Original Article

Access this article online
Quick Response Code:

Website:
www.carcinogenesis.com
DOI:
10.4103/jcar.jcar_22_02_12

Occupational and Environmental Carcinogens: Assessment and Regulation

Adana Llanos[1]

Abstract

This investigation explores the complex field of "Occupational and Environmental Carcinogens: Assessment and Regulation," revealing the complex relationships between scientific knowledge, legal frameworks, and public health. The interaction between occupational exposures and more general environmental hazards demands a thorough analysis, acknowledging the critical role this field plays in influencing public health policy and protecting people globally. For national and international regulatory organizations, the standardized categorization of carcinogens provides a solid foundation upon which to formulate regulations aimed at reducing risks without obstructing advancement. Because industries and technology are changing so quickly, we need frameworks that can adapt to new situations and make sure regulations are still relevant. As a principle that guides risk assessment and regulation, equity recognizes the unequal cost that some groups bear. The investigation emphasizes the necessity of an inclusive strategy in which a range of stakeholders—from business to advocacy organizations—participate in a discussion that produces clear and efficient regulatory measures. The amalgamation of themes culminates in an appeal for ongoing dedication and creativity in the end. This investigation has created a tapestry that illustrates how science, law, and compassion are intertwined. In order to achieve a safer and healthier future, it is imperative that we work together, highlighting the need of flexible regulatory frameworks, international cooperation, and a dedication to resolving differences in carcinogenic exposures. The heart of our investigation into occupational and environmental carcinogens is captured in this research, which also provides an overview of the promises, difficulties, and complexity that characterize this important nexus between research and public health.

Keywords:

Occupational (OO), Environmental Carcinogens (EC), Regulation (R), Smart PLS Algorithm.

Introduction

The word "Occupational carcinogens" can be explained in these words "those carcinogens which are present in different workplaces that can cause cancer in human body and in other animals as well". There is a wide range of occupational carcinogens, such as waste chemicals from industries, dust, different types of metals, and the products from combustion, such as exhaust from diesel engine[1]. The word "environmental carcinogen" can be enumerated in these words "the type of the carcinogens which are present in environment which are may be physical, chemical or biological agents which are responsible for causing cancer in living organisms ". There are different forms of environmental carcinogens such as benzene, vinyl chloride, arsenic, radon gas, asbestos and others. There is high risk of cancer by occupational carcinogens at global level[2].

The regulation and assessment of environmental and occupational carcinogens play a crucial role in the complex web of public health, balancing advancement and protection in a sensitive manner. The discovery of chemicals that can cause a cancer in the workplace and in the

[1] *Department of Chemistry, University of Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal.*

Address for correspondence:
Adana Llanos, Department of Chemistry, University of Aveiro, Campus de Santiago, 3810-193 Aveiro, Portugal.

Submitted: 06-Jan-2023
Revised: 08-Aug-2023
Accepted: 03-Sep-2023
Published: 01-Oct-2023

How to cite this article: Llanos A. Occupational and Environmental Carcinogens: Assessment and Regulation. J Carcinog 2023;22(2):97-105

surrounding environment has sparked an unrelenting search for knowledge, controls, and legal frameworks. To fully understand the magnitude of the issues at hand, a thorough investigation is required into the intricate interactions between science, policy, and human wellbeing. The intrinsic link between work environments and environmental exposures, which both significantly increase the global cancer burden, is at the core of this complex problem. Although it's commonly believed that the workplace fosters creativity and productivity, there are risks there that might negatively impact employees' health. Concurrently, the surrounding environment, which includes the air, water, and soil, turns into a communal space where people deal with the effects of different carcinogens.

The most important types of cancer caused by occupational carcinogens are lung cancer, mesothelioma, and other cancers such as leukemia. Data was collected from cancer patients who were workers, and it came to know that there are some substances at the workplace that are able to cause cancer in the human body. For example, cancer of the scrotum was caused by a type of polycyclic aromatic hydrocarbon, which has carcinogenicity. The important types of cancer caused by occupational carcinogens are lung cancer, bladder cancer and mesothelioma. The number of cancer cases because of occupational carcinogens has been tremendously increasing day by day. The intensity of cancer caused by occupational carcinogens depends upon different factors such as the route of exposure, the concentration of carcinogens, the dose or toxicity of carcinogens, the frequency of visits of workers at work place, the duration of exposure, and characters of an individual's such as age, immunity, gender and others[3]. The International Agency for Research on Cancer, which is an agency of the World Health Organization, classified occupational carcinogens into four different groups depending on their carcinogenicity.

Group one includes such occupational carcinogens, which are truly carcinogen to the human body, and group four has such occupational carcinogens, which are probably having no carcinogenicity[4]. Each type of cancer is related to a specific workplace. For example, the chances for bladder cancer increase for barbers, petroleum workers, firefighters, cable makers, metal workers, plumbers, tobacco workers, and others. This bladder cancer is caused by chemicals such as aromatic amines, mineral oils, nitro benzene, coal tar, exhaust of diesel engine, arsenic compound and others. In the same way, the cancer in bones and tissues is more common in workers in the accelerator sector, industrial sector, medical sector, mining sector, and others[5]. This type of cancer is caused by ionizing radiation such as alpha radiation, beta radiation, and gamma radiation. The cancer to brain and nervous system is more common in workers of nuclear sector reactor because of harmful ionizing radiations. Breast cancer is more common in shift work, which includes Disruption in the circadian cycle of the body. This type of cancer is caused by ethylene oxide, polychlorinated biphenyls, and others. Colon and rectum cancer is common in automobile workers, machinery laborers, petrol station workers and dry cleaning workers and others[6]. The main carcinogens responsible for these types of cancer are asbestos, soot and petroleum products. Environmental carcinogens are also able to cause cancer in the human body. These substances change the function of the cell by changing DNA, thus resulting in abnormal cell division, which produces cancerous cells which accumulates to form tumors in the body.

The most important environmental carcinogen is tobacco smoke and radiations from sun6. Not only can this, but the polluted water that we drink also leads to the development of cancer in the human body[7]. The identification and detection of environmental and occupational carcinogens need a deep comprehension of the complex pathways via which these agents interact with living things. The fields of toxicology and epidemiology have been instrumental in elucidating the complex mechanisms by which certain chemicals manifest their carcinogenic potential. The list of recognized carcinogens, which includes benzene and asbestos, highlights the variety of substances that can be harmful to human health. A careful balance between the requirement for realistic regulatory measures and scientific rigor is necessary when assessing the danger posed by these carcinogens. Risk assessments are based on the convergence of toxicological evaluations, laboratory tests, and epidemiological investigations [8].

However, the subtlety of these evaluations draws attention to the difficulties in generalizing research results to situations in which exposure levels, individual susceptibility, and cumulative effects are relevant. The most important environmental carcinogens are aflatoxins, crystalline silica, erionite, cadmium, beryllium and others. Most cases of lung cancer are related to air pollution. There is no doubt that different forms of pollution are linked to different types of cancer such as breast cancer, lung cancer, liver cancer and pancreatic cancer[9].

Most importantly, liver cancer is mostly caused by hepatitis, which is caused by drinking polluted water which may contain different viruses. The mechanism of action of all these carcinogens is the same. These carcinogens move to body to cause mutation in genetic material. This mutation is passed from parent cells to daughter cells to form malfunctioning cells. These cells are mainly called cancerous cells, which have faulty DNA because of mutation [10]. When genetic material is altered, the number of cell divisions increases in the body which produces an abnormal number of extra cells in the body, which can accumulate to form tumors in the body[11]. There are two types of tumors named as benign

tumors and malignant tumors. If tumors do not leave their place and thus cause no harm to other cells of the body, then these tumors are named benign tumors, but the other type of tumor which move to other parts to cause metastasis in the body, these tumors are named malignant tumors.

There are different and versatile suggestions for prevention of occupational and Environmental Carcinogens. For example, occupational carcinogens can be prevented by improving the physical environment of working place, fewer working hours6, less exposure to radiation, less frequency of Carcinogenic places, covering the body, proper screening tests, and others. The prevention of environmental carcinogens is quite difficult because environment is sum of physical, biological and chemical factors which affect living organism. We need water, air, soil, food, and shelter from the environment; thus, the prevention of these carcinogens is very difficult. The prevention of carcinogens from polluted water is only possible by drinking pure water with balanced minerals quantity. The access to safe and pure water should made possible to each individual for healthy life across the world.

The prevention of carcinogens from air pollution is possible by mitigating the factors which cause air pollution, such as cutting of wood, deforestation, climate change, combustion, and others. All of these preventive measures are necessary for Mitigation of unceasing and increasing level of cancer cases across the world. The occupational and Environmental Carcinogens are important types of carcinogens for elevated risks of cancer in human body and in other animals as well[12]. The main objective of regulation is to protect public health without impeding economic development. At the municipal, national, and international levels, strong regulatory frameworks must be developed and put into place in order to achieve this equilibrium. To effectively create regulations that reduce risk, regulatory agencies must negotiate the complex terrain of scientific uncertainty, political concerns, and economic ramifications.

International organizations that catalog and categorize drugs according to their potential for cancer, such as the International Agency for Research on Cancer (IARC), are essential. The IARC monographs provide a standardized method for assessing the existing data, making them a vital component of international efforts to comprehend and control carcinogens. However, national regulatory agencies—each juggling a distinct mix of issues and priorities—are responsible for translating these results into workable policy. The relationship between environmental and occupational carcinogens emphasizes how interrelated the world's health issues are. The discovery of new carcinogens becomes a changing goal as industries change and new technology appear. This necessitates the development of flexible regulatory frameworks that can react to the changing range of possible risks. Furthermore, an equity-focused approach to regulation is necessary to ensure that disadvantaged people are not disproportionately exposed to carcinogenic hazards due to the disproportionate burden that some groups bear.

Research Objective

The main objective of this study is to understand the composition and causes of occupational carcinogens and environmental carcinogens. The effects of these carcinogens are also viewed in this study. The assessment and regulation of these types of carcinogens are also explained in this study. The research study describes that Occupational and Environmental Carcinogens: Assessment and Regulation. The research is divided into five specific chapters. The first section presents the introduction and objective of the research study. The second portion determine the literature review, and the third section present the result and applications of dependent and independent variables. the fourth section describes that result and its descriptions. The last section summarized overall result and research it's also present those specific recommendations about topics.

Literature Review

Researchers claim that employees working in various industrial companies are at higher risk of getting exposed to carcinogens. The SIERP was developed to collect information about the percentage of employees exposed to carcinogens. Most workplaces dealing with carcinogenic substances are at higher risk of spreading the carcinogenic substances in the atmosphere. The workers working in this atmosphere gets exposed to carcinogens that result in the onset of cancer cell in their body. IARC is a carcinogen-related data assessment organization that provides data regarding the risk of carcinogenic substances in various workplaces[13]. Studies reveal that the main source of public exposure to harmful organic carcinogens substance is the consumer's products. Certain consumer products release volatile carcinogenic substances into the atmosphere is the main cause of smog formation. The data of CARB on VOCs' presence in the atmosphere helps in developing various strategies to overcome the release of these VOCs in the air by regulating its emission process[14]. Studies explain that some carcinogen releases from industries have genotoxic effects.to overcome the release of these genotoxic carcinogens, OELs are employed.

For making the OELs implication, the approach of BMD is preferred[15]. Studies reveal that effective strategies provided by the IARC are used for making a framework to minimize the spread of carcinogenic substances [16]. LAC is a framework that works to reduce the level of carcinogens present in the environment[17] Studies claim

that several industries use formaldehyde as a substance to be used for various purposes. ARC declared the formaldehyde substance as carcinogenic. Various strategic approaches are used to overcome the spread of carcinogenic substances. The risk assessment against the presence of a carcinogenic substance in occupational industries is made to stop its spread. Carcinogenic substances pose a great health risk for the employees working in the carcinogenic substance-producing industries[18]. Studies show that the field related to genotoxic is revolutionized through the NGS. The ecnNGS is a modern technology used for regulating the genotoxic field.

For the implication of ecNGS in the clinical process, various challenges are faced by the workers working with this technology. This technology is so advanced that it is used for testing the genotoxicity associated with carcinogenic substances[19]. Studies explain that carcinogenic substances are very harmful to the public working in chemical production areas. To protect the public from the harmful substance the field of regulatory toxicology is used. This field helps regulate the effect of harmful chemicals and reduces the exposure of public to the harmful carcinogenic substances[20].studies predict that OSH works by regulating the working of places that produce occupational diseases. The OSH works to prevent workplace diseases from spreading in the environment[21]. Studies suggest that for assessing and identifying the risk factors associated with carcinogenic providing workplaces, the use of PTEW is made. the PTEW is a preventive technique that works to reduce the chances of exposure to formaldehyde in the general public.

The main purpose of this PTEW is to assess the possible risk associated with the exposure of formaldehyde[22] Studies highlight that HBM4EU is a biomonitoring-based initiative made to assess the harmful effect of chromium production in various industries.in European-based industries, various regulatory measures are taken by OSH authorities [23]. Stakeholders play a crucial part in the process of achieving successful regulation. When developing and implementing regulatory measures, it is important to take into account the relevant viewpoints provided by industry, academics, healthcare professionals, and advocacy organizations. The interests of so many stakeholders must be balanced, and this calls for an open and inclusive strategy where cooperation and communication promote a shared commitment to public health. scholars explain that risk assessment is very essential step for controlling the spread of carcinogenic particles. The risk assessment and management team identifies certain things, including identifying the hazards associated with the spread of harmful chemicals, assessing the response of harmful chemicals dosage, and characterizing the risk type[24].studies predict that the main source of various carcinogen substances is stationary source. HAPs are the pollutants that spread in the environment through these stationary sources. In developed countries, VOCs are regarded as toxic substances by the hazardous pollutant assessment team[25].Studies suggest that the main source of lung carcinogens is DEE. The biological process involved in inducing lung carcinogenesis is not fully understood through various studies. the role of genes involved in causing lung cancer is alerted due to the lung cancer-inducing carcinogenic substances. the regulatory role of genes involved in causing cancer management through the use of Micro RNAs[26, 27]. Studies predict that azo dyes release the Amines through the textile industry. The information about the role of amines released by azo dyes is not properly understood.

The samples of azo dyes obtained from the textile industries of Brazil reveal that AA from these industries are carcinogenic[28, 29]. Studies explain that environmental exposure to carcinogenic substances harms the public and the atmosphere. These carcinogenic substances are often disease-causing and leads to the onset of severe disorders types. The neoplasm is a substance that is disease-causing and results in the death of millions of people worldwide[30]. Studies suggest that one of the leading causes of environmental pollution is glyphosate. This substance is classified as a broad-spectrum substance that is carcinogenic. Exposure to glyphosate in the environment develops serious health problems when people intake it through the air[31]. Studies reveal that human diseases caused by carcinogenic substances lead to the development of cancer in a large population around the globe [32]. The percentage of disorders caused by neoplasm is greater. neoplasm causes alteration in the chromosomal structure. The alternation caused in genes and genetic material leads to the onset of cancer [33]. Studies explain that chromium is among the carcinogenic substances that lead to the development of nasal tumors in workers who are exposed to chromium at the industrial level [34]. Exposure to chromium through the occupational industries is the potential source behind carcinogenic substances. The processes through which the minute quantities of chromium become toxic are least understood trough the Research studies[35]. Moreover, the release of DEE as a carcinogenic substance is caused due to the alternation in the nineteen biomarkers. The alternation in the biological mechanism results in the development of carcinogenic substances. To limit the release of DEE in the environment, OELs are employed in several industries[36].furthermore, the release of toxic substances in the atmosphere is controlled through the use of modern approaches. technology-based tools are usually employed in industries to overcome the release of carcinogenic substances. the modern and innovative technological advancement helps overcome the challenges faced by workers working in carcinogenic-producing industries[37].

Descriptive Analysis

Table 1

Name	No.	Mean	Median	Scale Min	Scale Max	Standard Deviation	Excess Kurtosis	Skewness	Cramér-Von Mises P Value
O1	0	1.837	2.000	1.000	4.000	0.841	-0.112	0.750	0.000
O2	1	1.816	2.000	1.000	3.000	0.690	-0.874	0.267	0.000
O3	2	1.571	1.000	1.000	3.000	0.639	-0.477	0.692	0.000
EC1	3	1.592	2.000	1.000	3.000	0.636	-0.535	0.623	0.000
EC2	4	1.898	2.000	1.000	3.000	0.707	-0.975	0.152	0.000
EC3	5	1.755	2.000	1.000	4.000	0.821	0.407	0.950	0.000
EC4	6	1.510	1.000	1.000	4.000	0.703	1.994	1.415	0.000

The above result describes descriptive statistical analysis the result represents those average values, the median rates, the skewness present at that rate, probability values, also that minimum values and maximum values. The O1, O2, and O3 shows that average values are 1.837, 1.816, and 1.571, which shows positive average rates. The standard deviation rates of 84%, 69%, and 63% deviate from the mean. The overall probability value is 0.000 showing 100% significant rates. The EC1, EC2, and EC3 shows that 1.898, 1.755, and 1.510 all present that positive average value of mean. The overall minimum value is 1.000, the maximum value is 4.000, and the median rate is 2.00, respectively. The results describe that 82%, 70% deviate from mean values related to the Occupational and Environmental Carcinogens assessment and Regulation.

Applications

The implications of identifying, classifying, and controlling environmental and occupational carcinogens are extensive, impacting several societal domains. Let's examine a few important uses:

Policies for Occupational Safety and Health

The identification and control inform occupational safety and health policies of carcinogens present in the workplace. By shielding employees from dangerous material exposure, these regulations aim to lower the incidence of malignancies related to the workplace.

Industrial Procedures & Methods

• Industries frequently modify their procedures and practices in response to legal frameworks. In order to reduce hazards to workers and the surrounding community, safer technologies, materials, and manufacturing techniques are developed via an understanding of carcinogens and their regulation.

Initiatives in Public Health

• Reducing the overall rate of cancer through public health measures benefits from the assessment and regulation of environmental carcinogens. Policies that address air, water, and soil pollution contribute to creating healthier living conditions and reducing threats to the general public's health.

Monitoring and Research in Epidemiology

• The identification of environmental and occupational carcinogens improves monitoring and epidemiological research. Tracking patterns in the occurrence of cancer makes it possible to identify new dangers and makes early intervention tactics easier.

Safety of Consumer Products

• Regulations affect consumer product safety requirements. Regulations serve to protect customers' health by ensuring that commonplace products, including household and personal care items, are free of toxins that might cause cancer.

Infrastructure Development and Urban Planning

• It is imperative that carcinogenic hazards be taken into account while developing infrastructure and urban planning. Zoning, trash management, and transportation policies can be formulated to reduce environmental exposures and encourage healthier living environments.

Risk Education and Communication

• Efforts in regulation aid in the efficient teaching and communication of risks. By raising knowledge among employees, communities, and the broader public about possible carcinogens and regulatory measures, people are better equipped to make educated decisions.

International Cooperation and Standards

• International cooperation is frequently required for the evaluation and control of carcinogens. Common standards like those set by agencies like the IARC facilitate international risk understanding and harmonize national regulatory strategies.

Legal Structures and Accountability

• Regulations offer a framework for the law to handle responsibility for exposures to carcinogens. Businesses that respect safety regulations, promote a culture of accountability, and support advancing safer technology may face consequences.

Campaigning for Environmental Justice

• Carcinogen assessment and regulation support the cause of environmental justice. Regulations can be used by communities that are disproportionately impacted by environmental dangers to rectify injustices and guarantee equitable treatment when environmental laws are enforced. Fundamentally, the applications of evaluating and controlling environmental and occupational carcinogens go beyond the domains of health and safety; they impact practices, policies, and

behaviors in a variety of sectors, ultimately leading to the development of a more sustainable and healthy future.

Correlation Coefficient

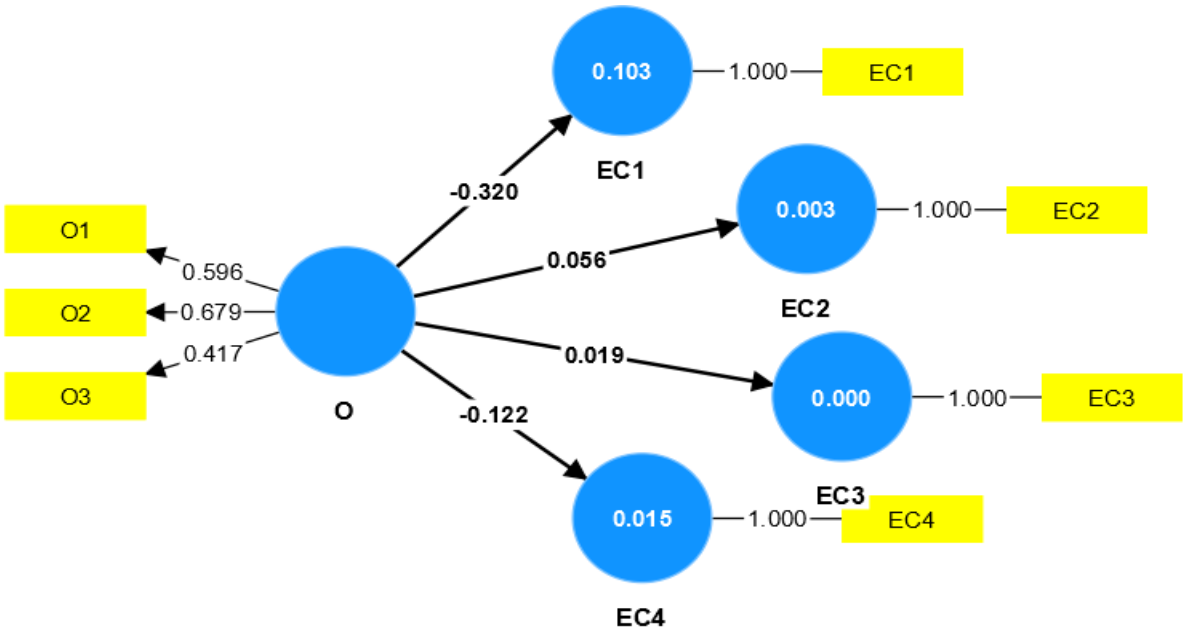
Table 2

	O1	O2	O3	EC1	EC2	EC3	EC4
EC1	-0.163	-0.264	-0.079	1.000	0.000	0.000	0.000
EC2	0.041	0.045	-0.006	0.089	1.000	0.000	0.000
EC3	0.090	0.029	-0.161	0.121	0.238	1.000	0.000
EC4	-0.101	-0.017	-0.149	0.055	0.064	-0.031	1.000
O1	1.000	0.000	0.000	0.000	0.000	0.000	0.000
O2	-0.087	1.000	0.000	0.000	0.000	0.000	0.000
O3	0.249	-0.086	1.000	0.000	0.000	0.000	0.000

The above result represents the correlation coefficient analysis result that EC1 shows that -0.163 negative correlation links with O1. The EC1 also represents that -0.264 -0.079 negative relation with them. The overall effect presents a negative and positive correlation in between Occupational and Environmental Carcinogens related to assessment and Regulation. The result also describes that O2 relation with O1 its rate is -0.087 negative relation between them. The basis is laid forth in the introduction, which highlights the careful balancing act needed to manage the intricacies of environmental and occupational carcinogens. A broad overview of the state of science is presented, emphasizing the various pathways and origins by which chemicals might cause cancer. A major issue that emerges is the evaluation of risk, which makes use of toxicological findings, laboratory tests, and epidemiological investigations to unravel the complex link between exposure and possible harm. As the research develops, the emphasis moves to regulatory environments, examining the international initiatives run by organizations like the International Agency for Research on Cancer (IARC).

The below model represents the smart PLS Algorithm model in between Occupational and Environmental Carcinogens results describe that assessment and Regulation. The model shows that Occupational present 0.596, 0.679, and 0.417 shows positive rates between them. The environmental carcinogens show -0.122 negative rates between occupational and environmental carcinogens. The occupational and EC1 present a -0.320 negative link with them.

Smart PLS Algorithm



Significant Analysis

Table 3

Matrix	Original (O)	Sample	Sample Mean (M)	Standard Deviation (SD)	T Statistic	P Values
O->EC1	-0.320		-0.271	0.214	1.499	0.134
O->EC2	0.056		0.027	0.183	0.303	0.076
O->EC3	0.019		-0.017	0.224	0.085	0.093
O->EC4	-0.122		-0.128	0.185	0.658	0.051

The above result describes that significant analysis results present the original sample, the sample mean value, standard deviation rates, and the t-statistic values, which also represent the probability rates of each matrix. The original sample value of the first matrix is O->EC1. Its original sample rate is -0.320, the sample mean value is -0.271 the standard deviation rate is 0.214 This shows that 21% deviates from the mean. The probability value is 13% its T statistic rate is 1.499 showing positive and 13% significant values between the Occupational and Environmental Carcinogens. The second matrix is O->EC2. It presents that the original sample rate is 0.056, the sample mean value is 0.027, the standard deviation rate is 18%, and the probability value is 7% significant level between them. According to the result, the third matrix is O->EC3 shows a 9% significantly level between them.

Conclusion

We have uncovered the vital need for a flexible and fair approach to regulation and evaluation in the complex field of occupational and environmental carcinogens. Scientific knowledge, legal frameworks, and community involvement create a tapestry that contains the secret to protecting public health and advancing advancement. It is clear from all the complexity that have been revealed that the process of achieving effective regulation is dynamic. Because industries, technology, and environmental exposures are always changing, we need a regulatory framework that can change with the times and meet new problems. As a result of continuing research and scientific developments, flexibility becomes crucial in the fight to remain ahead of any dangers. Carcinogen classification and comprehension are standardized thanks to international cooperation exemplified by institutions such as the International Agency for Research on Cancer (IARC).

However, a coordinated effort at the municipal and national levels is needed to translate these categories into workable policy. Regulatory organizations are faced with the challenging task of crafting regulations that balance protection against advancement by navigating the complex interactions between scientific facts, political reality, and economic concerns. At the end of our investigation, equity shows up as a guiding concept. Vulnerable groups often bear an excessive amount of the risk associated with carcinogenic exposures, resulting in an uneven distribution of the burden. A dedication to resolving these discrepancies is necessary to support regulatory frameworks and guarantee that the advantages of protection are distributed fairly among communities. Every thread is essential to the overall picture of the stakeholders. The conversation around carcinogen regulation is enhanced by the distinct viewpoints contributed by business, academics, medical professionals, and advocacy organizations. A comprehensive and open strategy that promotes cooperation and shared accountability is essential for managing the intricacies of this diverse problem. The path ahead is full of opportunities and difficulties, even as we celebrate the advancements achieved in our knowledge of and ability to control environmental and occupational carcinogens. It's an undertaking that calls for unwavering dedication, creativity, and a common vision of a future in which the precarious balance between human advancement and health is unwaveringly preserved.

Research concluded that, the evaluation and control of environmental and occupational carcinogens sit at the nexus of human health, policy, and science. The need to build a route that preserves the values of scientific rigor, regulatory efficacy, and societal equality is evident as we negotiate this complex terrain. In order to strengthen the foundation of public health, comprehension, regulation, and compassion must be woven together in a collaborative effort toward a safer, healthier future. The cry echoes in the last tangle of our investigation: strengthen public health by making sure that the strands of research, law, and compassion are deeply entwined. We open the door to a safer, healthier world that is resilient to the complex web of cancer threats via our combined efforts and commitment to the welfare of current and future generations.

Recommendations

- Make significant investments in surveillance and epidemiological research to track changes in the incidence of cancer over time. Give top priority to research projects that look at new hazards and serve as a basis for evidence-based regulatory choices.
- Boost global cooperation on the regulation and assessment of carcinogens. Promote international collaboration on data sharing, methodology development, and best practices sharing to develop an international approach to risk mitigation and standardization.
- Create frameworks for regulations that can adapt to new risks and developments in technology. Make sure that laws are still applicable in light of changing business practices and advances in our knowledge of the dangers of cancer.
- In regulatory initiatives, environmental justice a high priority. Regardless of socioeconomic background, address differences in exposure and susceptibility and ensure that regulatory actions actively contribute to fair protection for all populations.
- Encourage inclusive and transparent stakeholder participation. Engage the private sector, academic institutions, medical experts, and advocacy organizations in regulatory decision-making to take advantage of different viewpoints and improve the efficacy of policies that are put into place.

- Launch extensive teaching programs and public awareness campaigns. Provide information regarding possible cancer risks, preventative strategies, and channels for reporting concerns to people, employees, and communities.
- Provide incentives for the development of safer materials and technology across sectors. Promote innovation that reduces or does away with the usage of recognized carcinogens to reduce risk in a proactive manner.
- Strive to make industry-specific regulatory compliance procedures more straightforward and efficient. Adherence to safety requirements is made easier by easily understandable rules, guaranteeing that firms may successfully incorporate preventive measures.
- Take carcinogen evaluations into account while developing infrastructure and urban planning. To promote better living conditions, zoning laws, waste management procedures, and transportation rules should consider possible cancer-causing exposures.
- Give occupational health initiatives that track and control exposures at work a priority. Work together with employers to reduce the incidence of occupational cancers by putting preventative measures, training, and health surveillance into place. These suggestions are meant to help stakeholders, regulatory agencies, and legislators pave the way for a day when the evaluation and control of environmental and occupational carcinogens will be dynamic, adaptable, and consistent with public health and equitable ideals.

References

1. V. Hartwig *et al.*, "Occupational exposure to electromagnetic fields in magnetic resonance environment: An update on regulation, exposure assessment techniques, health risk evaluation, and surveillance," *Medical & Biological Engineering & Computing,* pp. 1-24, 2022.
2. D. Hashim and P. Boffetta, "Occupational and environmental exposures and cancers in developing countries," *Annals of global health,* vol. 80, no. 5, pp. 393-411, 2014.
3. A. B. Lansdown, *The carcinogenicity of metals: human risk through occupational and environmental exposure* (no. 18). Royal Society of Chemistry, 2013.
4. F. M. Lynn, "The interplay of science and values in assessing and regulating environmental risks," *Science, Technology, & Human Values,* vol. 11, no. 2, pp. 40-50, 1986.
5. G. Chappell, I. P. Pogribny, K. Z. Guyton, and I. Rusyn, "Epigenetic alterations induced by genotoxic occupational and environmental human chemical carcinogens: A systematic literature review," *Mutation Research/Reviews in Mutation Research,* vol. 768, pp. 27-45, 2016.
6. P. Boffetta, "Epidemiology of environmental and occupational cancer," *Oncogene,* vol. 23, no. 38, pp. 6392-6403, 2004.
7. T. Kauppinen *et al.*, "Occupational exposure to carcinogens in the European Union," *Occupational and environmental medicine,* vol. 57, no. 1, pp. 10-18, 2000.
8. V. Murillo, P. Manonelles, A. García, and J. Álvarez, "PREVENTION MEASURES FOR FUTSAL INJURIES. A COMPARISON BETWEEN TWO SEASONS," *Revista Internacional de Medicina y Ciencias de la Actividad Física y del Deporte,* vol. 22, no. 85, 2022.
9. M. Yang, "A current global view of environmental and occupational cancers," *Journal of Environmental Science and Health, Part C,* vol. 29, no. 3, pp. 223-249, 2011.
10. C. F. C. Abrantes, M. R. Silva, R. C. Oliveira, C. Eloy, M. A. Cipriano, and L. P. Castro, "Inflammatory myofibroblastic tumour arising incidentally as a polypoid lesion in the gallbladder," *Jornal Brasileiro de Patologia e Medicina Laboratorial,* vol. 51, no. 6, pp. 422-426, 2015, doi: 10.5935/1676-2444.20150065.
11. J. Siemiatycki *et al.*, "Listing occupational carcinogens," *Environmental health perspectives,* vol. 112, no. 15, pp. 1447-1459, 2004.
12. A. Valavanidis, "Environmental Carcinogenic Substances, Exposure and Risk Assessment for Carcinogenci Potential. Classifications and Regulations by International and National Institutions," *Scientific Reviews. Athens, Greece: Department of Chemistry, National and Kapodistrian University of Athens, University Campus Zografou,* 2017.
13. L. Paris, A. Scarselli, A. Marinaccio, and S. Massari, "Assessment of Occupational Carcinogenic Risk by Comparing Data from the Italian Register of Occupational Exposures to Carcinogens (SIREP) with the International Agency for Research on Cancer (IARC) Evidence," *International Journal of Environmental Research and Public Health,* vol. 20, no. 10, p. 5850, 2023.
14. K. E. Knox, R. E. Dodson, R. A. Rudel, C. Polsky, and M. R. Schwarzman, "Identifying Toxic Consumer Products: A Novel Data Set Reveals Air Emissions of Potent Carcinogens, Reproductive Toxicants, and Developmental Toxicants," *Environmental science & technology,* vol. 57, no. 19, pp. 7454-7465, 2023.
15. K. Blum, R. FitzGerald, M. F. Wilks, E. L. Barle, and N. B. Hopf, "Use of the benchmark-dose (BMD) approach to derive occupational exposure limits (OELs) for genotoxic carcinogens: N-nitrosamines," *Journal of Applied Toxicology,* 2023.
16. M. T. D. d. Sousa, P. R. Savassi-Rocha, and M. M. D. Á. Cabral, "Impact of using a lymph node revealing solution in surgical specimens for pathological staging of gastric cancer," *Jornal Brasileiro de Patologia e Medicina Laboratorial,* vol. 50, no. 6, pp. 445-451, 2014, doi: 10.5935/1676-2444.20140055.
17. E. Blanco *et al.*, "Latin America and the Caribbean Code Against cancer 1st edition: Environment, occupation, and cancer," *Cancer Epidemiology,* vol. 86, p. 102381, 2023.
18. A. H. Khoshakhlagh, M. Mohammadzadeh, S. S. Manafi, F. Yousefian, and A. Gruszecka-Kosowska, "Inhalational exposure to formaldehyde, carcinogenic, and non-carcinogenic risk assessment: A systematic review," *Environmental Pollution,* p. 121854, 2023.
19. F. Marchetti *et al.*, "Error-corrected next-generation sequencing to advance nonclinical genotoxicity and carcinogenicity testing," *Nature Reviews Drug Discovery,* vol. 22, no. 3, pp. 165-166, 2023.
20. R. L. Prueitt, B. D. Beck, and E. J. Calabrese, "Use of Toxicology in the Regulatory Process," *Hayes' Principles and Methods of Toxicology,* vol. 2, no. 4.1, p. 41, 2023.
21. J. Gerding, S. W. Ng, and S. Crauste-Manciet, "Occupational Safety and Health," in *Practical Pharmaceutics: An International Guideline for the Preparation, Care and Use of Medicinal Products*: Springer, 2023, pp. 605-621.
22. F. Pattavina *et al.*, "From hazard identification to risk assessment: The role of the prevention technician in the carcinogenic risk

assessment for formaldehyde," *Frontiers in Public Health,* vol. 11, p. 960921, 2023.
23. T. Santonen *et al.*, "The HBM4EU chromates study–outcomes and impacts on EU policies and occupational health practices," *International Journal of Hygiene and Environmental Health,* vol. 248, p. 114099, 2023.
24. A. Mutti, "The Linear Non-threshold Extrapolation of Dose-Response Curves Is a Challenge for Managing the Risk Associated with Occupational Exposure to Carcinogenic Agents," *La Medicina del Lavoro,* vol. 114, no. 1, 2023.
25. W.-T. Tsai, "A Survey on Toxic Volatile Organic Compounds (VOCs): Toxicological Profiles, Health Exposure Risks, and Regulatory Strategies for Mitigating Emissions from Stationary Sources in Taiwan," *Atmosphere,* vol. 14, no. 2, p. 242, 2023.
26. W. Hu *et al.*, "Occupational exposure to diesel engine exhaust and serum levels of microRNAs in a cross-sectional molecular epidemiology study in China," *Environmental and Molecular Mutagenesis,* vol. 64, no. 3, pp. 159-166, 2023.
27. A. Ramos-Jiménez, R. P. Hernández-Torres, R. Urquidez-Romero, A. Wall-Medrano, and R. Villalobos-Molina, "Body image satisfaction as a physical activity indicator in university students," *American Journal of Health Behavior,* vol. 41, no. 5, pp. 599-607, 2017.
28. M. C. O. Souza *et al.*, "Screening of regulated aromatic amines in clothing marketed in Brazil and Spain: Assessment of human health risks," *Environmental Research,* vol. 221, p. 115264, 2023.
29. F. N. Amiri, Z. Basirat, S. Omidvar, M. Sharbatdaran, K. H. Tilaki, and M. Pouramir, "Comparison of the serum iron, ferritin levels and total iron-binding capacity between pregnant women with and without gestational diabetes," *Journal of natural science, biology, and medicine,* vol. 4, no. 2, p. 302, 2013.
30. M. Cani *et al.*, "How Does Environmental and Occupational Exposure Contribute to Carcinogenesis in Genitourinary and Lung Cancers?," *Cancers,* vol. 15, no. 10, p. 2836, 2023.
31. J. P. Muñoz, E. Silva-Pavez, D. Carrillo-Beltrán, and G. M. Calaf, "Occurrence and exposure assessment of glyphosate in the environment and its impact on human beings," *Environmental Research,* p. 116201, 2023.
32. J. Moral-García, M. Al-Nayf Mantas, S. López-García, R. Maneiro, and M. Amatria, "Nutritional status and physical condition in active vs. sedentary elderly people," *Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte,* vol. 19, no. 76, pp. 685-698, 2019.
33. J. D. Vitorino and P. M. Costa, "After a Century of Research into Environmental Mutagens and Carcinogens, Where Do We Stand?," *International Journal of Environmental Research and Public Health,* vol. 20, no. 2, p. 1040, 2023.
34. R. F. Allen, C. Jens, and T. J. Wendt, "Perturbations in Epidemiological Models: When zombies attack, we can survive!," *Letters in Biomathematics,* 2022, doi: 10.30707/LiB1.2Allen.
35. C. B. Klein, "Carcinogenicity and genotoxicity of chromium," in *Toxicology of Metals, Volume I*: CRC Press, 2023, pp. 205-219.
36. J. Y. Wong *et al.*, "Alterations to biomarkers related to long-term exposure to diesel exhaust at concentrations below occupational exposure limits in the European Union and the USA," *Occupational and Environmental Medicine,* vol. 80, no. 5, pp. 260-267, 2023.
37. K. Koss Schrager, A. Kingery-Schwartz, and J. Sobelman, "Not a Known Carcinogen: Health and Safety Considerations of New and Innovative Treatments," *Collections,* vol. 19, no. 2, pp. 137-158, 2023.