throughout the atmosphere as shown in fig (1) and attain a steady-state condition.

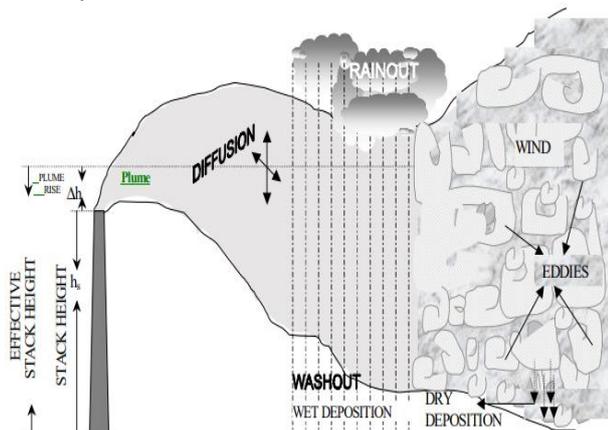


Fig.1 Behavior of effluents released to the atmosphere

According to the Gaussian distribution theory, the concentration of the pollutants in the plume is highest in the direction of the wind and decreases in the direction of the crosswind. The analytical solution of the mass conservation equation under idealized conditions, such as a constant wind field, is the Gaussian distribution. Consequently, some assumptions need to be taken into account while using GDM in air quality simulation:

1. Presumptions of constant, consistent wind direction and speed. Uniform wind fields are invariant in space, but steady wind fields are invariant in time.
2. The simulated air pollutants must be stable or inert

species found in the environment, such as sulfur dioxide, carbon monoxide, and so forth.

In general, the following applications could make use of the GDM:

1. Pollution control and chimney design
2. Applying for a stationary source permit
3. Monitoring network and station design
4. Evaluation of the fuel change
5. Assessment of technologies for reducing air pollution
6. Auxiliary control system planning and design
7. Evaluation of newly identified sources of environmental pollution
8. Air pollution control zone division
9. Research on programs to reduce air pollution

$$C(x, y, z) = \frac{Q}{2\pi \sigma_y \sigma_z U} \exp\left[-\left(\frac{x^2}{2\sigma_x^2}\right)\right] \exp\left[\left(\frac{-(z-H)^2}{2\sigma_z^2}\right)\right] \quad (1)$$

The Lagrangian models: geometric configurations, the dispersion of particles emitted from a point source can be modeled using Lagrangian models, which are ideally suited for the analysis of diluted gas–solid fluxes. Insofar as they make it relatively easy to account for phenomena like particle interactions, wall-particle collisions, or the physical laws of each particle (such as combustion, evaporation, rotation, etc.), these models are the most suitable for studying particle dispersion in turbulent flows. The eddy interaction model and the random flight or walk model are two significant families of Lagrangian stochastic (LS) models used to forecast the turbulent dispersion of the particles. Since this fluid velocity along the particle path is required to solve the equation of motion and determine the trajectory, the primary distinction between these two types of Lagrangian models is how they statistically create the turbulent fluid velocity in the particle vicinity. It is possible to classify things differently. All of them, however, depend on how the fluid velocity is simulated; models for turbulent diffusion, homogeneous or shear turbulence, heavy particles, EIM, RWM, NLWs (normalized Langevin models), GLWs (generalized Langevin equations), SDEs (stochastic differential equations), DRWs (discrete/discontinuous random walk), or CRWs (continuous random walk) will have distinct acronyms or terminology [29].

Radiological Applications of Atmospheric Dispersion Models

Assessing the risk requires an accurate simulation of the air dispersion of radioactive elements. Depending on the assessment's objectives, there are three different kinds of nuclear disaster effect assessments:

- (1) PRA, or probabilistic risk assessment. Probabilistic analysis would be used to evaluate the risk of a possible mishap, taking into account the likelihood of each incident occurring as well as its spectrum of consequences.

(2) Assessment of consequences in real time. The objective is to enable emergency response managers prior to accident releases and to provide advice for emergency response through assessment or prediction. The real-time consequence evaluation is broken down into three phases: latent, intermediate, and early.

(3) Evaluation of previous accident consequences. This entails conducting studies to evaluate the effects by tracking the movement of radioactive particles for previous releases. Because it provides technical assistance for environmental and health forecast and decision-making, atmospheric dispersion modeling is one of the most useful instruments for effective emergency response. Making models as precise as feasible is hence crucial /30-31/.

The Nuclear and Radiological Regulatory Commission's regulatory framework in the Kingdom of Saudi Arabia : /32/

1. The National Legislative Framework:

- The Law on the Control of Nuclear and Radiological Uses, issued by Royal Decree No. (M/82) dated 25/7/1439 AH. This law defines the scope of oversight for all nuclear and radiological practices within the Kingdom and establishes the legal basis for licensing radiological activities and permits, as well as protection from the effects of radiation.
- The Law on Civil Liability for Nuclear Damage, issued by Royal Decree No. (M/81) dated 25/7/1439 AH. This law regulates civil compensation for damages resulting from nuclear accidents within the Kingdom or during the transport of nuclear materials, in accordance with the standards of international agreements (such as the Vienna Convention).
- The Counter-Terrorism and Financing of Terrorism Law is linked to the implementation of nuclear oversight to ensure that nuclear and radioactive materials are not used in terrorist activities.

2. Organization of the Nuclear and Radiological Regulatory Authority:

A. Establishment of the Authority: The Nuclear and Radiological Regulatory Authority was established by Cabinet Resolution No. 334 dated 25/6/1439 AH (March 12, 2018), to create an independent regulatory body with its own legal, financial, and administrative personality, reporting to the Prime Minister.

B. The Authority's core tasks and powers, as defined by its regulations, include:

- Regulating and monitoring all nuclear and radiological activities and practices in the Kingdom.
- Developing policies and technical regulations related to nuclear and radiological safety and security.
- Adopting and implementing international safety standards that comply with the requirements of the International Atomic Energy Agency (IAEA).

- Issuing licenses and conducting inspections of facilities and practices.
- Monitoring the import, export, and trade of nuclear materials and radioactive sources.
- Regulating requirements for preparedness for nuclear and radiological emergencies.
- Raising awareness about the dangers of radiation and promoting a culture of safety.
- Cooperating with international organizations and their counterparts in other countries.

3. Implementing Regulations and Regulatory Support:

A. Implementing Regulations: Following the issuance of the Law on the Control of Nuclear and Radiological Uses, implementing regulations were prepared detailing operational and inspection procedures, clarifying the responsibilities of relevant authorities, and outlining procedures for reviewing violations and standards for applying penalties.

B. The guidelines and protocols also include parts of the legislative framework that integrate the roles of the Authority and government entities to ensure the smooth implementation of oversight tasks, based on the principles of Islamic Sharia and Saudi regulations.

4. International Commitment and Global Standards

Saudi Arabia fulfills its international obligations by participating in agreements and treaties related to nuclear safety and radiation security, such as the Treaty on the Non-Proliferation of Nuclear-Weapons (NPT) and other international protocols.

5. Objectives of the Legislative Framework: The legislative and regulatory framework aims to:

- Protect people and the environment from the harmful effects of radiation.
- Ensure compliance with international standards for nuclear safety and security.
- Regulate the peaceful use of nuclear energy and radioactive sources.
- Establish mechanisms for accountability and compensation in the event of damage.
- Promote a culture of safety and effective oversight through independent monitoring.

Literature Review

1- Abdullah bin Saleh Al-Khalawi and Abdulrahman bin Mohammed Al-Arfaj/33/ "The research found that, radiation is being used extensively in many different industries, including industry, medicine, scientific study, and measurement. Radiation protection plays a significant and active role in light of the large and continuous growth in the numerous and diverse uses of atomic energy.

2- Zubaida Abdul Hadi/34/ " The investigation found that, Sustainability of the legal regulation of nuclear security and

safety for the peaceful uses of nuclear and radioactive materials in the Kingdom of Saudi Arabia in accordance with regional and international agreements" came to the conclusion that there is a Saudi legislative framework that regulates the rules related to nuclear control.

3- Dalal Alamoudi, *et al* /35/" The study found that, in the medical field, ionizing radiation is frequently employed as a diagnostic and therapeutic technique. In healthcare settings, nurses are crucial because they must stay up to date on radiation safety regulations, accompany patients throughout tests, and expose them to internal X-ray processes. The purpose of this study is to evaluate nurses' knowledge and comprehension of ionizing radiation physics, safety, and protective principles related to related dangers. Developing radiation protection measures for nurses requires strengthening safety culture and creating uniform recommendations at the national and international levels.

4- N. Shubayr, *et al* /36/" The purpose of this study was to assess how medical radiological technicians in the Kingdom of Saudi Arabia perceived radiation safety culture. The study, which includes MRTs from several Saudi Arabian hospitals and medical facilities, was conducted between June 2022 and February 2023.

5- N. Shubayr, *et al* /37/" The research found that, the effective radiation exposures for Saudi Arabian diagnostic radiology workers between 2015 and 2019 were analyzed retrospectively using thermo luminescent dosimeters. They worked in 412 hospitals and clinics run by the Saudi Ministry of Health. Medical assistants, radiologists, and radiological technologists are the diagnostic radiology personnel in this study.

6- Ali Aldhebaib, *et al* /38/" This study received responses from 204 patients in total. It is made clear that there were 85.8.3% males and 55.4% females, ages ranging from 18 to 51 years and older, and educational levels ranging from less than higher school to Ph.D. Additionally, we discovered that a significant portion of the responders agreed with the queries. The majority of respondents were unaware of imaging techniques that do not require ionizing radiation, which was an unexpected finding. Additionally, 59 respondents gave a "No" response when asked where they got their information, and they did ask their doctor about radiation risks before X-ray exams. These respondents also gave a significant number of undecided and disagree responses (41.7% and 33.3%) regarding radiation exposure when traveling by airplane.

7- Abdulrahman A. Al-Sayyari *et al* /39/" The study's objective is to evaluate the degree of adherence to radiation protection standards in Buraydah, Al-Qassim State, all of the participants in this study were undergraduate internship students in the department of radiologic technology at the university. Every participant (100%) had a personal dosimeter in the form of TLD cards. 86% of participants knew that doors and walls are made of lead, and 92% of participants knew that a lead apron

should be worn when collecting radiographs. In this study, radiologic technologists' deep and shallow dosage exposures while performing their daily duties in hospital radiology departments were evaluated using TLD cards with two Lithium-Fluoride (Li-F) crystal chips.

8- R. Ahmed, *et al* /40/" This initial descriptive study was conducted in three hospitals in Taif City, Saudi Arabia, with the goal of assessing radiographers' performance and understanding regarding radiation protection during clinical practice. One of the paper's authors used a well-structured, pretested, self-administered questionnaire to gather data from 75 radiographers who work in different hospitals between September and November 2014. Concerning the circumstances in Taif City, As far as we are aware, no comparable study has been conducted on this topic therefore far. There were 30.7% women and 69.3% men in this study. The percentage of people with a diploma was 54.7%, a bachelor's degree was 44%, and a PhD was just 1.3%. The majority of participants (98.7%) were aware that doors and walls are made of lead, and they utilized their Thermal Luminance Dosimeters (TLDs) on a regular basis to check their radiation exposure, with 72% wearing lead aprons.

9- L. Alotaibi, *et al* /41/" The purpose of this research is to evaluate the present knowledge and attitudes of radiographers employed in medical facilities in Al-Qassim, Saudi Arabia, there were 69 male and 31 female radiographers among the 100 survey participants. The majority of radiographers were found to be under thirty years old, with 54% having less than five years of experience.

10- Jaber Alyami, Mohamed hamed Nassef /42/" The study show that, in order to reduce exposure to both patients and operators, the state's national regulatory agency oversees ionizing radiation sources, including diagnostic radiology. The level of technical radiation protection requirements and the state of implementing national regulatory standards for various diagnostic facilities in Saudi Arabia are evaluated and analyzed in the study.

11- A. Alyami, *et al* /43/" the purpose of this study was to assess the degree of radiation protection knowledge and safety procedures among Saudi Arabian nurses employed in nuclear medicine departments (NMDs) in public, private, and specialty hospitals. Forty-two nurses who worked in NMDs without rotating across different radiology departments were given a cross-sectional survey. The results of this study show how important it is to train and keep teaching nurses about radiation protection and radiological procedures in NMDs. This raises awareness of radiation protection and safety protocols.

12- Kholoud J. *et al* /44/" The study's objective is to evaluate medical students' understanding of nuclear radiation in Saudi Arabia's Riyadh universities. According to the study, 16.1% of respondents knew enough about nuclear radiation. Additionally, 39.2% lacked sufficient knowledge, although 44.7% possessed moderate knowledge. One of the limitations is that 81.5% of people don't know how to use personal monitoring devices, and

51.5% don't know about dose limits. Additionally, compared to clinical and preclinical students, who had numbers of 16.3% and 8.1%, respectively, 74.1% of interns demonstrated acceptable awareness, 70.8% preferred using medical websites for information, and 44.7% chose e-learning.

13- Xiaole Zhang, *et al* /45/" The main elements of the risk assessment of airborne CBR hazardous pollutants have been integrated into a framework called SAFER, which stands for source, assimilation, fundamentals, exposure, and risk. These techniques and models can support evidence-based policymaking, effective risk prevention, emergency response to airborne CBR contaminants, and risk preparedness.

14- Rafał Dąbrowski, *et al* /46/" It was discovered that a less sensitive equipment (such as a common GM counter) located more than 5 km from the nuclear reactor might not be able to detect the radioactive pollution following a little anomalous discharge. However, because the radiation field may be excessively strong, a more sensitive detector might not be suitable for measurements over a shorter distance.

15- YAO Rentai /47/" The technique and method of atmospheric dispersion modeling of radioactive material in radiological risk assessment and emergency response are briefly addressed in this study. A few recent developments regarding China's evaluation of the effects of nuclear accidents were presented. Future work should prioritize expanding the dispersion modeling scales to include urban buildings, creating high-quality experiment datasets and model evaluation techniques, improving real-time modeling techniques with constrained inputs.

16- Juliana de Sá Sanchez Machado, *et al* /48/" The dose rate study showed that the public is not at risk from the possible release of radioactive material in this situation. The radioactive plume's behavior throughout the three medium was successfully mapped using the chosen methodology, yielding precise.

17- Abubakar Sadiq Aliyu, *et al* [49]" The findings of this study show that the NPP has no appreciable negative effects on the environment or public health while it is operating normally. However, inside the emergency planning zone of the NPP facilities, precipitation-related unintentional situations will result in observable radiation dangers.

18- Cawood, L.; Friend, F. /50/ Accidental discharges were quantifiable in the environment, according to the evaluation of environmental monitoring data. According to international radiation protection standards, the additional routine impact to a member of the public downstream from Necsa was, on average, an annual dosage of 0.54 microSv more than that to a person residing upstream from Necsa. It may be concluded that the monitoring program has successfully achieved its primary goal, which is to ascertain how the discharges affect the local population and the environment.

19- Enis Kapdan, *et al*/51/" in this work the Lifetime cancer risks were assessed, and the annual effective dose equivalent was computed. According to our analysis, the water radioactivity ranged from 1.3×10^{-5} to 20.6×10^{-4} , with a mean of 10.1×10^{-5} , and two readings of water samples surpassed WHO standards and lifelong cancer risk.

20- Madalina Tronea /52/" An overview of the present procedures for the regulatory evaluation of safety culture in nuclear organizations, as well as the difficulties involved, are provided in this study. There is a recognized need for a more systematic approach to the identification, collection, and review of data relevant to the safety culture in licensees' organizations, even though the assessment and inspection procedures currently in use by regulatory authorities worldwide are primarily focused on verifying compliance with the licensing basis. In order to collect data pertinent to safety culture and evaluate it holistically, the report suggests utilizing the current regulatory inspection procedures.

21- Suleman A. Zakaria, *et al* /53/" One important but frequently overlooked aspect of nuclear safety is leadership for safety, especially in nuclear regulatory bodies (NRAs). The sociotechnical complexity that influence the efficacy of regulations have not been fully addressed, despite the fact that technical aspects of safety have received substantial attention. In addition to alleviating the difficulties experienced by middle managers and frontline employees, this evaluation looks at how leadership for safety can assist fundamental regulatory activities like review and assessment, formulation and enforcement of regulatory standards, and inspection of nuclear plants.

22- Mark Fleming, *et al* /54/" The culture of the regulator was found to be a contributing element in the International Atomic Energy Agency's (IAEA) 2012 investigation into the Fukushima nuclear accident in Japan. The IAEA and the Organization for Economic Co-operation and Development (OECD) have developed worldwide recommendations on evaluation as a result of their acknowledgment of the significance of regulator safety culture. A safety culture perception survey is one of the multi-method safety culture self-assessments that these recommendations encourage nuclear regulators to carry out. There isn't currently a psychometrically tested regulator safety culture perception poll that is accessible to the general public. The first testing of a perception survey created by an IAEA working group is described in the current study.

23- Romain Bizet, *et al* /55/" Using a novel dataset on safety, radiological, and environmental standard deviations documented in the French nuclear fleet since 1978, we estimate the impact of local monitoring and information disclosure on safety and compliance with self-reporting standards in the French nuclear power industry. We find that local monitoring and information disclosure significantly increases compliance, but we are unable to find any short-term effects on safety.

24-Koyel Roy, *et al* /56/" With a focus on the regulatory efficacy of frameworks like the Atomic Energy Act of 1962, the Environmental Protection Act of 1986, and the Civil Liability for Nuclear Damage Act of 2010, this study critically evaluates the legal and environmental safeguards governing nuclear resource development in India. Empirical data gathered through field interviews with legal experts, environmental scientists, and stakeholders from impacted regions—such as Jaduguda (Jharkhand) and Kudankulam (Tamil Nadu)—reveals significant regulatory gaps, procedural opacity, and inconsistencies in environmental impact assessment (EIA) enforcement, despite India's strategic goals for clean energy. Using a mixed-method approach, the study combines non-doctrinal data from structured interviews ($n = 25$), public response surveys ($n = 100$), and RTI (Right to Information) replies on nuclear project compliance data with doctrinal legal analysis.

25-Michele Di Giovanni, *et al* /57/" The architecture of a monitoring system that can ensure both energetic sustainability and safety objectives is presented in this research. The flexibility to define various system configurations (such as sensor scheduling strategies, site geometry, and sensor reliability) promotes a high degree of adaptation to various monitoring scenarios, which are defined by varying degrees of sustainability and safety. To quantitatively assess system configurations, a methodology is suggested that combines data gathering and processing with a model-based approach. This approach is predicated on the definition of two indicators, one for sustainability and one for safety, as well as an evaluation model. The model calculates the metrics taking into account the location's geometry, scheduling, and monitoring sensor reliability.

Conclusion

The study showed that in order to ensure effective monitoring, environmental modeling results must be in line with international standards published by the United Nations Scientific Committee on the Effects of Atomic Radiation and the International Atomic Energy Agency (IAEA). This guarantees that, both in regular operating settings and in emergency scenarios, the results of scientific study are converted into instruments that assist regulatory decision-making. Additionally, taking a risk-informed strategy improves institutional readiness and increases the effectiveness of regulatory resource allocation. Sustainable protection of the environment and human health is based on the combination of rigorous adherence to dose limits, quantitative measurement of pollutant dispersion, and ongoing environmental monitoring, regulatory accountability for radiation safety is the cornerstone that guarantees the application of national and international standards and safeguards public health against possible risks. In order to support regulatory frameworks and rules pertaining to radiation safety in nuclear reactors, air diffusion models are an essential

scientific instrument. Regulators can evaluate radiation exposure levels for the general public and the surrounding environment by using these models to forecast how radioactive pollutants would diffuse into the atmosphere under typical operational conditions or in the case of a possible disaster. These models offer a scientific foundation for regulatory decisions pertaining to environmental and public health protection by calculating pollutant concentrations and their movement patterns. Additionally, diffusion models help regulatory agencies create environmental monitoring and incident response plans, identify emergency planning areas, and determine radiation safety limits. The ability of responsible authorities to carry out preventative measures and guarantee adherence to international nuclear safety standards is strengthened by integrating the findings of scientific models with norms and regulations. In this regard, international organizations like the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA) stress how crucial it is to use trustworthy scientific models to support radiation monitoring and regulatory policy creation. Because of this, using air diffusion models effectively helps improve nuclear emergency preparedness, regulatory system efficiency, and radiation risk management capabilities. To ensure the safe use of nuclear technologies and to establish sustainable protection for people and the environment, two crucial components are the ongoing development of these models and the strengthening of legislative and regulatory frameworks.

Recommendations

- 1- Improve the Application of Models of Atmospheric Diffusion: In order to evaluate possible environmental effects and aid in regulatory decision-making, regulatory organizations should employ sophisticated scientific models to simulate the diffusion of radioactive pollutants in the atmosphere.
- 2- Create Environmental Monitoring Systems for Radiation: Expanding radiation monitoring networks around nuclear sites and connecting them to air diffusion prediction models is advised. This will make it possible to monitor radiation levels in real time and enhance the ability to respond to any radiological disaster.
- 3- Improve the Regulatory Framework's Integration with Scientific Models: The environmental evaluation and licensing procedures for nuclear sites should incorporate the findings of atmospheric diffusion models. This will guarantee that strong scientific concepts form the basis of regulatory decisions.
- 4- Create plans for radiological emergencies: In order to determine emergency planning areas and create efficient protocols for safeguarding the public and environment in the event of a nuclear catastrophe, nuclear emergency response plans must be based on the findings of diffusion models.
- 5- Increasing Global Collaboration on Nuclear Safety To take advantage of global expertise and apply best

practices in radiation protection and nuclear regulation, regulatory bodies should strengthen their collaboration with specialized international organizations like the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA).

6- Developing Regulatory Staff's Technical Capabilities To increase monitoring and supervision of nuclear sites, it is advised to set up specific training programs for regulatory staff to improve their skills in utilizing air diffusion models and assessing radiation data.

7- Promoting Research in the Field of Radiation Risk Assessment: In order to improve the efficacy of regulatory systems for safeguarding human health and the environment, it is crucial to encourage scientific research that focuses on creating radiation diffusion models and increasing the precision of anticipating the impacts of nuclear accidents.

References

- [1] [https:// laws.boe.gov.sa /BoeLaws/ Laws/ Law Details/c447d12a-6c10-40c2-a51e-a9f7000a97cb/1](https://laws.boe.gov.sa/BoeLaws/Laws/LawDetails/c447d12a-6c10-40c2-a51e-a9f7000a97cb/1)
- [2] Alfred Micallef, *et al* "The Gaussian Plume Model Equation for Atmospheric Dispersion Corrected for Multiple Reflections at Parallel Boundaries: A Mathematical Rewriting of the Model and Some Numerical Testing" *Sci* 2024, 6(3), 48; <https://doi.org/10.3390/sci6030048>
- [3] Fathi Wali, Civil Jurisdiction law, Dar Arab renaissance - 1980.
- [4] Atomic Energy Regulatory Board, "Atmospheric Dispersion And Modeling", AERB Safety Guide NO. AERB/NF/SG/S-1, India, (2008).
- [5] Abubakar Sadiq Aliyu, Ahmad Termizi Ramli, Nuraddeen Nasiru Garba, Aminu Ismaila, Habu Tela Abba, Muneer Aziz Saleh and Mustapha Aliyu "Assessment of Environmental and Human Health Impacts of a New Nuclear Power Plant using Hybrid Single-Particle Lagrangian Air Dispersion Model" *Indian Journal of Science and Technology*, Vol 8(S9), 489–500, May 2015.
- [6] Barrat, Rod (2001). *Atmospheric Dispersion Modelling* (1st ed.). Earthscan Publications. ISBN 1-85383-642-7.
- [7] Cooper JR, Randle K, Sokh RG (2003). *Radioactive Releases in the Environment* (1st ed.). John Wiley & Sons. ISBN 0-471-89924-0.
- [8] Godish, Thad (2003). *Air Quality* (4th ed.). CRC Press. ISBN 1-56670-586-X.
- [9] U.S. Environmental Protection Agency (2009). Chapter 4: Offsite Consequence Analysis. In *General Guidance on Risk Management Programs for Chemical Accident Prevention* (40 CFR Part 68)
- [10] IAEA, "Generic Models for Use in Assessing the Impact of Discharges of Radioactive Substances to the Environment", Safety Reports Series No. 19, IAEA, Vienna, 2001.
- [11] Good Practice Guide for Atmospheric Dispersion Modelling, Published in June 2004 by the Ministry for the Environment, PO Box 10-362, Wellington, New Zealand
- [12] Deardoff, J.W. & Willis, G.E. (1975). A parameterization of diffusion into the mixed layer. *J. Applied Meteor.*, Vol. 14, page numbers (1451-1458).
- [13] International Atomic Energy, " Atmospheric Dispersion in Nuclear Power Plant Siting, Asafety series No. 50-SG-S3, IAEA, Vienna (1980).
- [14] Summary of the Fukushima accident's impact on the environment in Japan, one year after the accident, IRSN institute de Radioprotection, 28 February 2012.
- [15] Tsuang, B. J. (2003). "Quantification on the source/receptor relationship of primary pollutants and secondary aerosols by a Gaussian plume trajectory model: Part I theory." *Atmospheric Environment* 37(28): 3981-3991.
- [16] Canepa, E, Dallorto, L, Ratto C.F, Plume rise description in the code safe air. *International journal of environment and Pollution*, 14 (6), 2000, 235-245.
- [17] IAEA "The Fukushima Daiichi Accident' Technical Volume4, Radiological Consequences, 2015.
- [18] Randerson (Ed), *Atmospheric Science and Power Production*, US DOE, 1984.
- [19] https://www.eurosafeforum.org/sites/default/files/pe_172_24_1_4_3paper.pdf.
- [20] IAEA (2024). *Atmospheric Dispersion Models for Application in Relation to Radionuclide Releases – A Review*. International Atomic Energy Agency.
- [21] Shnaider, I.A., Kushnikov, V.A., & Bogomolov, A.S. (2025). Simulation modeling of atmospheric pollutant dispersion considering dry deposition and the influence of liquid atmospheric precipitation. *Izvestiya of Saratov University. Mathematics. Mechanics. Informatics*, 25(4), 589–599. <https://doi.org/10.18500/1816-9791-2025-25-4-589-599>.
- [22]. IAEA " Atmospheric Dispersion Models for Application in Relation to Radionuclide Releases" A Technical Document issued by the International Atomic Energy Agency, VIENNA, 1986
- [23]. Chanin D.I., J.L. Sprung, L.T. Ritchie, *et al.*, "MELCOR Accident Consequence Code System (MACCS)", NUREG/CR- 4691, Sandia National Laboratories, USNRC, Washington, DC, (1990).
- [24]. Commission of European Communities, "COSYMA: A New Programme Package for Accident Consequence Assessment", EUR 13028 EN, CEC, (1991).
- [25]. Athey, G. F., A. L. Sjoreen, and T. J. McKenna, "RASCAL Version 1.3 User's Guide", NUREG/CR-5247, USNRC, Washington, D.C., (1989).
- [26]. Nuclear Regulatory Commission, "RASCAL 3.0.5: Description of Models and Methods", NUREG-1887, USNRC, (2007).
- [27]. Hussaini Muhammad, X. Wang, M. Wang & G. Su (2025). Review of spatial scale dispersion models (ATDMs) to simulate environmental dispersion and deposition of radionuclides and the overview of GIS coupling with dispersion models. *International Journal of Advanced Nuclear Reactor Design and Technology*, 6(4), 256–280. <https://doi.org/10.1016/j.jandt.2025.03.004>.
- [28]. Homann S. G., "HotSpot – Health Physics Codes Version 2.07 User's Guide", LLNL-TM-411345, LLNL, (2009)
- [29]. Daniel G. F. Huilier " An Overview of the Lagrangian Dispersion Modeling of Heavy Particles in Homogeneous Isotropic Turbulence and Considerations on Related LES Simulations" *Fluids* 2021, 6(4), 145; <https://doi.org/10.3390 /fluids6040145>
- [30] YAO Rentai " Atmospheric Dispersion of Radioactive Material in Radiological Risk Assessment and Emergency Response" *Progress in Nuclear Science and Technology*, Vol. 1, p.7-13 (2011)
- [31]. Dr. Adel Mohamed Ahmed Associate Professor, Faculty of Science strategy - Naif Arab University for Security Sciences scientific paper entitled (legal regulation and Regulatory for peaceful uses of nuclear energy), the Forum of scientific and peaceful use of nuclear energy and its impact on the eco-security) 18-20- -3-2014 - MANAMA – Bahrain
- [32]<https://nrrc.gov.sa/%D8%A7%D9%84%D8%A5%D8%B7%D8%A7%D8%B1%D8%A7%D9%84%D9%82%D8%A7%D9%86%D9%88%D9%86%D9%8A>
- [33] Abdullah bin Saleh Al-Khalawi and Abdulrahman bin Mohammed Al-Arfaj " An evaluative study of the status of radiation protection in the Kingdom of Saudi Arabia" (Sixth Saudi

Engineering Conference – King Fahd University of Petroleum and Minerals – Dhahran – Shawwal 1423 AH)

- [34] Zubaida Abdul Hadi - Prince Sultan University - Riyadh - Kingdom of Saudi Arabia - (Arab Journal of Scientific Publishing - 2023) " Sustainability of the legal regulation of nuclear security and safety for the peaceful uses of nuclear and radioactive materials in the Kingdom of Saudi Arabia in accordance with regional and international agreements".
- [35] Dalal Alamoudi, Amani Y. Alhalwani, Mohamed Eldigire Ahmed, Ammar Adel Hamidaddin, Nasser Mohammed Asiri, Saleh Adnan Abuzenada, Wael Munshi, Wafa M. Al-Saleh" Radiation Protection Knowledge for Nurses at King Abdulaziz Medical City-Jeddah in Saudi Arabia: A Cross-Sectional Study "J. Radiat. Prot. Res > Volume 50(2); 2025.
- [36] N. Shubayr, Md. Muawwadhah, M. Shami, H. Jassas, R. Tawhari, O. Oraybi, A. Madkhali, A. Aldosari and Y. Alashban " Assessment of radiation safety culture among radiological technologists in medical imaging departments in Saudi Arabia" Radioprotection 2024, 59(1), 30–35.
- [37] N. Shubayr, Yazeed Alashban, Maryam Mabrook Almalki, S Aldawood "Occupational radiation exposure among diagnostic radiology workers in the Saudi ministry of health hospitals and medical centers: A five-year national retrospective study "Journal of King Saud University – Science 33 (2021) 101249.
- [38] Ali Aldhebaib, Oinam Gokulchandra Singh, Ziad Almutlaq Abdulrahman Alaqueel" A Study Based on Perception towards the Radiation Exposure to Adult Patients at King Abdul-Aziz Medical City, Riyadh, Saudi Arabia", Journal of Advances in Medicine and Medical Research,2018
- [39] Abdulrahman A. Al-Sayyari, Sunil Kalagi "Assessment of Radiation Protection practices among University Students, Buraydah, Saudi Arabia " 2018, Medicine, Environmental Science
- [40] R. Ahmed, A. Mohamed, Taha Elamin, Mohamed Omer Elsamani, W. Hassan "Knowledge and Performance of Radiographers towards Radiation Protection, Taif, Saudi Arabia " Environmental Science, Medicine,2015.
- [41] L. Alotaibi, Bassam Alkhalifah, International Journal of medicine, 2019" Assessment of knowledge and attitude of radiographers towards radiation protection in al Qassim region, Saudi Arabia
- [42] Jaber Alyami, Mohamed hamed Nassef " Assessment of Diagnostic Radiology Facilities Technical Radiation Protection Requirements in KSA", Appl. Sci. 2022, 12(14), 7284; <https://doi.org/10.3390/app12147284>.
- [43] A. Alyami, N. Majrashi, N. Shubayr, N. Alomairy and N. Abuhadi " Assessment of radiation protection awareness and safety practices among nurses in nuclear medicine departments in Saudi Arabia", Radioprotection 2022, 57(1), 49–54
- [44] Kholoud J. Sandougah, Afnan F. Alhallafi, Salman F. Alkhodairy, Mossab M. Aldosary, Mohammed M. Al Qahtani, Majmaah J Heal Sci. 2023; 11(1): 68-81" Assessment of Knowledge about Nuclear Radiation, and Awareness of Radiation Protection among Medical Students in Riyadh Universities, Saudi Arabia
- [45] Xiaole Zhang, Jing Wang" Atmospheric dispersion of chemical, biological, and radiological hazardous pollutants: Informing risk assessment for public safety" Journal of Safety Science and Resilience,2022
- [46] Rafał Dąbrowski, Daniel Kikoła" Application of atmospheric dispersion modelling in finding optimal locations of early warning stations around a nuclear power plant" Progress in Nuclear Energy Volume 155, January 2023, 104519
- [47] YAO Rentai " Atmospheric Dispersion of Radioactive Material in Radiological Risk Assessment and Emergency Response" Progress in Nuclear Science and Technology, Vol. 1, p.7-13 (2011)
- [48] Juliana de Sá Sanchez Machado, *et al* " Assessment of Radiological Plume Dispersion in LBLOCA-Type Accidents at Nuclear Power Plants" Atmosphere 2025, 16(9), 1089; <https://doi.org/10.3390/atmos16091089>
- [49] Abubakar Sadiq Aliyu, *et al* " Assessment of potential human health and environmental impacts of a nuclear power plant (NPP) based on atmospheric dispersion modeling " Atmósfera,2015
- [50] Cawood, L.; Friend, F." Evaluation of 38 years of radiological environmental data for the nuclear research facility in South Africa " Journal of Environmental Radioactivity79 (2005) 255–271
- [51] Enis Kapdan, *et al*" Radioactivity Survey and Risk Assessment Study for Drinking Water in the Artvin Province, Turkey" Water Air Soil Pollut (2015) 226:49
- [52] Madalina Tronea" Trends and Challenges in Regulatory Assessment of Nuclear Safety Culture" insj , April 2014
- [53] Suleman A. Zakaria , *et al*" Advancing Nuclear Regulatory Effectiveness: Integrating Leadership for Safety Into Nuclear Oversight Functions" 06 January 2026,<https://doi.org/10.1155/stni/5535689>
- [54] Mark Fleming , *et al* " Development and testing of a nuclear regulator safety culture perception survey" <https://doi.org/10.1016/j.ssci.2022.105792>
- [55] Romain Bizet, *et al* " The effect of local monitoring on nuclear safety and compliance: Evidence from France" <https://doi.org/10.1016/j.jeem.2022.102651>
- [56] Koyel Roy, Yugdeep Kaur, Subrato Kumar Dey, Sunita Banerjee, Abhishek Upadhyay, Md. Jiyuddin" Legal and Environmental Safeguards in Nuclear Resource Development: A Critical Study of Regulatory Frameworks and Safety Protocols in India" Vol. 46 No. 1 (2025): May 2025.
- [57] Michele Di Giovanni, *et al* " Assessing Safety and Sustainability of a Monitoring System for Nuclear Waste Management" DOI: 10.1109/ACCESS.2025.3586735.