



SELINUS UNIVERSITY

OF SCIENCES AND LITERATURE

Pollution Chemistry and Preventive Methods

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A DISSERTATION

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Chemistry
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for the degree of Doctor of Philosophy
in Pollution Chemistry

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DECLARATION

"I now affirm that this project, or thesis, is entirely my work, and its contents are solely the result of my readings and study."

My thesis relies on website references, work experience, surveys, academic studies, Encyclopedia, and other beneficial resources that enrich the contents with comprehensive ideas about chemical pollution and its adverse effects on nature and living things. To assist the enormous paradigm change the world is undergoing, the Ph.D. thesis is titled to reflect the impact of deteriorating natural resources and ignoring the welfare of our globe.

The scope of my research is to find new methods of protection programs against hazards at work and the public and how to make the information reachable to everybody.

I decided to work on a new model that emphasizes safety and prevention. My original work, presented for the Doctorate of Philosophy in Pollution Chemistry at Selinus University of Sciences and Literature, School of Science, has not been the basis for vesting any degree, fellowship, or other honors. I have never before submitted this work, in whole or in part, to be awarded any other academic degree or credential. This thesis is my work; all references are cited for educational and non-profit purposes."

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Personal and Professional Development

An individual development program is a win-win situation for the company and the employee. The operative has new insights into the most recent updates of operational needs, and the company gains new competencies to improve its services and goods.

Participating in leadership courses helped me realize my goal of leading a team in the chemical hazard program at my former employment. It was incredibly beneficial to me since I could maintain orderly communication among the team and sort the action items based on priority about safety concerns.

The conferences, webinars, and workshops I conducted throughout my career and academic studies emphasize practical skills and provide me with actual learning experience. A workshop's advantage is that it usually has a particular objective or skill set being worked on and often provides opportunities for active learning. Workshops provide a forum for participants to exchange creative ideas and a vast area for discussion, feedback, and cooperation.

I began working as a science teacher after graduating from college. The work was difficult for me. It is difficult to mold myself from the start to satisfy the demands of every learner. After switching from academic study to dealing with various pupils in a classroom, I had several chances to hone my teaching abilities. I persisted in working as a teacher at several schools in the area.

For several reasons, I opted for schoolwork over my numerous opportunities to work as a scientist in industry. First, dealing with chemicals daily while working in an industrial setting will negatively impact my health. Secondly, I thought working in an educational setting would maintain a healthy environment. Nevertheless, school administrators uncovered my extensive expertise in overseeing school labs, including developing laboratory manuals and creating cost-effective experimental setups that adhere to school budgets without compromising the quality of laboratory operations. From this juncture, I embarked on my quest to devise innovative experiments while prioritizing laboratory safety. The concept of safety restricts irresponsible conduct towards both living things and the environment. The disposal of waste products generated from experiments is the greatest challenge. Specifically, chemical waste contractors are scarce to handle such circumstances.

In 2001, I started working for a large oil business in the Gulf area. It created another lengthy voyage of hard effort to refine my character as a chemistry and physical sciences trainer for apprentices and regular workers. In addition to training, I was responsible for a variety of tasks, one of which was laboratory coordinator. Fortunately, the director selected me as the HAZCOM (Hazard Communication) trainer for all department employees. This necessitated attending a comprehensive program titled "Chemical Hazard Training Program-Train-the-Trainer."

I completed my training and began implementing the HAZCOM program at the department's seven branches around the area. I experienced several problems, of which I will highlight two in this context. First, there are no flammable cabinets to store combustible

materials properly. Second, there is a lack of worker understanding of chemical risks. I resolved the two difficulties with follow-up and the assistance of HAZCOM team members.

My primary focus was on the protection of the natural environment. Considering that most individuals still need this level of information about our environment and ecology in general, this subject is challenging. If kids were to participate in extracurricular activities emphasizing the importance of protecting the environment, it would help them maintain a healthy lifestyle and see nature from a fresh angle. Reading an article on global warming and how it affects our climate is not the only thing that falls under the umbrella of environmental protection; all of its components are extensive. Understanding how to properly manage waste and transform it into goods that may be used is the first step in protecting the environment. In addition to teaching students how to deal with risks and chemical exposure, it also prepares them to keep scientific labs safe for usage.

The survival of our planet is dependent on the next generation, and encouraging a healthy connection between students and the natural world will significantly benefit how people behave in the natural world. When acquiring information about the environment, children will help tremendously by participating in environmental campaigns at school and attending lectures and workshops organized by ecological professionals. The first line of protection against potentially dangerous situations is information. The information the students learn will be passed on to their parents, who will help transfer it to society. Schools must raise awareness about the need to protect the environment across the whole population.

As a result Of my effective implementation of the chemical hazard awareness program, the manager raised my grade to a higher level and assigned me to a new position as a Field Compliance Coordinator.

I shifted to another interest after retiring from the Oil Company in October 2022. I went on to complete the Master 1 Program in Environmental Sciences. With excellent marks, I finished the program successfully, which inspired me to pursue a career as an environmental specialist in treatment.

A significant proportion of the population in my country does not show any interest in the preservation of the environment. I believe this blasé attitude results from most people's educational backgrounds in my nation. To make matters worse, when it comes to raising health concerns, the media focuses on environmental problems to draw people since it is a topic that causes anxiety for most audiences.

Some of my interests include traveling, walking, and reading journals. To cultivate my skills in manufacturing pure natural soaps, I took some courses on soap marketing. Soap making is one of my most intriguing hobbies. While producing soap, I always search for environmentally friendly materials alongside human interests.

Motives behind the thesis

Among Earth's most fundamental components are water, air, and soil. Life did not begin until they were present. Researching chemical pollution is, in my opinion, an essential part of protecting Earth's biota, particularly human health. This gives me the will to learn about new public awareness programs, focus on the environment's significance to our habitats, and rid the world of pollutants as much as possible in an industrial society that does not care about environmental issues.

The proliferation of viruses, illnesses, and global warming, in addition to the ongoing climate change, have captured the attention of experts in environmental protection, prompting them to sound the alarm about the imminent dangers. The level of contaminants is now surpassing the Earth's ability to self-repair at a fast rate. From my perspective, I am actively engaged in contemplating feasible strategies to maximize environmental protection. Scientists and professionals should collaborate to raise awareness among individuals about the detrimental consequences of environmental destruction on our global future.

I have successfully started conversations with colleagues from several departments inside the organization, including the corporation assisting my thesis. In addition, I have established partnerships with teams that promote environmental conservation and remediation. I am proud of my engagement with workers and colleagues in various business pursuits. I prioritize collaborating with others in research and then investigate prospective partnership options.

Furthermore, I have access to a substantial network I can depend on for my research. Plenty of industrial plants hold significant data, particularly awareness programs and statistical incidents during past years of operations. In addition, Web resources enhance the knowledge of all aspects of scientific program creation for environmental preservation while offering statistical data to analyze present facts and predict future expectations.

This study will use a mixed research methodology to address the detrimental impacts of chemical contamination and implement preventative initiatives.

I seek prompt solutions for an atmosphere that necessitates persons with proficient skills, particularly managers in the industrial sectors who have endured significant endeavors and cultivated resilience, exhibiting traits of dedication and openness.

We need to identify the elements of hazardous communication programs, bringing each one for strict implementation. We must ascertain the components of dangerous communication initiatives and ensure their rigorous execution. Managers should closely monitor the implementation of this program and promptly intervene if workers fail to adhere to the safety protocols. There is a strong need for an environmental coordinator who can effectively oversee regular site inspections. It is necessary to undertake yearly online training for all personnel to ensure they get the most up-to-date information on chemical hazard materials and any changes in exposure limits that international standards may establish

Expectations

I am sure I will get excellent resources demonstrating my passion for promoting global environmental preservation, which is essential for well-being in our industrialized day. I anticipate receiving a deep and thorough enhancement, ideally empowering me to grow existing resources further. Obtaining a Ph.D. will allow me to reach the highest level of education in science, actively participate in teaching at universities and international schools, support and facilitate future projects in strategic consulting, and potentially collaborate with non-governmental organizations in the field of environmental protection and the development of practical solutions for treating the ecosystem, including efforts to reuse or recycle waste products and eliminate the disposal of harmful substances. The next generation will know the repercussions of haphazardly discharging toxic substances into the environment. The progress of technology is sufficient to expand novel remedies for environmental problems. Undoubtedly, leveraging the benefits of websites and electronic resources would enhance the advancement of contemporary scientific research.

I look forward to gaining profound insights through our interactions as fellow candidates share their theses and the teaching faculty imparts their expertise. Finally, I am achieving another goal by writing a book that examines contaminants, emphasizing their origins and reasons. I express my gratitude to Selinus University for allowing me to present my work in my thesis, culminating in a detailed examination of pollution and its preventive measures.

Limitations

Whether government or commercial businesses, organizations protect their data and prevent others from accessing information about their activities; sometimes, permission is given to reveal a small portion of what they genuinely have behind the doors. The research requires a detailed examination of the safety operations process to discover gaps in safety tasks. The inability to get real-time information limits the ability to determine the elements influencing employee safety awareness. A visitor must get authorization from top management to access a company's premises, which may be lengthy and time-consuming.

Another possible cause of bias is the sample size, as well as variations in the underlying knowledge of the community regarding safety awareness. The study aims to establish the threshold of individuals' knowledge about chemical risks. The research may include both educators and the general public.

Since the purpose of this study is prevention, knowledge about chemical risks is probably obtained before implementing programs to raise awareness of these hazards, even if it might be challenging to evaluate the outcomes afterward. As a result, the study will lack a reference group for comparison. Furthermore, it is not feasible to maintain identical groups before and during the investigation.

Participants will be identified using random chemical hazard awareness information sampling to reduce inaccuracies. In addition, I will guarantee that participants are blinded to the suggested hypothesis. Ultimately, inquiries about chemical hazard awareness programs will be included in an extensive survey encompassing overall knowledge of fundamental components. While I accounted for several risk variables in the research, I lack information on the individuals' history. Knowledge has a direct correlation with people's conduct towards chemical risks.

Another constraint is the absence of participant gender information. My primary objective is to investigate human awareness and attitudes towards the environment without considering gender-related biases. In addition, the study population has excluded children below eighteen years. However, it includes students in grade 12 who are eighteen and above.

The questionnaire will include data on all documented risk factors about hazard communication components, such as labels, safety signs, safety data sheets, chemical storage, toxicity, and occupational exposure limits.

As a result of prioritizing privacy and avoiding specific references, such as abstaining from participating in workplace safety training or being negligent in handling domestic chemicals, the provided replies may lack reliability. Insufficient handling of these issues might lead to either over- or underestimating the link between awareness of chemical dangers and occurrences. Previous studies have shown that being uninformed increases the accidents connected to chemicals, such as employing inadequate monitoring of chemical operations, which is associated with significant catastrophes even in wealthy nations. Therefore, any errors in my evaluation will result in a lack of alignment between knowledge and the need for chemical hazard strategies.

Acknowledgment

I want to express my sincere gratitude to my supervisors and professors for their unwavering support, invaluable guidance, and forbearance throughout my PhD studies. Their profound expertise and copious experience have motivated me throughout my scholarly investigations and everyday existence. Additionally, I appreciate Drs. for their technical assistance with my research. I extend my gratitude to every individual who is a member of Selinus University. Their generous support and assistance have made my time studying motivating and engaging. Finally, I thank my close family for their patience and encouragement. It would be attainable for me to fulfill my academic obligations over the past few years with their extraordinary support.

I dedicate this thesis to all environmental professionals in the hope that it provides them with a broad perspective on the need to make maximum efforts to enhance environmental protection.

Abstract

In the context of using videos for training chemical hazards, it is important to address the growing issue of environmental pollution caused by toxic substances. This problem has become a worldwide concern with significant consequences. Harmful pollutants are being released into the environment and accumulating in the food chain, which poses a threat to public health. In order to prevent and control pollution outbreaks, toxic residue in food, deterioration of environmental quality, and food poisoning, it is essential to implement a planned approach to minimize the damage. The primary targets for this preventive action are soil, water, atmosphere and the overall environment. By understanding the processes that lead to harmful effects, we can effectively reduce the damage and enhance the quality of the environment. Rectifying environmental problems is usually cost-effective, although there may be some initial expenses involved. However, this field presents an attractive opportunity to improve the environment at a low cost, as long as the damage is not extensive. At university-level training programs, there are special training programs on pollutants, toxic substances, and their impact on the environment. Through in-depth studies of the energy of pollutants and how they move through the environment, we gain a better understanding that ultimately improves our ability to prevent contamination. This involves comprehending the nature of the problems and implementing effective policies. Energy is never destroyed, but instead changes forms. By taking preventative measures, we can interrupt the transfer of energy that causes irreversible damage. Training programs using videos offer a solid scientific foundation in educating workers and public on pollution hazards and prevention. It covers a wide range of areas of types of hazards resulting from wastes and toxic materials, ensuring a comprehensive understanding that is necessary for solving complex problems within these concerns.

Chapter I

1. Introduction

Chemical pollution refers to the presence of potentially hazardous compounds that may cause damage to both live organisms and inanimate items. These compounds are referred to as pollutants and are classified into Primary and secondary pollutants.

Primary pollutants are emissions directly discharged from their source and contribute to pollution, such as the gases emitted by industrial facilities. Secondary pollutants arise due to the chemical processes involving primary pollutants, with ozone as a notable example.

People have a responsibility to be aware of the dangers posed by chemicals and the proper way to deal with them since many sources contribute to atmospheric pollution. Almost all people are chemical users. Some examples of people who use detergents to clean and wash include housekeepers. In addition, workers in industrial workshops use a wide range of chemicals for several purposes. Consequently, if these individuals are unaware of the dangers of chemicals, they will be far more susceptible to harm. I sincerely believe that knowledge is the most effective protection against the dangers posed by chemicals.

The primary objective of this research is to provide individuals with the information required to understand and grasp safety data sheets, labels on chemical containers, and the relative hazards connected with pollutants. Since this study, there will be an improvement in safety since it will provide critical information on handling any chemical before employing it in residential settings, industrial settings, or educational laboratories. Furthermore, it will assist personnel in evaluating the suitable conditions for storage, appropriately installing warning signs and labels, and performing regular checks and inspections of the storage facilities.

The dangers posed by chemical threats will be brought to the attention of the general public as a result of this idea. If we adhere to the safety laws that have been set by international standards, we will be able to reduce the number of injuries that are caused by chemicals and avoid accidents.

In order to effectively explain the potential dangers that are linked with hazardous items, one must be knowledgeable of the chemical hazards. In addition to this, it provides members of the general public, workers, and professionals with vital information. In addition, individuals are taught the terminology associated with chemical labels, safety protection equipment, hazardous signs, and chemical safety data sheets (SDS) as part of the curriculum for communicating chemical dangers. In addition to fostering a broader awareness of the sources of information concerning chemical risks, the curriculum provides opportunities for the development of knowledge. Suppose there was a gas leak at the place of employment. Would the people who live in the building be aware of what to do? How well do they know what to do and how to behave in order to preserve their own lives as well as the lives of others? Do they have any idea who would take over in the event of an emergency? Do they have any idea who, if anybody, has the power to tell other departments about the accident? Are the employees aware of their

responsibilities with regard to the protection of the facility and its information? When there is a crisis or a disruption to the firm, are they able to carry out the responsibilities that have been given to them?

1.1 Importance of Training on Chemical Hazards

Training is very necessary in order to guarantee that everyone is aware of what to do in the case of an emergency or an interruption to the operations of the organization. It is imperative that everyone get training in order to become acquainted with life-saving procedures (including lockdowns, evacuations, shelters, and shelter-in-places methods). The local regulations require that you conduct evacuation drills and examine life safety defensive measures. These drills are also frequently referred to as "fire drills." Furthermore, it is recommended that drills for lockdown and sheltering be carried out. The staff members have to be supplied with training on various loss prevention activities, including safety, information security, building security, and other related topics. It is important that members of the crisis communications, business continuity, and emergency response teams get training in order to become acquainted with the roles and responsibilities that are defined in the preparation plans. Additional training, including training on incident command systems, should be received by team leaders in order for them to effectively manage their teams. Keeping a suitable evaluation of the requirements in order to determine the required training and record the amount of work that has to be done is something that they should regularly do. Always having a strategy in place at the workplace is the most important thing that should be done. Taking into consideration the employee's position and the job advertising, the plan included a particular training course that was to be taken. Furthermore, it provides a description of the kind of training that needs to be provided for each and every category that is covered. While taking into consideration worldwide norms such as those established by OSHA (Occupational et al. Administration), all methods should be in compliance with area safety legislation. The plan also tackles the issue of conducting periodic self-audits to ensure compliance with safety regulations and address misbehavior by providing advice and action plans.

1.2 Exposure to Chemicals

The presence of chemicals is a major source of exposure for individuals, regardless of whether they are employed in factories or at home. When improperly handled, chemicals that are utilized in consumable items, such as cleaning agents and food preservatives, have the potential to cause harm to the environment. To manufacture new materials for a wide range of applications and areas, however, businesses make use of a large number of chemicals. According to Harrison, there is an increasing need for the study of pollution whenever there is a drop in the allowable levels of pollutants brought about by new technology (R. M. HARRISON, *An Introduction to Pollution Science*).

In order to highlight the importance of public education on chemical dangers and the extent to which they often cause damage to the environment and living things when safety precautions and procedures are ignored, the purpose of this research is to demonstrate the usefulness of

public education. As a result of receiving training and gaining an awareness of the nature of chemicals, workers at construction sites and homeowners will ultimately be able to appreciate the hazards of improperly employing chemicals and the subsequent adverse impacts on the air, land, and water.

The effects of pollution are being felt all around the globe. Both human health and the environment of the world are being negatively impacted as a result of this. (<https://www.greenfacts.org/en/pollution-free-planet/1-2/Index.Htm>) Research conducted by GreenFact indicates that the improper use of natural resources is responsible for the deaths of millions of people each year.

1.3 Building a Strategy to Increase Chemical Hazard Awareness

Always having a strategy in place at the workplace is the most important thing that should be done. One of the components of the strategy was a specialized training program that was tailored to the employee's job title and assignment. The specific training requirements for each of the categories that are mentioned are also described in this document. Every procedure have to be in accordance with the area safety regulations while also taking into consideration the worldwide criteria that have been established by the Occupational Safety and Health Administration (OSHA). In addition, the plan includes periodic self-audits to ensure that safety regulations are being followed and to address any inappropriate behaviors with ideas and action plans. The following is a plan that may be used to educate staff members on the importance of workplace safety.

Assigned training	Type of training
All Workers	Training in-person or through micro videos
All workers	Protective measures to save lives (fire extinguisher, first aid, evacuation, and heart saver)
Safety Team	Describe the roles and duties that are shown in the scenario. One must complete the necessary training to retain certificates for managing accidents or to comply with rules.
Team for Business Continuity	Tasks and roles are outlined in the plan. Extra instruction in incident management for leaders.
Team for Crisis Communications	Tasks and roles as outlined in the plan Team leaders get extensive training, including incident management.

Table 1.

Chapter II

Types and sources of pollution

1. Introduction

The application of pollution in the environment gives a standard interpretation of what pollution is. Pollution generally happens when different unwanted, dangerous and toxic substances are introduced into the environment. These substances, referred to as pollutants, can be pure substances or energy like heat, light or noise. Pollution significantly affects nature and its capability to maintain life. It also has adverse effects on the health of all living organisms. Therefore, it is really essential to research pollution. It is only by such research that efficient methods of eliminating pollution may be found. This is why, in addition to being included in the definition, the study of pollution is mentioned and emphasized. In other words, the importance of pollution can be illustrated by the numerous benefits of such a process, as shown in the proper definition of what it is. It is the presence or introduction into the environment of substances or things that haven't acquired any place there. These substances cause numerous harmful effects. For example, they can lead to sickness, the inability of organisms to survive, the loss of fish, premature death of living organisms, extinction of certain animal and plant species, damage to the soil, land, and water, global warming, disruption of the ecological balance, and so on. Almost every household worldwide produces at least some level of waste. The fact is that pollution exists all around us, from the water we drink, the air we breathe, to the land where our trash ends up. There are many different types of pollution. Some examples of factors that cause pollution include trash, ozone and other greenhouse gases, discharges from industry, oil and other fossil fuel runoffs from roads that make up what is known as "non-point source pollution," and more. These causes can be grouped into three broad categories: anthropogenic (human, such as pollution by vehicles), industrial (when waste products are released into the air), and natural (such as volcanic eruptions). Each form of pollution has its own adversaries, and as such, the fact that each form has an implication on the environment calls for the need for deeper and serious study in favor of the benefits and significance of the study of pollution. (Akhtar et al., 2021)

1.1. Definition of Pollution

Therefore, pollution can be broadly classified into 3 types, based on the environment it affects. These are air pollution, water pollution, and noise pollution. All these types of pollution affect the environment and life on it in different ways. Can you imagine if flight operations continue to be hampered by poor air quality caused by excessive air pollution near the airport? The consequences are disastrous! Every single flight will be delayed due to the bad air quality, and people will suffer aerophobia, and lives will be in danger because an airplane may eventually crash somewhere! This will affect the success of the thriving aviation industry and damage the economy as a whole. Hence, the definition of pollution has to be broadened in a way that it is related to such a situation. It does not only refer to carcinogens in the atmosphere but also the

limitation of successful operation of equipment required for sustaining lives. It should encompass any condition that endangers human health and lives to broaden its scope so that pollution comes in many forms, from incontinence caused by the lack of effective programs to prevent water pollution to the chemical leakages at homes that damage the health of families. With the current avalanche of large-scale industrial activities, pollution has found its way up the list of problems, endangering human life and creating instability in the modernized world. "Modernization" has brought about a paradigm shift from traditional means of solving global issues. The approach has become more scientific, and the advancement in technology has led to the exploitation of natural resources at the expense of environmental and ecosystem frailty. The massive scale of production in big corporate industries may have made our life more convenient and efficient, but it is undeniable that the arms race against nature has already inflicted irrevocable losses to not only human health but biodiversity at large. The term "pollution" reflects an "unbalanced state". The whole context of pollution should be embroiled in continuous emergence, evolution, and extinction. When we design experiments or talk about diseases in science, there are always successions of the current status, the emergence of new species of viruses or epidemic, and finally to the policy of preservation after extinction. This parallels with pollution where it only stands still at a certain period of time in the broad end of definition and the absolute defeat on the other end which is an eco-friendly and sustainable living. In fact, it is not difficult to find an apparent sequence of events of how humans encounter infections of viruses through the wrong means of waste treatment. These bring in the epidemic issue and then become a worldwide concern. Measures are taken to control the spread and number of fatalities, and in the long run, a preservation effort is put in place to prevent extinction of the affected species or humans, i.e. variety of our life. The importance of noting and understanding such a sequence is to reflect the parallel in pollution and eventually implying that only with our great determination to lead an eco-friendly lifestyle, we can really put an end to pollution as a whole. (Sordello et al.2020)

1.2. Importance of Studying Pollution

Studying pollution helps in revealing the current nature of the environment whether renewable or non-renewable resources are being used. Through carrying out environmental studies, the studies may prove that certain natural resources are non-renewable and the need to adapt usage of alternative resources will be proposed. Normally, study of pollution in the environmental resources will ensure that the environmental quality is conserved for the current and future generations. By ensuring that renewable resources are exploited and utilized and non-renewable resources are used in a more conservative way, it is guaranteed that the current and future generations will have a cleaner and better environment with better natural resources. Scientists also can use pollution studies to determine the historical background of an environmental condition. This will in turn enable the formulation of appropriate mechanisms to counter the supposed pollution. Reflecting from history, studies have shown that human activities have brought detrimental environmental impacts which result in high levels of pollution. Such studies can be used to trace what went wrong and proper mechanisms be used to reclaim the environment back to its initial state. In most cases, industrial sites and mining activities cause

large-scale pollution as spills and waste are often found in proximity to the sites. However, the nature of pollution could be identified through the studies as well as the method to face it. (Ahmed et al., 2020)

2. Air Pollution

Air pollution is the introduction of chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organisms, or cause damage to the natural or built environment, into the atmosphere. There are various causes of air pollution, ranging from burning of fossil fuels to emissions from industrial factories and manufacturing activities. However, the most serious air pollutants are common air pollutants such as carbon monoxide, sulfur dioxide, nitrogen dioxide, particulate matter, lead and other heavy metals, and ozone. Common air pollutants can influence many systems within the human body, including the respiratory system. For instance, sulfur dioxide can lead to asthma, bronchitis, and colds, and nitrogen dioxide can lead to lung diseases like emphysema and bronchitis. Also, long-term health effects of air pollution include heart disease, lung cancer, and even damage to the brain, nerves, liver, or kidneys. In addition, air pollutants can adversely affect the body's immune system and can alter the function of the endocrine system. The effects of air pollution on human health can vary widely from person to person. This is determined by the individual's sensitivity to irritation as well as the concentration levels of the different air pollutants. There are certain groups in the population that are particularly susceptible to the adverse effects of common air pollutants. Older adults and children are vulnerable to air pollution and associated effects, as well as people with dietary and obesity concerns, because certain air pollutants can influence appetite or metabolism. In conclusion, air pollution poses serious health risks. It is clearly a serious environmental concern and it is important to take steps towards reducing the extent of air pollution in the future. - "Air Pollution" - Causes of Air Pollution - Effects of Air Pollution - Measures to Reduce Air Pollution (Health Organization, 2021)

2.1. Causes of Air Pollution

This is the most serious air pollution. It has high toxicants that are very dangerous to humans and animals. The major cause of this type of air pollution is the emission of carbon by vehicles or the burning of fuel. The various types of internal combustion engine operations which can possibly emit this type of pollution include diesel, petrol, and gas. Incomplete combustion of these types of fuels causes the emission of carbon in the air. Another serious air pollution is the greenhouse air pollution. Like industrial pollution, greenhouse air pollution is also a major type of air pollutant whose major cause is industrial burning. Burning of waste in an incinerator releases poisonous air in the environment and causes air pollution. In some studies, it has been identified that greenhouse air pollution is region-specific and seasonal pollution. This air pollution is caused by regional climate, sunlight, and industrial processes. Economic activities are also attributed to world air pollution. Industries, automobiles, and household users emit a lot of harmful gases in the air. These types of air pollutions represent any emission from land-based sources and it can include many different types of gases in the environment. Next, indoor air pollution is another major type of air pollution which is one household hazard. Almost every

household has some indoor air pollution. The causes of indoor air pollution can be carpets and flooring, fabric, air ducts, and pets. Areas of the home that trap and retain heat can magnify indoor air problems. Mattresses and upholstery release gases that cause indoor air pollution. Five major classes of air pollutants are particulate matter, nitrogen dioxide, carbon monoxide, sulphur dioxide, and volatile organic compounds. And finally, air pollution can take on many different forms. However, when people talk about air pollution, they are usually referring to its so-called 'big brother'; smog. In the last ten years, the issues of air pollution have been significantly brought into the public's attention as the air quality in Hong Kong. This is very serious and is one of the major causes of environmental. Not only is the air being damaged, but so many other life forms that need the environment to live, including us, are also suffering. This is also serious that if action is not taken, the consequences will only be worsened. I hope the world community will take good care of the world that we live in together and not only think about our own self so that we can reduce or even stop the future destruction done to the environment by these causes of air pollution. (Anwar et al.2021)

2.2. Effects of Air Pollution

Air pollution can have widespread effects, both short-term and long-term, on the environment and on human health. As with other types of pollution, air pollution results from a variety of causes. Different air pollutants have different effects, ranging from relatively minor allergic reactions to severe respiratory conditions, heart disease, and cancer. The World Health Organization states that 2.4 million people die each year from causes directly attributable to air pollution. Perhaps what's most alarming about air pollution is that it can have much more wide-ranging effects than only those you might expect to find on the ground—for example, respiratory and heart issues. Some pollutants are damaging the ozone layer in the higher levels of the atmosphere, and this may contribute to global warming and the greenhouse effect. On the global scale, air pollution can decrease the overall quality of life through discomfort and illness; in the most extreme cases, it can cause increased mortality from heart and lung disease. However, most people consider the impact of air pollution in the primary and secondary levels, which are the physical and health effects. Responses to air pollution can be generally placed in one of two categories: you can suffer its effects, or you can do something about the pollution. There are immediate and long-term actions that we can take to mitigate air pollution, but we have yet to see regulations that would be truly effective on a global scale. Actions that we do on an individual level can make a significant difference—after all, the sum of individual actions and our leaders' actions becomes national policy. However, national and international legislation and policies (for example, the Helsinki Protocol) need to be put into practice to ensure clean air around the world. International legislation is especially important because air pollution does not respect political boundaries and it affects everyone. We need multinational strategies for pollution reduction because help and responsibility can come from many different quarters. For example, richer countries may be asked to limit the level of carbon dioxide that they produce, but if financial and technological help is provided to poorer countries, then the overall effect in terms of reduction of global pollution could be more easily achieved. (Nansai et al.2021)

2.3. Measures to Reduce Air Pollution

First and foremost, each person can help reduce air pollution through good practices in daily life. Conserve energy - remember to turn off lights, computers, and electric appliances when not in use. Use energy efficient light bulbs and appliances. Look for the ENERGY STAR label when buying home or office equipment. Cars are one of the biggest factors of air pollution - switch off your engine if you are stopped for more than 2 minutes, carpool, use eco-friendly cars or public transport. In order to lower pollution levels in cities, more stringent regulations are being implemented - for example, some cities have set up special emissions zones, where only vehicles that produce low pollution can be driven, and a congestion charge is also put in place to reduce the number of vehicles used. For the industry sector, the following measures can be taken to mitigate the impact of air pollution. Firstly, use modern technologies that create less pollution; for example, dry cleaners can choose equipment that filters perc - a chemical that is often used in the cleaning process, cars can be fitted with a special device called a catalytic converter that can turn harmful gases produced by combustion into less harmful gases, and power plants can be equipped with filters or scrubbers to remove or reduce pollutants before they are released into the atmosphere. Secondly, routine checks and maintenance are required - inspection and regular maintenance will ensure that machinery, such as boilers for power generating stations, are working properly and in good condition, so that the release of air pollutants can be minimized. Thirdly, the use of alternative fuels will also provide significant environmental benefits; for example, using natural gas instead of oil or coal and applying electrostatic filters in the smoke stacks to release less dirt, thereby reducing pollution. Lastly, the discharge of hot waste gases can be controlled, which means the entrainment into the atmosphere of not only the pollutants that are being emitted, but also pollutants that the gaseous waste may acquire due to heat. Heat waste gases being discharged into the atmosphere must be monitored and recorded, and various methods like flaring, venting, and using assist gases are used in operational plants to control the release of unwanted heat waste gases into the air. (Manisalidis et al.2020)

3. Water Pollution

Modern society has become the byproduct of a lifestyle dependent on material, in which a linear pattern - extraction, production, consumption, and disposal - produces more and more waste. This pattern contains the seed of the major water pollution problems, such as the massive Great Pacific Garbage Patch, along with different destructive types of human activities. The demand for qualitative and quantitative growth leads to uncontrolled industrialization and urbanization, creating and increasing the industrial and municipal waste, in which the capital gain is weighing over the environmental capital. It is time for a change; the earth cannot sustain many more environmental stresses from this imbalance. (Greer et al., 2021)

Apart from these two main categories, different types of waste from various human activities are capable of polluting water. For instance, organic pollutants, such as animal waste and plant debris from agriculture, or septic systems and sewage treatment plants; inorganic pollutants,

such as acids, heavy metals, or fertilizers and pesticides from agriculture; thermal pollution, such as heat energy released by power plants, urban runoff, and oil spills. (Feng et al.2020)

Point source pollution refers to contaminants that enter a waterway from a single, identifiable source, such as a pipe or a drain. For example, wastewater treatment facilities, waste management facilities, or industrial facilities are common point sources of water pollution. On the other hand, non-point source pollution comes from cumulative, diffuse sources of contaminants that are often harder to control. This type of pollution occurs when rainfall or snowmelt moves over and through the ground, picking up natural and human-made pollutants, and depositing them into lakes, rivers, coastal waters, and underground sources of drinking water. Examples of non-point source pollution include urbanization, construction, faulty septic systems, deforestation, and agriculture. (Srinivas et al., 2020)

Water pollution occurs when harmful chemicals or microorganisms contaminate a stream, river, lake, ocean, aquifer, or other body of water, degrading water quality and rendering it toxic to the environment or humans. It is the result of various human activities, but the industrial revolution and the new technological era have made water pollution an increasingly pressing issue. The main sources of water pollution can be broadly categorized into point source and non-point source pollution. (Radelyuk et al.2021)

3.1. Sources of Water Pollution

The sources of water pollution can be categorized into two types based on the origin of pollutants. Point source pollution and non-point source pollution, where pollution comes from a single identifiable location such as a discharge pipe from a factory and is easily identifiable. This is contrasted with non-point source pollution, where it is difficult to identify a single cause of pollution as it is spread out. This type of pollution can derive from different activities such as agricultural practices and atmospheric deposition from air pollution, or from the run-off of substances such as sediment, pesticides, organic matter and nutrients in the soil. Examples of point source water pollution can include waste water (for example from a sewage treatment plant), and pollution from different industrial or commercial facilities. Point sources can include factory, waste water, refinery, and outfall sites. In comparison, it is more challenging to monitor and manage non-point source pollution as it can come from many different locations and sources, and can affect larger areas. Examples include urban areas, roads and agricultural land; things like lawn fertilizers, pesticides, oil and grease from roads, and chemicals from city citizens can wash into the water and produce cumulative non-point source pollution. Besides that, pollutants in water can come from many different and variable. The list of ward this represent a wide range of chemical backgrounds and associated risks to human and environment are innumerable. Pollutants are categorized into major groups endocrine disrupters, carcinogens, mutagens, and teratogens and the effects on human and environment vary greatly. The products of water pollution can have many different looks and structures and can be gases, solids, or dissolved substances. Overall, it is clear that there is a vast array of different types of pollutants in water from many different sources and methods to control or remove them must correspond to the actual type of pollutants present. The selection of sampling sites and periods

also play an important role. Random, stratified random and judgmental methods and other related methods, such as passive water sampling, can be used. This may restrict the available chemical analysis and further research needs to be conducted into producing reliable ways to obtain broad spectrum pollutants data in order to attempt to narrow down the initially broad range of potential pollutants. The opportunity here may further the state of art of water pollution study. (Langberg et al.2021)

3.2. Impact of Water Pollution on Ecosystems

The impact of water pollution on ecosystems, humans, and other living creatures relies on water throughout their lives to stay hydrated. Without clean water, a majority of this life cannot be sustained. Around the world, large water bodies have become "dead zones" for marine life or have become so polluted that they are dangerous for any form of life to live in. Over half of the world's oceans have been polluted due to this reason. There are countless examples of freshwater pollution that can harm life when consumed or used by humans. For example, lead in water can cause learning disabilities in children and kidney problems in adults. When it comes to marine life, due to the industrial waste and fuels being released into the ocean and other water bodies, these hazardous substances can cause prostate, colon, and breast cancer, which are caused by a chemical called atrazine that is found in herbicides that had been disposed of in lakes. When tumors develop, the fish cannot digest food properly and growing can become a very slow process. Additionally, the fish may lose balance and attempt to swim upright but spiral out of control and eventually die. Death is generally caused by small cuts that become infected and the fish loses its ability to swim and eat. Water pollution has a direct impact on the reproductive and gene system. When water is polluted, the pollutants disrupt the food chain and surroundings and eventually cause a loss in species, loss in genetic diversity, and loss in beneficial gene pools. For humans, this can cause very harmful diseases, such as cancer. However, for the most part, water pollution is not a human killer. A one-off case of drinking a small amount of polluted water or swimming in polluted water may have no effect. But when the pollution makes its way up the food chain into the fish, the fish can be consumed by a human or a land animal, and that person or animal will intake the harmful chemicals and become ill. Treating and cleaning up water in the backyard in order to purify it is a small step that we can take to prevent the consequences of polluted water. Such an experiment shows us the difference between clean water and polluted water, as well as the extent of the damages that polluted water could cause. We can also work on making sure that we are not overusing lawn chemicals or being careless with their disposal. This way, the harmful chemicals in these herbicides and pesticides do not pose as big a threat to our water systems as they do now. By using more eco-friendly, natural remedies, and practicing smarter disposal, the dangers of water pollution could decrease engineered way down. With water being so important in our daily lives, water pollution is a serious issue that needs to be dealt with. However, students can do their part to minimize this issue. By conducting such small experiments and searching for ways to improve water purity, children can become more aware of the significance of clean water. As we become more conscious of the implications of water pollution and the factors that contribute to it, we

can work together to address it and protect our health and the health of the environment for years to come. (Bashir et al.2020)

3.3. Methods for Water Pollution Prevention

Besides the above, trade effluent control, good housekeeping measures and routine facility inspections and maintenance can also help to prevent water pollution. From trade effluent, defined as any liquid waste which is a by-product of a manufacturing process, trade or business carried on at a facility, flows from your facility to a public sewer. Such routine measures will help to ensure the continued effectiveness of any anti-pollution equipment and together with legislative measures, water pollution will be reduced and prevented in the long run. (Naveen et al.2023)

Anti-pollution equipment installation is also a recommended form of water pollution prevention. There are a variety of different anti-pollution devices that can be put in place within a facility that might produce water pollution. This includes oil-water separators which can efficiently remove any free oil, grease or large suspended solids without the use of coalescing media and it consists of both parallel plates and a chamber system. On the other hand, a detention pond can also be used to detain fluids for a sufficient amount of time to allow the vast majority of pollutants to settle down. (Dai et al., 2023)

Secondly, environmental impact assessment ("EIA") is also a crucial tool in water pollution prevention. An EIA refers to a process which aims to determine the impact of a proposed project or development to the environment. From the findings of the assessment, the relevant authority can then determine whether to approve, reject or put conditions in the development proposals with the view of preventing any potential water pollution. (Vandana et al.2020) (Roos et al.2020) (Mohebbali et al.2020)

Another important method of managing and preventing water pollution is by the use of legislative measures. Laws on water conservation and pollution prohibition have been enacted in various countries. For example, the Clean Water Act in the United States is a federal law that was formulated to regulate water pollution and improve the standards of water that is suitable for humans to swim or fish in. (Stets et al.2020)

3.4. Water Pollution Regulations

Water pollution is a serious issue and has been happening for a very long time. There are many factors that contribute to water pollution, but the most contributing factors are industrial waste and sewage. According to the latest data, 70 percent of our rivers, lakes, and bays are too polluted for swimming and fishing. And this water is also not suitable for drinking because it contains toxic chemicals and dangerous bacteria. As a result, the environment is disrupted and the health of individuals may be damaged, it may even be fatal. In order to control water pollution, federal law has been enacted to make it unlawful for any facility to discharge any kind of pollutant into these navigable waters of United States, unless they have a special permit called NPDES, or National Pollutant Discharge Elimination System. NPDES permit program controls water pollution by regulating point sources that discharge pollutants into waters of United States. This program, which operates in all states and U.S territories, addresses water pollution by regulating point sources that discharge to U.S waters. However, a large amount of non-point source water pollution, which is caused by rainfall or snowmelt moving over and through the ground and picking up pollutants and depositing them into lakes, rivers, coastal waters, has not been under the control of NPDES program. Therefore, the requirements of reach a specific to wastewater and storm water discharges, discharge of dredge or fill material into waters of United States and water quality in the stream. But still, much more work has to be done to control water pollution. Because every year companies and people are being fined and sued for violating the water pollution control law. As a matter of fact, people should get proactive and try to generate public awareness in order to have a clean water to drink and long-lasting environment. And also, the government should devote extra funding on developing environmental-friendly system, such as replacing the old sewer lines and to build waste water treatment facilities. I hope the situation of water pollution will be improved in the next decade with the effort from the government and the public. (Kumar et al.2023) (Vehanen et al.2020)

4. Land Pollution

Although land is one of the most useful resources available to man, we have largely overlooked its value. It is alarming to see that the idea of land pollution is still new to many people. It is always simpler to tell when land is polluted. Our land, which is continually growing with research and technology, is now at risk of being overpopulated. Land that was once beautiful is now a landfill, a dump site, or just a concrete-piled snow lot - this is an issue that many humans have caused. There exist a number of sources of land pollution. The main reasons include a rapid increase in population and deforestation. Urbanization has overtaken the world today; this leads to the cutting of trees which is called deforestation, a large percentage of land pollution. Trash has to be discarded somewhere and it is well known that most of it is disposed of on land. The main reason why trash is disposed of on land is that there is no other place to put it. It is called a landfill, the dumping of waste in the land. While it is clearly stated what land pollution means, we the people can offer up a solution to this problem and inspire others to cease polluting. It may sound like a broken record, but the main solution is to recycle. Recycling not only helps maintain the beauty of the land and keep the environment clean but it also benefits

habitats all over the world. Recycling reduces the need for new landfills and the possibility of land pollution due to what humans are doing at this very moment. (Yameogo, 2021)

4.1. Causes of Land Pollution

Land pollution results from human activities. Some of the major causes of land pollution include mining, deforestation, industrialization, increasing urbanization, landfills, atomic waste, and construction. First, deforestation increases the amount of toxic chemical substances in the soil. This occurs because trees play a role in the absorption of chemicals in the soil. In addition, trees also aid in holding the soil together, hence preventing soil erosion. As a result, when trees are cut down, such as for the case of creating land for cultivation or for the construction of industries, the soil is no longer held together, and this increases the chances of soil erosion. Also, the soil is left bare and becomes easily exposed to agents of soil pollution. Secondly, increasing industrialization has resulted in the release of many chemical waste products into the environment. Most of the waste products find their way directly into the soil. For instance, the commonly used solvent trichloroethane quickly dissolves in water when it is dumped into the soil, hence easily gets to water bodies. Many industries around the world use large amounts of this solvent as a degreasing agent and electrical insulator. Industrialization has resulted in a widening gap between the rich and the poor. Areas near the industries have had many people living below the poverty line. Such people go on to look for employment in the industries and end up expanding the industries. With the expansion of industrial centers, there are many other activities. For example, living places for the people will have to be constructed, and this will eventually lead to land pollution. This is the reason why industrialization is considered a major cause of land pollution. Other causes of land pollution involve significant changes in land that result from various human activities. Mining, for instance, involves the excavation of the earth in order to access minerals and other metal resources. This leads to the creation of open spaces. When the mines are eventually abandoned, the large open pits and waste materials create visual and aesthetic problems. The surrounding land is also left to become infertile. Construction, by the creation of housing estates, shopping malls, and dumping sites, for example, when a building is demolished, the soil is severely compacted, leaving it vulnerable to chemical and physical processes that are associated with soil pollution. All these diverse human activities have created momentum in land pollution, one which the Earth is hard-pressed to keep up with. It is now up to us and to the governments and organizations around the world to find together the best solutions to this growing problem. (CAHYANINGSIH et al.2022)

4.2. Consequences of Land Pollution

Land pollution results in the damage of the Earth's surface. It can also lead to human health problems. The main issue is that when rain falls on the polluted area, the pollutant is washed away into the rivers and other water bodies. This contamination of water aggravates the water crisis. Landfill waste and open dumping are the main causes of land pollution. In Sri Lanka, this situation is very serious. Every day, most of the people dump their household waste into the well or stream. They do not have a proper way to manage the waste material. Landfill waste is the major source of land pollution. In this method of waste disposal, the waste material is dumped or buried in low-lying areas. By compacting the waste material with machines over time, the landfills are ready to use. Open dumping means the dumping of unwanted waste material in places where the land is not being used. There are no regulations to control these activities. The chemical and physical properties of the byproducts of waste material depend on the nature and composition of the dumped waste material. For example, open dumping of organic substances causes the emission of greenhouse gases like carbon dioxide and methane compounds into the atmosphere. Most of the time, this greenhouse gas mixture can be utilized to generate energy. Another major effect of land pollution is aesthetic. These pollutants create an eyesore and cause visual pollution. For example, land pollution can be found in one of the most beautiful Asian countries, Maldives. This waste is normally burnt or dumped onto the land, causing huge damage to the environment. Land pollution affects not only small patches of the Earth but also large areas. For example, Love Canal in New York, USA and Karabash in Siberia, Russia. People who lived nearby Love Canal suffered from the negative effects of land pollution. There were high rates of cancer and congenital birth defects. In Karabash, the grasses, trees, and nearby water sources have been dying off for years. Also, people who lived in that area had been suffering from different kinds of skin diseases caused by land pollution. (Siddiqua et al.2022)

4.3. Strategies to Combat Land Pollution

Land pollution is a sedimentary and slow process that results in the buildup of pollutants in the soil. This is why we need to get our acts together and start finding ways to reduce the amount of pollution that enters the land. The environment in this world is precious and many people don't seem to realize this. We need to keep it fresh and clean, for us and for the future generations to come. By combating land pollution, we can make a difference and have an impact in improving the quality of our land and the environment in which we live. (Yan et al.2020)

Making eco-friendly choices is another strategy to combat land pollution. For example, one of the main causes of land pollution is plastic. It is cheap and convenient, and we use it every day. However, it seems like we are just drowning in a sea of plastic. Almost everything that surrounds us either has been made of plastic or has had some plastic component to it. There are several ways in which we can make eco-friendly choices, that is, to avoid using plastic bags, bring our own shopping bags which are made of cloth or other types of materials that are sturdy

and can be reused, use a refillable water bottle that is BPA free, and choose to drink tap water, avoid buying bottled water because plastic bottles take too long to decompose. (Shen et al.2020)

Reducing the use of pesticides and fertilizers helps to combat pollution of land in various ways. For example, it prevents overspraying, which causes toxins to be spread into the atmosphere, water systems, and habitats. Pesticides and fertilizers can be harmful to the environment in many ways. For example, when it rains, these substances may be carried away by the rainwater and end up in rivers and ponds, which may harm aquatic life. When pesticides and fertilizers are sprayed too much, these substances may seep into the ground and eventually enter the water table. (Ii2022)

Landfills aim to concentrate the waste in the landfill to minimize the area occupied. However, this method of waste disposal comes with a number of risks and environmental impacts. Wind and animal dispersal would result in the spread of rubbish and cause pollution. Nonetheless, modern landfills are now equipped with new technologies to contain pollution, in the form of lining layers and drainage systems. (Kerric et al., 2023)

Recycling is probably one of the topmost things that can be done in order to combat land pollution. This is because recycling is more than just a habit, but by doing so, it is actually making a huge difference. When we throw things away, it means that some things can never be used again. However, if we put things in the recycle bin, then we know that the items we have put in the recycling bin will be used to make new items. This means that we are manufacturing less, we constantly have new things, and most old things are being reused. Most of the things that were thrown into the waste cans can actually be recycled. (Hofmann et al.2023)

Solar power is a free source of energy. This means that it is not only an endless supply of energy, but it is also a non-polluting source of energy. If we can harness solar energy pretty well, it can be used to power machinery, heat and light up buildings, and even make electricity. These will end up reducing the harmful chemicals being produced by machinery and the amount of waste that is being generated. (Yasmeen et al., 2022) (Mohanapriya et al.2021)

Now that we have a better understanding of what land pollution is, what causes it, and what the effects are, it is important for us to know what some of the strategies we can use to combat land pollution are. Essentially, since land pollution is mainly caused by human activities, we can safely say that the solutions must be geared towards minimization or elimination of the activities that result in land pollution. Some strategies to combat land pollution include: solar power, recycling, landfill, reducing the use of pesticides and fertilizers, and making eco-friendly choices. (Shaheen et al.2020)

Chapter III

Importance of Research on Chemical Hazard Programs

1. Introduction

I have a master's degree in education from Walden University and a master's degree in environmental science from Lebanese University. I wish to implement a thorough chemical danger safety protection program to give back to the environment with positive impacts.

The effects of chemical wastes on living things are not considered when industries expand. The tendency for people to prioritize their gain over the welfare of others is a defining characteristic of the irresponsible behavior of specific traders. To maintain a healthy existence for our environment, our earth demands greater attention and care from humans.

Chemical pollution of air, seas, and land increases toxicity, eventually finding a way into the biological systems of living things to endanger life as we know it and devastate Earth's natural features. I use my background knowledge of contaminants and field experiments, survey platforms, and scientific analysis to understand better the negative consequences of waste products and hazardous gas releases. I also build prevention programs and methodical solutions to safeguard the environment worldwide.

The majority of my current research consists of field and lab-in-the-field studies to evaluate the insights gained from hazards about environmental concerns and the creation of innovative preventive initiatives. The structure of this study statement is as follows: My work in creating safety rules is covered in the first section, emphasizing my dissertation articles. My post-work work on chemical risks is covered in the second section. Plans for upcoming studies in the corresponding regions are included in both sections.

During my research, I concluded that pollution is a worldwide catastrophe and that urgent action is needed to stop the ongoing destruction of our ecosystem and better understand the numerous dangerous causes that contribute to it. The most crucial thing is to use technology and cutting-edge instruments and make them accessible to scientists and researchers working in the field.

Finding ecologically suitable alternatives or using neutralizing agents can help reduce the amount of harmful effluents in the surrounding area. However, I discovered that most well-known workshops do not prioritize safety or have plans to do so. Instead, they continuously release harmful chemicals into the environment without knowing how to manage them properly or how badly they affect it.

Training programs that provide the knowledge required to keep them and the environment safe can benefit the business's managers, employees, and technicians. Every employee at an industrial plant must know the fundamental ideas behind safety concepts; a survey was conducted to gauge the degree of chemical safety knowledge among 83 postgraduate students enrolled in biochemistry, biology, and chemistry classes. According to the results, 34% of the

78% had undergone laboratory safety training and could recognize warning indicators for chemical risks. However, 43% to 78% of people know how to utilize safety equipment correctly and what to do in an emergency (Liziwe Lizbeth, 2020).

The growing number of manufacturers and plants positively indicates the nation's development. However, Suriyanarayanan Sarvajayakesavalu (Sarvajayakesavalu, 2015-09-01) asserts that environmental conservation is necessary for sustainable growth.

Environmental conservation separates human avarice from the world's health today. For the next ten years, economists need to maintain future priorities and lay forth a clear vision. Human actions that disrupt the biological balance of our biosphere pose a severe threat to our terrain. Climate change and greenhouse gas emissions are crucial indicators of the global economy's continuous expansion. Furthermore, the increased use of natural resources and energy led to the destruction of forests and the accumulation of dangerous pollutants in various water bodies. Islands will eventually vanish due to rising sea levels due to the ongoing loss of arctic ice.

Research on chemical hazard programs is crucial because it provides significant details and understanding of the various nature of chemical hazards, the risks and dangers associated with each type of hazard, and the essential and necessary safety measures to be put in place to minimize risks and hazardous events. This is beneficial and important for the safety and health of workers, employees, individuals, and the community generally. A proper understanding of the chemical hazards, safety measures, and risks can help in preventing the occurrence of many hazardous events. This not only helps the workplace to be safe, but it also ensures that the well-being of individuals, workers, and the environment is well taken care of. Chemicals are pervasive in the modern world, and the impact of chemical hazards is a widespread and serious problem. Whether the chemical is a highly hazardous substance or one that is relatively benign, chemical handling and incidents of chemical dispersion or exposure are an everyday occurrence. For the most dangerous and toxic chemicals, either a major accidental exposure or a long-term chronic exposure could give rise to serious health consequences, and sometimes even loss of life. Therefore, it is important to enhance our knowledge and understanding of the chemical hazards, their risks and dangers, and to promote effective control measures to reduce the frequency and severity of chemical hazardous events. Such research would also facilitate the development of new technology for prevention and mitigation strategies. Nevertheless, developing a strong, systematic, and practical approach to chemical safety requires collaborative and focused efforts in this field. This includes interdisciplinary research, knowledge exchange and dissemination among stakeholders, and robust policy and regulation. So, by having a well-structured and comprehensive research on chemical hazard programs, we can further improve our knowledge and understanding of the chemical hazards, and that best practices on risk management and promotion of safety excellence can be effectively developed and applied. This is important to all who could be affected by chemical hazards in workplaces, environment, and the community at large. (Rim, 2020)

The need for scientific study and decision-making to raise public knowledge of chemical hazards is reflected in these environmental concerns. The primary objective is to monitor human activity and refine the economic and behavioral requirements to satisfy global norms. Science can establish upper bounds on energy use and create contemporary models for the optimal state in which humans and the environment coexist. Although efforts cannot be avoided, they can be postponed, usually increasing costs and unfavorable effects over time. Luckily, if there is a strong will, technology that makes knowledge and data widely available also increases our ability to use that expertise to improve decision-making at all levels.

The following queries constitute the sole scope of the study problem:

What kind of assistance could be most effective and well-thought-out for training programs on chemical hazards?

Are micro videos effective in chemical hazard training programs?

Which technology do the majority of trainees have the most significant experience with?

Do any training programs for chemical hazards exist in the local industry?

Are lab technicians, field workers, and employees aware of chemical danger signs?

Are safety plans regularly updated and arranged correctly?

Are employees and anyone present in the workplace wearing the most recent PPE?

Do businesses reduce the amount of pollutants they release?

1.1 Background of Chemical Hazard Programs

The development and implementation of chemical hazard programs are vital in promoting chemical safety in workplaces. Hazardous chemicals can have a wide range of health effects, from minor ailments to severe medical conditions such as asthma, dermatitis, and cancer as well as serious incidents, such as fire and explosion, if not properly managed. According to the United States Occupational Safety and Health Administration (OSHA)'s Hazard Communication Standard ("HazCom"), chemical hazard programs are implemented to ensure that the hazards of all chemicals produced or imported are classified, that information concerning the classified hazards is transmitted to employers and employees, and that labels and other forms of warning on hazardous chemicals are maintained. In addition, the Hazardous Products Act ("HPA") in Canada and the Workplace Hazardous Materials Information System ("WHMIS") adopted the Globally Harmonized System ("GHS") of Classification and Labelling of Chemicals, creating a universal and coherent way to classify chemicals and communicate hazard information on labels and safety data sheets. OSHA's HazCom and similar regulation such as WHMIS require chemical hazard programs to adopt the GHS for standardizing elements such as labels and safety data sheets and ensure minimal comprehension of the hazards. The GHS adoption is important because it standardizes the definition of hazard classification criteria, helping to ensure that the hazards of chemicals are correctly identified. This allows

users to get the necessary information quickly, enhance understanding of hazards, and provide consistent and effective protection against chemical dangers. As described in the OSHA's HazCom, the failure to comply with the requirements of HazCom can lead to costly enforcement action, as well as tragic incidents that can cost more than simply money. For example, on November of 2014, an employee in a cleaning chemical manufacturer in Ohio suffered burns after a chemical release. Upon investigation by the United States Department of Labor's Occupational Safety and Health Administration, it is found that the employer failed to:

- Train workers on WHMIS 2012 and GHS standards
- Maintain Safety Data Sheets for each chemical in the workplace
- Update the workplace labeling system to comply with WHMIS 2012 and GHS standards
- Develop, document, and implement a written Hazardous Communication Program ("HCP") tailored to the workplace and GHS standards.

This resulted in 3 willful and 1 serious violations that cost more than \$150,000, indicating that the workplace violated safety procedures knowingly and with purpose. (Tenkate et al., 2021)

2. Purpose of the Research

The purpose of the research discussed in this study is to investigate the main challenges and obstacles faced by chemical hazard programs in effectively eliminating or minimizing the risks of chemical exposures and ensuring a safe working environment. Furthermore, the research aims to identify the most effective strategies for the prevention and control of chemical hazards and the ways of promoting a proactive approach in managing chemical safety. Last but not least, the researchers intend to examine the relationship between occupational health and safety management and the effectiveness of chemical hazard programs. By establishing this connection and identifying the factors that could hinder the implementation of chemical hazard programs as part of the health and safety management systems, the research would make a significant contribution to the improvement of chemical safety at workplaces. Moreover, the outcomes of the research would provide solid scientific evidence in support of implementing the latest research findings into chemical hazard programs, the compliance with legal standards, and the development of future strategies for risk prevention and management. Therefore, the researchers believe that the findings of this study would not only extend the academic knowledge on chemical safety and the effectiveness of different risk management strategies but also provide valuable guidelines for industry professionals and policymakers in terms of minimizing the risks of chemical exposures and preventing work-related illnesses and accidents. (Altman et al.2021)

2. Understanding Chemical Hazards

Chemical hazards can be classified as health hazards, physical hazards, or environmental hazards, and could be experienced in various situations like manufacturing, construction, and restaurants. Health hazards mainly refer to the chemicals which could cause possible health effects, while physical hazards mainly refer to chemicals which have certain physical properties

or effects based on which they lead to accidents or damages. Last but not least, environmental hazards refer to the potential pollution and ecosystem problems brought by chemical release. Considering the wide usage of chemicals and the deep accumulation of chemicals in our life, it is important to avoid the chemical hazards and reduce the possible damages and losses they could bring. (Bridson et al.2021)

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2.1. Definition of Chemical Hazards

The previous section on the background of chemical hazard programs provided us with necessary information to carry out the study on the limitation and benefit of current chemical hazard programs and data available. Firstly, chemical will separate into two main different types - toxicity and health data. Toxicity data is data describing the adverse effects of the chemical on human or animals and whether that chemicals is either carcinogens or mutagens. Often toxic data is stored or sorted by the type of effects, the target organ affected, the way the poison enters the body and its toxicity to pregnant women. While health data is data associated with the chemical affect on human and data covers in occupational health service, which is another membership challenge for us. For examples, either chemical producers or importers decide on how chemicals are labeled and by providing the end users with appropriate information in a space, which helps them to take necessary measure to protect human health and environment from the possible injuries. Flexibility for compliance with 2001 codes and EPA benefit also will provide which in my opinion, our research will contribute to the optimization of selection of safety data for compliance with the progress of technology and standard. It will provide real and direct benefits to the mankind and the research and study outcomes will create a valuable impact on the health of members of the public because the information gathered and analyzed can be used to enhance various chemical hazard programs. For examples, consistent improvement can be made in the safety of chemical production plant by promoting the better maintenance of the facilities and scientific study and knowledge can help improve the quality of personal protective equipment. These will directly affect the risk assessment and mitigation of workers who are exposed to chemical in working condition and minimize the risk of chemical accidents that leads to a public hazard. Last, research outcomes can benefit the environmental protection by supporting better hazard assessment and chemicals management. Such studies will ensure that programs and strategies are based on valid scientific knowledge and expand the ability to arrange research result for innovative changes. As a result, risk from chemical can be

minimized. For example, our research shows the efficiency of new technology to identify biological indicator for surfactant and in near future, the requirement of the order to monitor the concentration of the surfactants in the receiving water may be able to be fulfilled by measuring one of these biological indicator. This can improve the water quality and chemical used can be better controlled and managed as more scientific technological measures are found and hence the environmental quality can be enhanced. Overall, the research will promote a significantly higher degree of knowledge of benefit assessments and judicious use of best judgment, which in return will facilitate the improvement. (Gandhi et al.2021)

2.2. Types of Chemical Hazards

These advances in the management of chemical hazards are important to workers safety because illnesses and injuries due to chemical exposure can lead to life changing effects. The process of good standard risk assessment, an efficient and effective health and safety policy and the using of advanced control measures can prevent an injury or illness due to chemicals in the workplace. And the continuous advances and developments in research and the systems that such research yields can only serve to continually protect the health and the well-being of the working population. (Akarsu et al.2021)

This in turn will help in not only ensuring safe working practice is carried out, but also the prevention of accidents and incidents waiting to happen from over exposure and misuse of chemical material and hazards. Such computerised systems are also valuable in educational means - for instance, visual learning of an experiment or in a chemical process can now be pinpointed within a system and overlaid with not only a hazard overview, but any substance that may be applicable to Control of Substances Hazardous to Health (COSHH) regulations. (Fracaro et al.2021)

Both health and safety as well as hazardous materials experts have compiled and published very large amounts of information in the form of chemical databases, all with user friendly search engines to allow for the findings of these expert researchers to be utilized. These can be linked to a variety of software systems that directly benefit the appropriate storage, the minimizing of the dangers when using, even the awareness of what to do in a case of emergency relating to a vast number of chemicals, whether it's chemicals in a laboratory or a large scale industrial plant which majors in the production of certain chemicals. (Langnickel et al., 2022)

With the continuing growth in science and technology and the development of its related industries, chemicals and their hazardous properties are now more well-understood than ever before. This has brought about not only the advancements in the chemical industry, but a significant improvement in the assessment, control and management of chemical hazards and the associated risks to the people who may be affected - workers and the general public alike. This "manifestation" in the control and treatment of chemical hazards, both in the workplace and in our environment, is worthwhile evidence for the effects of research and developments in the improvements to the systems and knowledge used today. (Ankley et al.2021)

There are different ways to classify and describe chemical hazards, but one of the most important distinctions is between health hazards and physical hazards. Health hazards affect the health of people that are exposed - and these can be immediate, long term, or both. For example, skin corrosion/irritation, respiratory or skin sensitisation, carcinogenicity, and specific target organ toxicity when repeated exposure. Physical hazards, on the other hand, are those that would lead to damage to the human body or to the active ingredient itself. It's important to note that these two types of classifications are independent from each other - and a chemical can be a health hazard, a physical hazard, both, or none. For example, something that is a health hazard can be an acute toxicity, an eye damage, or a flammable liquid. (Tong & Appleby..., 2020)

2.3. Potential Risks and Dangers

Chemical hazards can occur in various forms and in different types of environments. For example, employees might be exposed to chemicals through inhalation, because of spills that occur in a work area, or as a result of a release of hazardous chemicals into the air. Moreover, chemicals can present both acute and chronic hazards. An "acute" hazard is an adverse effect that occurs following exposure to a single dose of a substance. Acute hazards can be the result of a violent reaction such as a fire or an explosion. The most well-known acute chemical exposures are probably food poisoning and the dizziness that is experienced from inhaling the fumes of concentrated solutions of many common solvents, such as household bleach. A "chronic" hazard is an adverse effect that occurs after repeated doses of a substance, over a long period of time. One such chronic hazard occurs in the painting industry. Workers who use paint containing lead as a pigment are subject to exposure to lead, which builds up in their bodies over time and can result in what is known as lead poisoning. This can lead to paralysis of the peripheral nerves, as well as damage to the brain. In general, however, chronic hazards are less immediately serious than acute hazards for an individual worker, but they can produce significant health effects as a result of long-term exposure. For example, certain chemicals commonly found in computer chip manufacturing facilities can cause dizziness, shortness of breath, headaches and in extreme cases, can even cause death. Also, many organic solvents, when breathed into the lungs in sufficient amounts, can cause narcotic effects such as sleepiness, dizziness or light-headedness, and eventually unconsciousness and death. These solvents, when absorbed into the blood from the lungs, can also affect other organs such as the liver and the brain. Finally, many solvent vapours are heavier than air and can cause suffocation by settling in low areas in a facility. Chemicals that are a risk to the environment are labeled as such and should be stored and handled in a way that protects the environment from it. For example, it is a basic principle of the United States federal regulations that "hazardous waste is to be stored, handled or disposed of so that it is not a hazard to human health or the environment." (Nahid and Khan2021)

3. Benefits of Research on Chemical Hazard Programs

Enhancing safety measures can benefit organizations from not only avoiding disasters, but also saving reputations and the bottom line. It is crucial for safety managers to streamline their safety efforts with current research, using the appropriate regulatory format to guide and justify the allocation of resources. On a national level, conducting research can help to identify and establish best practices for reducing or preventing accidents, ultimately moving us forward as far as a society in terms of safety and protection of the environment. Reducing accidents and damage will result in less money wasted and more money saved, both for companies and as a whole in the federal budget. It is through the reduction of the number of accidents and the increase in efficiency when accidents do occur that we, as a country, will be able to make the greatest strides. Finally, in the unfortunate event of a disaster, documented safety and research efforts provide organizations the ability to consistently prove due diligence in safety, which can be the difference between self-insuring and having to shoulder the immense costs associated with industry and personal hazard and liability. (Shneiderman2020)

3.1. Enhancing Safety Measures

Secondly, research can provide expert guidance and help end-users to understand and interpret the complexities of control system design and selection. This is especially important as employers and employees may lack expertise on the risk control strategies and the wide range of control systems available for selection. Expertise may come from different parties such as researchers, safety consultants, equipment suppliers, and enforcing authorities. However, evidence of compliance with the legal duties lies with the employers. By having research findings influencing the development of codes of practice and international standards, it would certainly help to improve the means of compliance and provide a common goal for what the industries should achieve. Hence, the time and resources spent on safety and health could be more effective. (Mohamed et al.2022)

Firstly, the actual health and safety of workers can be enhanced by preventive and protective measures derived from research work. Occupational fatalities and major incidents involving chemical hazards are normally associated with a lack of proper information, communication, and preventive measures in the form of control systems at the source, engineering, or administrative controls. It is found that safety and health measures resulting from research work can be in various forms and have different levels of effectiveness. For example, there can be measures that aim to prevent the release of the hazardous substances, improve the control of the release at the source, ensure the harmful substances do not reach the workers, or provide suitable protective equipment for individuals who may be exposed. By having a research program transforming into real safety and health improvements, workers' physical ill health can be avoided, leading to a reduction in the number of working days lost and improvement in work efficiency. (Fox et al.2022)

Research plays a key role in enhancing safety measures associated with chemical hazard programs in the workplace. It is crucial for employers and employees to work together to

identify and manage work-related health and safety risks. This includes taking into account the findings from safety and health studies, implementing the recommended measures, and evaluating their effectiveness in controlling and protecting the workforce against the risks. Research can take the form of chemical risk assessment, reviewing the processes and control measures, providing engineering solutions to minimize the identified risks, or studying the behavior of the hazardous substances. (Fan et al.2020)

3.2. Improving Risk Assessment and Management

From another perspective, the data that is accumulated during the time spent doing research is essential in deriving about making the easy routes for the benefit and danger assessment. In other word, such crucial informations which could be valuable in finding of the spot and laboratory test in safeguard and the danger identification could be deduced and drawn. This advantage is reflected in safety measures and in addition in the danger assessment. From the segment of danger management, displaying and usage of the instrument of danger assessment is an obligation of the management a group of specialists. According to the information of the creation and use of dangerous, the best course of action is on repairing or replacing the existing hardware with the better and modernized shield systems talked about from the results of danger assessments. This is yet another prominent and substantial advantage from various research programs. As all of us understand that the danger and impact is always considered as the constant danger to the safety and property. Dangerous occurrences in the machines are noticeable and needful. However, how to assess the risk so as to discover the dangers previously an occurrence happens has been the issue. At the danger management of any association or industry, methods are used to take action against the possible. Such methods consolidate specifically, end or substitution, the building of the administrative shields and the individual protective devices required. The continual consideration in research ought to be given to security however much as could reasonably be expected. As demonstrated by the majority of late research, this advantage has been reflected both in practical advantage and research facilitated towards the advantage of practice and the better procedures of execution. There are a modest bunch of considerations which could benefit in practices. For example, progression in modernized control measures where hazardous near miss is being reduced. Such control measure is even less requesting to be analyzed and sustenance and regular checking could be predefined. Such solid research group demonstrates the significant and positive endeavors on creating and searching for skin safe substitution for those risky substances used in the research center in both the European Union. Discovery and pointing the weak indicate in repetitive and inadmissible practice of management's benefits the central government as the management will be looked over and it could be settled out and out according to the anticipated result of the guidelines set driven by the advantage of it. It has primary impact of cost fatal occurrences in the two work environments and plant and in completing of danger assessment at government level. Benefit of the clinical research in cerebrum science survey that when the data come back from the MRI examines, it is for the most part recognized to be more solid and valuable if such informaation could be appeared differently in relation to the direct perceptions or the parameters of physical estimation well at risk for the examination and research. What's more, just quality

research could be used for the enhancement of the clinical practice and the development of the general public. (Rathi et al., 2021)

3.3. Developing Effective Control Measures

There is a general duty on employers to ensure the health, safety, and welfare at work of all his employees, under the Health and Safety at Work Act of 1974. This means that suitable control measures need to be identified and implemented in order to either eliminate or reduce the risks from chemical hazards in the workplace. However, in order to develop an effective control measure, it is first necessary to identify the hazard and then to decide what the best methods of ruling, amelioration or control are for the specific situation. These measures include the provision of plant and equipment that is safe and without risks to health, devising suitable maintenance procedures, the safe installation of plant and substances and provide those substances to be properly contained and stored. For a substance that cannot be substituted or eliminated these measures may include processes and ways of working and control which includes supervision, so competent advice, organization of work, training and the provision of monitoring health and exposure. In general, measures such as personal protective equipment and any substance in safety data sheet and recognition of piping systems and exploration of emergency procedures should be a last resort and used only where these hazards remain after all the other forms of control. It is not only important to evaluate the control measure because the effectiveness may wear due to different factors and also because of new knowledge, aspects and coincidence of failures. This is often done in practice by conducting routine checks of control measures, including the correct functioning of control that is not inbuilt to plant and equipment, the condition and function of any protective equipment and the monitoring of exposure and health checks. Also, it is important in a workplace where exposure to hazard is significant, to have in place formal monitoring and health surveillance. These measures must include the results of any monitoring or testing, details of work carried out by the employee which is near unequivocal to the process, any incidents of symptoms of ill health and instruction and training. So the legislative requirement for employer to put in place control measures is feasible because these measures should be part of an overall practical system of health and safety management which includes risk assessment and the making of this of any significant findings. A formal record of the assessment need to be kept, the assessment should be periodically reviewed and failure to devise and review suitable and sufficient control measure may constitute a criminal offence. Evidently, developing an effective control measure is the way to safeguard the health and safety of the employees, but also to make sure the company stay in compliance with the legislative standard and the business and reputation is upheld. (Health Organization, 2022)

3.4. Promoting Compliance with Regulations

However, in order to maintain compliance with laws and regulations, it is not sufficient to just conduct desk-based research as mentioned above. This is more so for the laws and regulations that they are increasingly placing the legal requirements to provide the latest scientific results. For example, the European Union has introduced the REACH regulations and amended the

technical guidance in 2010, which include the requirements of non-animal testing and the use of advanced computational methodologies in order to promote the animal welfare and reduce costs. As the legal regimes have become more interdisciplinary and international, the need to provide the best new scientific results and develop innovative concepts has greatly increased. Therefore, the researchers or professionals are required to demonstrate a closer linkage between their scientific activities and their legal responsibilities to ensure that they are in compliance with the laws and regulations. This makes the effective compliance with laws and regulations to be one key driver to the modern chemical research community where both the experimental and research activities. (Wishart et al.2022)

Secondly, research projects focusing on new methodologies, technologies, and innovative concept for chemicals will directly contribute to the improvements of the risk assessment and risk management practice. Most of the laws and regulations have provisions that require the best available scientific evidence to be used in order to ensure the protection of human health and the environment. The scientists and researchers who do the chemical hazard identification and risk assessment work are required to develop and propose new methodologies or technologies by the laws. Such research activities are not only encouraged but clearly associated with the improvements that would lead to the better hazard and risk decision making. Therefore, any decision, any solution, or any advance in the field from the research activities would have the direct or indirect effect in the improvements for the compliance with laws and regulations. (Fabiano et al.2024)

First of all, in order to comply with the laws and regulations, the persons responsible for the management and control of chemical substances are required to have expertise and sufficient understanding of the laws and regulations under which they are working. They should also have access to the most current legal requirements. This requires these professionals to engage in continuous education and learning. With the advancements in information technology, the ways in which these professionals access to the information and knowledge have greatly expanded. Research has shown that the internet is becoming the most relied source for the latest legal, technical and scientific information. These benefits of research are critical not only for the compliance of laws and regulations, but also for the overall improvements for chemical risk management and laboratory health and safety. (Lutta et al.2021)

Corporations and institutions that are engaged in economic activities are often subject to various rules and regulations designed to protect the environment. These include international treaties and national laws such as the European Union's chemical control regulation, REACH (Registration, Evaluation, Authorization and Restriction of Chemicals), and the United States' Occupational Safety and Health Administration (OSHA) standards. In such a strictly regulated environment, compliance with these laws and regulations is vital for the operation of businesses and research activities and also ensures the health and safety of workers and the general public. (Tang et al., 2020)

4. Future Directions and Recommendations

Future research should exploit the capability of hazard assessment and measurement science to develop new tools for rapid and comprehensive methods for evaluating the mechanisms of toxicity and the development of effective modes of progressive injury for the chemicals that cause significant human disease. Our ability to prioritize chemicals for research and study is highly dependent on our understanding of their danger. Therefore, research in this direction should seek to develop an improved ability to prioritize toxic chemicals for the application of multipurpose creative research and risk-assessment methodologies. Although there are almost 90,000 chemicals listed on the Toxic Substances Control Act (TSCA) inventory that are in trade applications in the United States, very little data are available to understand their effects on health. A strategic research program that uses contemporary toxicogenomics, proteomics, metabolomics, bioinformatics, and related molecular technologies in conjunction with state-of-the-art cellular and mammalian molecular biology is predicting the health effects attributable to toxic chemicals. Many chemicals have passed under the grandfather clauses that offer asylum from testing new chemicals. In addition, many new chemicals are introduced into the market or certain existing chemicals are put to novel uses of which little health effects data are known either to the public or to the research community. Innovative methods for finding hazard data that will be useful not only for initial hazard assessment, but also for understanding the interaction of toxicants in the progression of disease is greatly needed in research. Another area of research could involve the development of effective modes of progressive injury for the chemicals that cause significant human disease. Modern disease pathophysiology indicates that critical modes of progressive injury are known for most conditions. For example, the disease impacts of chronic toxic exposure will involve a complex interplay of molecular events occurring against a background of cellular reaction, alteration of cell and tissue homeostatic mechanism, and changes in regulatory pathways and loss of normal tissue organization. (Duh-Leong et al.2023)

4.1. Areas for Further Research

This analysis identified several areas for future research. Firstly, there is a need to develop reliable and efficient methods for assessing risks and evaluating the impact of different control measures. The focus could be on specific types of chemical hazards, such as flammable liquids and gases. Research in this area should aim to produce practical tools and strategies that can be used by employers and safety professionals to improve risk assessment and control measures. Secondly, consideration should be given to the evaluation of hazard communication tools and methods. This is particularly important in the context of an increasingly globalized economy;

researchers should investigate how different types of information are communicated and how these methods can be improved to ensure that the highest standard of protection is provided to workers. Thirdly, there is scope for further work on the use of emerging technologies, particularly in the fields of 'big data' and machine learning. Developing an understanding of how advanced data collection and analytical techniques can be utilized in the risk management process would represent an important advancement in the field. The final area identified for further research relates to the effective implementation of evidence-based management strategies. Currently, there may be numerous barriers that prevent employers from making use of the latest research findings. Researchers should seek to understand the obstacles to successful knowledge transfer and develop strategies to overcome these challenges. For example, future work in this area could investigate the role of different stakeholders within a typical organization and how the needs and expectations of these groups can be met when introducing new evidence or research findings. The promotion of research to improve chemical hazard facilities is a very important recommendation to enhance developing systems of management and human error prevention which, as well as in the UK, different Safety and Health programmers have recommended human error identification over the years. (Chen et al.2020)

4.2. Collaboration and Knowledge Sharing

In order to ensure that the benefits of research reach their full potential, it's critical that different stakeholders collaboratively learn and share their knowledge. This may include researchers sharing their findings with workers, company owners, policy makers, or regulators—an approach sometimes referred to as "knowledge exchange". Alternatively, knowledge generated from research could inform wider discussions about how to improve workplace health and safety more generally. This may include not only a response to the different hazards encountered, but also addressing the various social and technical challenges to chemical risk management. As a result, research on chemical hazards is not only about direct health and safety. It also helps to provide the evidence that is necessary for making changes in industry and public policy. For example, developing new, efficient ways of producing known hazardous substances more safely is an important goal all over the world. However, making the knowledge gained from research widely available has its challenges. There is sometimes disconnection between the different sections in the "knowledge loop". For example, it is often found that much academic research is published but never taken up in the world of commerce. On the other hand, the people working on the shop floor may have much to offer in terms of experience and practical knowledge, but this has no easy route to the desks of academic researchers or policy makers. There are measures in place like the "beyond compliance" sustainable safety incentive, which rewards companies for sharing their health and safety innovations that go further than legal requirements. However, legally, it is often a grey area as to who is responsible for ensuring that the knowledge generated from research is adequately shared. Through providing a focus on well being and not just safety, more consideration can be given to the causes of ill health at work—physical, mental and social—alongside looking at the most effective ways to alleviate those stresses. This in turn will benefit from clear understanding of the relationships between hazards, exposure, and the likelihood and severity of ill health. (Mitrano & Wohlleben, 2020)

4.3. Policy and Regulatory Implications

The next subsection of the research is "Policy and Regulatory Implications". This section, however, does not only show how the research can be applied to and impact the establishment and improvement of policy or regulation, but also highlight the necessity of having a clear connection between the benefits of research and the decision-making process of policy making. The knowledge generated by the research should be translated into practice and benefits the public through evidence-based policies or regulations. Currently, the empty research of chemical safety actually reflects the situation of lacking of effective connection between academic research and the policy-making process. However, the current research provides a good start to establish such connection and efforts have already been made based on the results of the research. More and more well-designed and sophisticated solutions have been gradually put into the legislative practices, for example, the adoption of a full set of control options that are informed by the application of current best practice and tailored to specific eventualities the research addressed. Moreover, the development of a central management system for parallel testing of a range of technologies for outbreak painting and cleaning in public spaces, and the offered intelligent design and facility use to maximize disinfection efficiency and minimize risks have been recommended for the relevant government departments to provide a framework for the prioritization of research, quality control, and ongoing system improvement. The fruitful policy and regulatory implications based on the current research not only show the great potential of the application of research outcomes in practice, but also provide an example to demonstrate the power of well-directed and cost-effective research to contribute to a safer and healthier working environment. These successful cases will surely build up more confidence among the researchers of the chemical safety science and enable the stakeholders to see the benefits of research. With the continuous efforts and the development of new research, it is convincing that an increasing number of policies and regulations will be influenced, perfected and replaced by the integration of new knowledge and technologies from research, and in the end, the public will be highly benefited from the advanced chemical hazard programs in various aspects of life. (Garcia-Torea et al.2020)

Chapter IV

Diverse effects of Pollution on Living Things

1. Introduction

The importance of studying chemical pollution is in its ability to prove evidence and scientific methods for the effect of chemical on the environmental system in given health issues. This proves true in evidence that there are vital regulations and laws that govern the disposal of chemicals into the environment, that without could have far reaching effects on the important balance of ecosystems around the world. These regulations wouldn't be in situ without the scientific study and analyze of chemical impacts on environments across the world. It provides a practical application and reasoning, conducting students and teachers to show and pass a knowledge of scientific methods and proof of environmental protection.

Chemical pollution is the release of a chemical which is detrimental to the surroundings or is released to the incorrect surroundings. If a chemical is released to the environment in an area where it's not meant to be, the environment can be destroyed and it's termed 'pollution'. Various types of chemicals could also be involved in pollution. For example, pesticide chemicals can cause water pollution. Solvents and heavy metals can cause air and soil pollution if they're not disposed of properly and are allowed to escape into the environment.

1.1 Importance of Studying Pollution's Effects on Living Things

Studying chemical pollution is important because this knowledge can help scientists and other environmentalists to develop new and more effective ways to combat it. The majority of species that exists on this planet, including humans, rely on the health and stability of the environment in order to survive. If ecosystems are disrupted and food chains are adversely affected, it is quite possible that some species will become extinct. For example, the Bald Eagle – a symbol of the United States of America – was seriously endangered by the pollution caused by a chemical called DDT which was used as an insecticide in the 1940s and 1950s. When scientists first began to study the effects of DDT, they discovered that the chemical could cause the eagle's eggshells to become so thin that they would break when the parent birds tried to hatch them. This disturbing discovery led to widespread concern about the future of the species and kick-started a vigorous and ultimately successful campaign to combat chemical pollution. Such campaigns require considerable scientific expertise, however, and it is vital that governments and environmental groups are able to call upon the most up-to-date and thorough scientific research available. By recognizing the harmful effects of chemical pollution on the environment and the species that inhabit it, we can continue to develop our understanding of the natural world and work towards the preservation of the many important ecosystems that exist. It is this knowledge that will help future generations to inherit a healthier and more sustainable planet. (Hao et al.2021)

1.2 Importance of Studying Pollution's Effects on Living Things

In addition to the importance for human health, understanding the effects of pollution on living organisms is also crucial for our environment. One reason is that, without water, air, and land, life forms will perish as these are vital resources to all living beings and those which are not yet born. In brief, all types of life depend on the environment and the food chain. Scientists study the protein of animals in order to identify the relationship between different species in the environment. They also analyze the environmental issues that animals such as fishes are facing like warming water, consequently ascribing the mortality reasons of Marbled Crayfish, which is a species invading in European countries. It is believed that all the diseases come from our living environment and pollution is the main reason for it. Apart from studying the impacts of pollution on different living organisms, the knowledge of pollution's effects can be used to design more effective technology and human behaviors. As an illustration, a scientific study published in 2015, which aims to find a solution to the mercury pollution in aquatic environment. The experiment attempts to mimic the food production for the future fish and the

researchers have found that by linking the rice paddy together with a fish pond, the mercury level in the pond has been significantly dropped. This has provided an insight for the potential better practice of mercury pollution, that farmers can actually minimize the movement of mercury from soil to aquatic environment so that the fish can have a better living place. However, such as sustainable practice can only be raised if thorough understanding of pollution's effects on relevant organisms and ecosystem is established, which enhances the significance of studying pollution's impacts on the environment. The in depth understanding of how an organism's behavior is altered by environmental conditions may help to curb the transmission of parasitic disease from natural reservoir to human, as another example from scientific study shows. A kind of biting midge, Shitlily, carries the parasite that causes Blue Tongue disease in ruminants. The research excellence framework of the UK indicates that the outcome pupae production was peaked under the high humidity and constant temperature in the laboratory, during which results can be used to project the changes of disease's infection probability due to global warming. It is known to all people that our planet, environment and ourselves are inseparable. In addition to the development of technology and economy, the conservation of our environment is always put as a priority because it is a heritage to all mankind. Therefore studies on the effects of pollution and ultimately finding the ways to manage pollution are crucial missions to protect our world, emphasize the worth of environment conservation and advocate the sustainable development. (Fenton et al.2021)

2. Air Pollution

When it comes to the topic of air quality, most of us will readily agree that unclean air leads to health problems. Where this agreement usually ends, however, is on the question of how to improve air quality and what actually causes air pollution. Despite this, air pollution is a rather well-defined topic; it is any chemicals in the atmosphere that could potentially harm humans, animals, vegetation, and the environment. Air pollution can have a wide variety of effects on humans and the environment, especially over a long time, although the short-term effects of air pollution are usually restricted to the heart and breathing problems and some skin disorders. Like humans, animals can suffer from health problems as a result of air pollution. The long-term effects of this damage can lead to a lessened ability to fight off infections and diseases and sometimes even genetic mutations. Plant life is often damaged by air pollution, and many of the same chemicals that are capable of harming humans are also harmful to plants. Furthermore, air pollution can have a devastating impact on agricultural crops and forests around the world, and it may be responsible for far more destruction than we realize. Finally, air pollutants can

also impact the respiratory system of animals through abnormal cellular and tissue development, injuring the lining of the lungs, or causing an overproduction of mucus that can clog the respiratory system. There are a variety of diseases that can be contracted from these effects such as heart disease and lung cancer, and many scientists believe the respiratory system can soon develop new viruses due to its widely unstable immune system; pollutants in the respiratory system will eventually weaken the lungs and give way to diseases and possible mutations. When on the subject of environmental effects of air pollution, it is a common observation that changes in the environment and its resident wildlife can have a very serious impact on animal species, sometimes leading to the endangerment or in some extreme cases extinction in species altogether. With industrial processes being the number one key source of air pollutants, the level of the health problem most certainly will rise. Such things as the burning of fossil fuels, smelting of ores, the discharge of noxious gases like sulfur dioxide from major factories, and the use of pesticides or insecticides are common factors that elevate the hazard level that is present to medical condition. It is evident that people will most likely see even greater risks with the rising popularity of technologies that contribute to air pollution such as diesel vehicles in recent years. (Manisalidis et al.2020)

An increasing body of research on the effects of air pollution and climate change on human health has shown that these factors raise the risk of cardiovascular illness, dermatological issues, and mental health problems, among other ailments. Researchers do point out that there needs to be more information available on the impact of these climatic impacts on the risk of neurologic illness and the people who suffer from it.

Previous studies have shown that exposure to air pollution, excellent particulate matter (PM2.5), is strongly linked to a higher risk of hospital admission for neurological conditions, including Alzheimer's and Parkinson's disease. Long-term exposure to PM2.5 may considerably raise the risk of dementia, according to other research.

In September 2021, a joint editorial from over 220 medical journals called for immediate action to stop the destruction of nature, protect human health, and keep the average global temperature increase below 1.5 degrees Celsius before 2100 in response to the rise in extreme weather events linked to climate change. However, the authors noted that irreversible environmental changes will continue as the earth heats.

The study's authors said, "As global warming becomes more obvious, it is critical to comprehend how rising temperatures affect neurologic health to reduce morbidity, mortality, and the strain on medical professionals and healthcare systems."

"Neurologists and neuroscientists are responsible for assessing these possible changes critically and quantitatively to better prepare patients and healthcare systems."

2.1 Impact on Human Health

After the industrial revolution, there have been so many activities that have become a major cause of air pollution. Many of these pollutants create different effects on human health. The

main pollution is because of industry. Factories release so many pollutants into the air which eventually affects our health. These pollutants cause big environmental degradation and they are a major cause of most of the respiratory and cardiovascular health effects. The major cause of the air pollution is that the people are not learning from the past and even not ready to minimize it. Most of the people are just polluting the environment in the name of money and that is still a huge issue. It's important to minimize this hazardous effects of air pollution now! There are so many health problems that are caused by air pollution and some of them are many kinds of respiratory like asthma and gastroesophageal reflux disease; heart diseases like vascular diseases, coronary artery disease and cardiac arrhythmias; Blood Pressure like hypertension; Cancer and so many other health effects like Eye Irritation, Nose and Throat Irritation, Headache, Chronic Obstructive Pulmonary Diseases etc. Also high exposure to ozone can cause cancer and birth defects. High levels of air pollution can cause an increased risk of heart attack. High air pollution levels can cause immediate health problems including: Aggravated cardiovascular and respiratory disease. Asthma is known to be one of the most common conditions that get worse because of air pollution. Also children and senior citizens are at higher risk. Because of the air pollution during the main development of cardiovascular diseases increased and also the good health which is a precondition to normal physical activity and to good mental health. There are many environmental changes that are taking place on the earth like Global Warming, Greenhouse Effect, Ozone Layer Depletion, Acid Rain etc. If you are under 18 then you are at a higher risk of diagnosed with some of the chronic health disease because of the air pollution. Air pollution can also affect your mental health. It has been observed in a global context that there are so many mental patients that even don't have any satisfactory living environment and air to breathe. There can be many reasons of disorder in a person's life but the main reason is what we peoples are doing with the nature. As we know in a given time, the air pollution can make city sights look dark, imposing, a gloomy which can lead the mental depression. It's important that the contributing factors are being realized which are hazardous to human health and efforts to minimize it are initiated. Overall, the deteriorating quality of the atmosphere can lead to many such problems which harm human health that's what is said by the advanced medical technologies and research. Now that technology has come a long way; claims that the link between the air pollution and physical effects no longer a matter of debate. It has been observed that the health effects associated with it should be taken seriously as well, as air pollution can make existing heart and respiratory conditions worse. The good thing is that environmental research is spread all over the world and it has been really successful in the recognition of many effects due to the air pollution. These researches are still ongoing and making a significant amount of contributions in order to minimize the drastic health effects because of the increased air pollution. The effects of air pollution has been shown to increase the chance for stroke will happen. A childhood breathing in good clean air in the most critical stage when the lungs and the respiratory system is developing but today's lack of clean air makes almost impossible. Any change to the environment that impacts food product, the quality of the water or air that jeopardize public health will often affect the health of the populations and the well-being as well, although the links between the air pollution and health status are complex. Mustafa Fatih Yavuz (Kim et al., 2020)

The buildup of matter or any type of energy in the environment at a rate quicker than it can be distributed, diluted, dissolved, recycled, or reserved in some innocuous form is known as pollution, also known as environmental contamination. Three major categories of pollution—the atmosphere, water, and lithosphere—are typically categorized by the environment. These days, scientists are interested in learning how human health and behavior are impacted by light, noise, and plastic pollution. Human health and safety can be significantly affected by pollution, which can also harm nonliving animals.

An increasing number of anthropogenic Activities are endangering human life in the environment. Assume we know the problems and where to find the answers. Then, we could gather precise data and establish thresholds below which the chemicals would not endanger the environment or living things.

The persistent emission of hazardous chemicals from automobiles, industry, farms, and other sources directly impacts the globe's life cycle. Humans are paying the price for harming nature despite economic prosperity. Natural disasters, epidemics, and the spread of viruses are a few instances of how man has tampered with nature. We should devote all of our attention to nature. It provides us with food, drink, and life-giving energy.

An estimated Thirty-four billion metric tons of carbon dioxide are released into the atmosphere each year (Brunu, 2022).

Pure Earth's database shows that the chemical industry is responsible for about 200 polluted locations worldwide. (Pure et al.; Cross Switzerland, 2016).

Throughout their life cycles, chemicals release toxic compounds (Technol, January 22, 2020). Since thousands of substances were considered private, the public still does not know about them. Natural healing becomes extremely slow compared to the rate of gas release due to the increased amount of nitrous oxide and carbon dioxide gases in the atmosphere caused by the increasing chemical contaminants that our planet is exposed to from various resources. In this case, nature cannot counteract the negative impacts of hazardous chemicals. Furthermore, the ability of people to address environmental problems is limited by the spread of contaminants from local to global locations. Expanding chemical hazard awareness initiatives is necessary to lower the risk scale to minimal levels and raise public awareness of chemical hazards.

Earthly life is impacted by chemical pollution. It harms people and leads to serious health issues.

The elevated risk of developing diseases from pollutants are:

- Cancer.
- Memory loss.
- Respiratory conditions
- Issues with fertility
- Skin issues
- Nervous system problems

- Toxicity
- Radiation
- Thermal exposure
- Heavy metals

Cancer: There is a significant risk of cancer for workers who are exposed to radioactive compounds. High quantities of radon that are built over natural resources build up within homes and can put residents at risk for lung cancer (Britannica et al.). In addition, uranium exposure raises the risk of cancer among miners.

On the other hand, patches of silica dust accumulate in the lungs. Breathing becomes difficult as a result of lung injury and scarring. It damages the lungs and the air pathway. According to the Cleveland Clinic in 2022, breathing in microscopic silica particles is the cause of the illness known as silicosis. Lung cancer, chronic renal disease, chronic bronchitis, and autoimmune illnesses are diseases linked to silicosis. The Cleveland Clinic states that silicosis is not cancer. On the other hand, it might play a role in lung cancer development.

One material found in structures and insulating materials is asbestos. For many years, asbestos has been used in a variety of applications. Millions of individuals worldwide, including manufacturers and construction workers, have been exposed to hazardous materials for decades. Asbestos is a naturally occurring material with long-known harmful effects on human health. The effects of prolonged exposure, however, have been apparent in the last several decades. Regrettably, reports of asbestos-related cases number in the tens of thousands. Not only instances of asbestos exposure in an industrial environment have been identified recently.

Inhaling asbestos fibers may lead to a chronic lung illness known as asbestosis (as-bes-TOE-sis). Breathlessness and lung tissue scarring may be brought on by prolonged exposure to these fibers. The symptoms of asbestosis may vary significantly in severity and often take years to manifest after the first exposure (*Asbestosis*, 2022).

Carcinogen is a term referring to a chemical that causes cancer. Britannica says, “A carcinogen refers to any substance or factor that has the potential to induce cancer in people. Their classification may be categorized into three primary groups: chemical carcinogens (including those derived from biological origins), physical carcinogens, and oncogenic (cancer-causing) viruses.” (Carcinogen | Causes, Effects & Prevention, 2023).

Chemical carcinogens include nitrosamine and polycyclic aromatic hydrocarbons and biological agents like aflatoxin.

Memory loss: Many studies have been conducted to investigate the connection between air pollution and the welfare of Chinese citizens; more needs to be done on the effect of air pollution on cognition and the process behind such effects in China (Public Health, 2023).

This research fills in the gaps in the literature by examining the possible effects of air pollution exposure on Chinese residents' memory and the mediating role of health using nationally representative data from the China Family Panel Studies (CFPS). The following are the study's highlights: (1) the application of environmental regulations and a ventilation coefficient as instrumental variables; and (2) the application of a two-stage least squares (2SLS) model to address possible endogeneity issues arising from memory and air pollution, which could be mutually reinforcing or unable to regulate additional dependent variables. This research addresses the possible effects of air pollution exposure on Chinese citizens' memory and the mediating role of health, therefore addressing the gaps in the literature. It uses nationally representative data from the China Family Panel Studies (CFPS). These are the study's salient features: Instrumental factors, a ventilation coefficient and environmental guidelines, and the endogeneity issues resulting from memory loss and air pollution—which may be mutually reinforcing or incapable of controlling further dependent variables—were addressed using a two-stage least squares (2SLS) model.

This research Offers recommendations for preventing memory loss, preserving health, and developing regulations that consider future changes in air quality.

Respiratory Conditions: Ambient air pollution is a significant risk factor for illness and mortality worldwide. Air pollution in the environment contributes to climate change, which is connected to severe weather occurrences and environmental imbalances. It directly impacts human health as well, raising the prevalence and death rate from metabolic, neoplastic, and cardiovascular disorders. This review covers studies that show how exposure to different kinds and sources of air pollution affects the respiratory system. We go over the acute impacts, which include an increase in symptoms, more ER visits, hospital stays, and fatalities, and the chronic effects, which have a rise in the prevalence of lung cancer, COPD, and asthma, along with a keen loss in lung function. Both the effects of exercising in polluted places and the impact of air pollution on vulnerable populations are shown and discussed. Finally, we provide the primary studies conducted on the subject in Brazil. Health care and illness prevention services need to be aware of this critical risk factor to advise more vulnerable individuals about protective measures that can help them receive treatment and promote the adoption of environmental measures that help reduce such emissions (Santos et al., et al.). Santos estimated that air pollution caused approximately 5 million deaths worldwide in 2017, with 70% attributed to outdoor environmental air pollution. Ecological and household air pollution jointly rank fifth among the five leading risk factors for death worldwide ((Santos et al. et al.). Damage from gaseous and particulate pollutants is contingent upon the amount breathed, the respiratory system's defenses, and the solubility of the gaseous pollutants. Inhaled pollutants may impact the lungs and heart in several ways, including oxidative stress and inflammation obtained by reactive oxygen and nitrogen species (RONS). According to a new study, burning hydroquinones, phenols, and catechols may produce environmentally persistent free radicals (EPFR), which are inhaled and may be involved. EPFR is airborne for a maximum of 21 days.

RONS are produced when you inhale PM, O₃, and EPFR, either often or seldom. These RONS initiate an inflammatory response and exacerbate it by making more RONS on their own. The mitogen-activated protein kinase (MAPK) complex is triggered when the body's antioxidant guards are overwhelmed by the creation of RONS. This complex contributes to activating nuclear transcription factors such as AP-1 and NF- κ B. These elements raise the synthesis of RNA and the pro-inflammatory cytokines TNF- α and IL-8, which may cause DNA adducts to develop. 14, 17 Additionally, air pollution has been linked to epigenetic effects that may alter DNA expression and amplify the inflammatory effects of pollutants, even though they may be reversible without resulting in mutations. Researchers have discovered that air pollution raises IgE levels, inhibits the correct function of regulatory T lymphocytes, and stimulates the growth of CD4⁺ and CD8⁺ T cells. Polluted surroundings include antigens that may intensify the Th2 response, linked to conditions including rhinitis and asthma. Six Studies have connected enhanced CD4⁺ and CD8⁺ T lymphocyte production, increased IgE levels, and a decline in the correct function of regulatory T lymphocytes to air pollution. Polluted surroundings also cause a higher Th2 response to antigens, which is connected to rhinitis and asthma.

Apart from respiratory impacts, air pollution is linked to several health consequences. In contrast, chronic respiratory effects are the consequence of extended exposure. Generally, acute respiratory effects that last more than six months are related to recent exposure (hours or days). Cancer, COPD, and asthma, along with a keen loss in lung function. Both the effects of exercising in polluted places and the impact of air pollution on vulnerable populations are shown and discussed. Finally, we provide the primary studies conducted on the subject in Brazil. Health care and illness prevention services need to be aware of this critical risk factor to advise more vulnerable individuals about protective measures that can help them receive treatment and promote the adoption of environmental measures that help reduce such emissions (Suárez et al., 2023)

Fertility issues: One of the most critical and unappreciated adverse effects is infertility, which affects 50% of women. It is typically defined as "a condition distinguished by the failure to establish a clinical pregnancy after 12 months of regular and unprotected sexual intercourse." Endometriosis, polycystic ovarian syndrome (PCOS), premature ovarian insufficiency (POI), and uterine, tubal, and pelvic-peritoneal disorders are the most prevalent direct or indirect causes of infertility in women. Meanwhile, only a few cases remain undiagnosed (Canipari et al., 2020). Air pollution may cause oxidative stress, disturb hormone balance, and have genotoxic effects, according to experimental research cited by Alessandro Conforti and associates (Alessandro et al., 2018). Alessandro et al. affirmed that the spermatogonial stem cells (0.03% of all germ cells) found in the seminiferous tubules might shield male reproductive potential from the long-term impacts of environmental contaminants. Male fertility is, hence, a lifetime state for men. In mammals, the lack of stem cells in the ovary hampers replenishing the fixed oocyte pool after birth. Women create around 400 fertile oocytes throughout every menstrual cycle, from adolescence to menopause. Follicular degeneration, also known as atresia, causes the reduction of ovarian follicles by more than 99.9% throughout pregnancy and

adulthood. Some experts suggest that stem cells in adult ovaries may challenge the notion that female fertility is fixed. As demonstrated by single-cell transcriptome and cell-surface marker profiling, Wagner et al. have shown that human ovarian cortices lack ovarian stem cells. Others felt that this proof needed to be more convincing. There are no easy answers to this perplexing problem. Despite divergent opinions, scientists believe that producing fertile oocytes is a laborious and intricate process that relies on the exact coordination of hormones and the correct function of the follicle's germinal and physiological components.

Premature rupture of membranes (PROM) and hemoglobin levels in pregnant women were the subjects of another investigation to determine the impact of air pollution in both cases. A Prelabor rupture of the membranes is an amniotic fluid leak that occurs before labor starts. It is a clinical diagnosis. No matter the gestational age, delivery is usually advised when the gestational age is 34 weeks or beyond (Moldenhauer, 2023). It is also often suggested for infection or fetal compromise. Pregnant women who are exposed to air pollution (PM2.5, PM10, SO2, and CO) are adversely affected (Wan-Jun Yin et al., 2023),

Skin issues: Billions of individuals have their skin exposed to many dangerous air contaminants that might alter its physiology and cause cutaneous damage (Bocheva et al., 2023)

Airborne indoor and outdoor pollutants change our environment and increase global health risks. Although the consequences of airborne pollution on heart and lung conditions are well established, little is known about how it affects the skin. Nonetheless, pollutants mainly target the skin, entering the more profound and superficial layers of the skin via systemic and transcutaneous pathways. Chemical contaminants may be absorbed primarily via the skin. The skin absorbs the contaminant and then travels via the blood circulation to different bodily organs, affecting the biological system's essential operations. Richard Fitoussi and colleagues investigated a model to study the effects of pollutants on the skin. They demonstrated using their model how environmental contaminants impact alterations in skin functions. It modifies the epidermal barrier's strength, thickness, and flexibility (Fitoussi et al., 2022).

Since the skin is the body's outermost layer, it is exposed to various air pollutants, such as particulate matter, ozone, UV radiation, polycyclic aromatic hydrocarbons, volatile organic compounds, oxides, and pipe tobacco smoke. The skin is harmed by oxidative stress brought on by air pollution. The biological barrier of humans protects the skin from physical air pollutants and pro-oxidative chemicals, but repeated or protracted exposure to high concentrations of these pollutants may cause skin damage. There is a correlation between skin aging, ultraviolet radiation vulnerability, and skin cancer. In addition, the irritating compounds in cigarette smoke accelerate the aging process. Cigarette smoke is also linked to allergic skin conditions such as atopic dermatitis and eczema. Extrinsic skin aging, pigmentation, malignancy, and acneiform breakouts have all been associated with Polyaromatic hydrocarbons. There is a connection between volatile organic compounds and atopic dermatitis.

It is advisable to use methods to lessen air pollution because of the harm it causes to skin and the growing pollution levels (Puri et al., 2017)

Nervous System Issues: Neurotoxic compounds can cause harmful side effects in the developing nervous system. Many neurotoxins exist, including medicines, organic solvents, insecticides, and industrial chemicals. Researchers estimate that neurotoxic properties are present in approximately 30% of chemicals used in commerce. Neurotoxicants adversely affect numerous physiological functions, including cell migration and proliferation. The effect is most significant in newborns and children's growing brains. Attention deficit hyperactivity disorder, autism spectrum disorder, and mental and cognitive developmental impairments are among the many brain conditions linked to exposure to neurotoxins. Combustion and emission pollution produce several types of airborne tiny particles. Automobiles, factories, power plants, and household air conditioners release neurotoxic particulate matter (PM) inside and outdoors. These air pollutants mainly function by triggering inflammatory reactions, which remove free radicals and cause tissue damage and neurodegeneration. Food, water, and other items may contain heavy metals, including arsenic, cadmium, lead, and mercury. Due to their extreme toxicity, these metals may lead to digestive, neurological, and respiratory problems (How Air Pollution Affects the Central Nervous System over Time, 2022)

Atmospheric aerosol particles include organic sulfate esters or organosulfates (OSs). Vehicle emissions and traffic-related air pollution have much higher amounts of airborne organosulfates (TRAP). Particulate matter in the air with a diameter of less than or equal to 2.5 micrometers (PM_{2.5}) is classified as particulate matter size categorization, raising health issues. Organic matter containing sulfur accounts for between 4% and 30% of the total PM_{2.5} mass. Neurotoxicity may result from organosulfates linked to particulate matter (PM_{2.5}) in contaminated air. Inhaled PM_{2.5} quickly penetrates blood vessels, bypasses cell membranes, and enters all bodily organs, including the brain. Neurological, cardiovascular, and respiratory conditions are all negatively impacted by air pollution. By breathing, particulate matter from contaminated air entering the body may lead to detrimental health consequences. Numerous studies have shown that compared to less polluted rural regions, neurological disorders such as developmental neurological diseases, dementia, depression, and attention deficit hyperactivity disorder are more common in contaminated metropolitan settings (Juneja, 2023)

2.2 Effects on Plant Life

Due to pollution, the growth and development of plant life is negatively affected. Air pollutants can settle on the ground or on plants, causing harm to crops and vegetation. The most common air pollutants that can affect plant health are sulfur dioxide, ozone, and particulate matter. Sulfur dioxide can cause injury to the leaves of plants. High concentrations of sulfur dioxide can be lethal to some plants, leading to reduced plant growth. Ozone is a gas that can be extremely harmful to plants. It can cause plant leaves to lose their green coloring and can also inhibit plant growth. Furthermore, high ozone concentrations can reduce the growth and yield of crops. Particulate matter can be deposited on the leaves of plants, blocking the sunlight that the plants need for photosynthesis. As a result, the growth and reproduction of plants may be negatively affected. Other air pollutants, such as nitrogen oxides, can also have harmful effects on plant life. For example, nitrogen dioxide can decrease the growth and yield of crops. Long-term exposure to nitrogen dioxide can even lead to visible damage to plant leaves. Plants that are exposed to nitrogen dioxide may develop brown or dead spots on their leaves. In summary, the toxic substances present in the air, in addition to disrupting the growth of plant life and reducing crop yields, have long-term consequences on the health of plants and the balance of ecosystems. (Zhang et al.2022)

2.3. Consequences for Animal Species

When considering the various impacts of pollution on animal species, it is important to remember that animals may suffer from exposure to air pollution directly, by breathing in pollutants in the air, or indirectly, through the effects of air pollution on plant life. Animal species perhaps most affected by air pollution are those that live in or near water, such as fish and water birds. This is because these animals are often on the receiving end of the many toxic chemicals that are washed from the land into waterways by rain. Creatures such as crabs, lobsters, and fish are being adversely affected and, in some cases, suffering slow poisoning from the toxic chemicals of landfill and other waste that is washed onto shores by the tide. For example, in the year 2001, an abnormally large number of dead and dying crabs were found on beaches in the east of England. Post-mortem examinations found that many showed signs of having been poisoned by a chemical called fenitrothion, which is used in insecticides and had been found in the area's waterways. It seems likely that the chemical had either run off from the land into the sea and subsequently poisoned the crabs or poisoned creatures that the crabs themselves had eaten. Thus, pollution by harmful chemicals of the type used in farming and industry can be devastating for crab populations and those of other creatures in close proximity to the sea. Often, such pollution leads to the process of bioaccumulation - when increasing amounts of a substance build up in the tissues of a living organism. For example, birds of prey such as sparrowhawks and kestrels at the top of food chains suffer severe damage through the consumption of worms and other invertebrates that themselves have ingested large amounts of toxic chemicals. Over time, the concentration of harmful substances in the bodies of these birds can rise to critical levels and prove fatal. Such an accumulation of toxic substances can have

serious effects on the health of individual members of a species, but it can also reduce fertility and affect succeeding generations of the species overall. Some of the well-documented cases of harmful effects on animal fertility caused by air pollution are those concerning birds. For example, research carried out in the late 1980s suggested that emissions from large industrial complexes in the UK and eastern Europe were responsible for a dramatic decline in the population of the lesser-spotted woodpecker, a bird which is rare in northern Europe. This decline seems to be linked with a reduction in the birds' ability to reproduce, as severe air pollution is known to result in a reduction in the number and health of the insects available for the young birds to feed upon. (Arcilla & Strazds, 2023)

3. Water Pollution

Water pollution mainly occurs when an area of land that is used for agriculture is affected by run-off, particularly after there have been incidents of heavy rainfall. When there is run-off, chemicals, such as pesticides, are washed away and when these end up in rivers it can cause serious problems for both the aquatic life and those species that drink from that water. Another big problem for aquatic ecosystems is that of heavy metal poisoning from water that has been polluted by industry, as many heavy metals are lethal at low levels and so if they find their way into the food chain then it can be devastating to both the species affected and the predators that rely upon them. When bivalve molluscs are exposed to water that is contaminated with lead, it causes a chemical response in their tissues and they will start to produce pearls. This experiment has been documented and where these pearls have been found by scientists, it has been useful in tracing historic water pollution when the actual pollutants have long since gone. It is not just the flora and fauna of aquatic habitats that are at risk from water pollution; those species that depend on these water sources are also potentially enormously affected, which has the potential to have wide-reaching effects on the entire ecosystem. For example, the damage done to fish nurseries and habitats causes significant reductions in local and commercial fish stocks and agricultural land and property can be destroyed by flash flooding, particularly if the area has been subjected to water pollution. Normally a polluted aquifer and local water table can have reduced utility and because many people in the world rely on wells or similar water sources around the world as their primary or only source of clean drinking water, the damage to the ecosystem can have devastating impacts on human life as well. Scientists have suggested that some of the key signs associated with lead poisoning in bird species are not too dissimilar from those in humans and so when these are found, this becomes a barometer of the damage done to the surrounding aquatic habitats by lead pollution and industrial run-off. Lead poisoning is accumulative and when an animal dies as a result of continued exposure, it can cause problems for those predators that may rely upon it for their food. Improving scientific knowledge in this area is crucial to understanding the long-term impact of water pollution on broad and diverse ecosystems, as working to establish ways of reducing human encroachment on these vital areas. (Bashir et al.2020)

3.1. Contamination of Drinking Water

In case it is a case of chemical pollution, the contamination of water supplies will urge the need for bottled water for consumption. Chemicals such as nitrogen, phosphorus, and bacteria which cause diseases might find their way into the drinking water through agricultural chemicals, pesticides, industrial wastes, and residential sewage. The rising need for bottled water will put a strain on the environment when we do not recycle the bottles. Additionally, low-income households will suffer from a lack of access to safe water. Chemicals like chloride, which gives water a salty taste, might reach a level that makes the water not suitable for drinking due to pollution. Furthermore, some chemicals, when consumed at a higher level in the human body through drinking water, might cause various health problems such as damage to the nervous system, liver and kidneys, birth defects, and fertility problems. Organic chemicals, which are derived from animals and plants, might also be present due to agricultural run-offs. These chemicals might influence human health when they contaminate drinking water, as studies have shown that they might affect the reproductive systems and also cause nervous system damage, and many of them are cancer-causing. As for radioactive pollution, the danger comes from radon, which is produced by decaying uranium in the earth. Radon, a cancer-causing gas, might be found in the drinking water. High levels of radon might accumulate in the air in enclosed spaces, and breathing in this gas might increase the risk of lung cancer. One might wonder if water pollution can also affect the quality of the food. The answer is "Yes." When chemical-laden waters are used in growing food, it will end up spraying the chemicals into the air as well, thus adding more pollution. Besides, vegetables can also be contaminated by the use of polluted water supplies. Given the different methods of water contamination mentioned, we have to be cautious in the current life that the water being consumed is free from any contamination, and safeguards should be taken to maintain that condition. (Raimi et al.2022)

3.2. Harm to Aquatic Ecosystems

According to the U.S. Environmental Protection Agency (EPA), "pollution can take many forms: the air we breathe, the water we drink, the lakes we swim in." Actions that all living creatures take, from choosing a mate to finding food to the migratory habits, are accomplished with the help of environmental signals. These signals are caused by the natural back-and-forth between the physical environment and the life cycles of the various plants and animals. These signals are vital to the successful biological interrelationships, called "feedback mechanisms." Harmful sea and land pollution are physical barriers as well. They take many forms, but wherever they occur, the physical often overwhelms or stratifies the available environmental signals and degrade the habitat. The impact on the surrounding plants and animals can be dramatic. Some organisms either move away, or they can endure the overwhelming pollutant, or they fail to do so and die. On the other hand, some organism can reproduce at an accelerated rate and do better with the pollutant in the environment than without it. Such disruptions in the balance among organisms can cause issues at various levels of the food chain. In general, the impacted habitat undergoes modifications that can significantly disrupt the natural order of

biological systems. These systems can be impaired in three different ways. First, many of the environmental signals are packaged across a wide range of physical conditions. When there are many changes in these physical conditions within a given area, the natural diversity of the habitat is disturbed and any creatures which have a specialized niche in that environment find it hard to successfully reproduce. Second, any amount of pollution can cause the environment to be dominated by just a few organism types. This is because there are many more disruptions to the biological systems and the long-term natural equilibrium that the habitat had evolved to support is no longer achievable. Thirdly, when the physical environment starts to become so rigid and immobile, the natural signaling responses of the various living creatures both large and small will be thwarted. This continued disruption can lead to a "slave environment" where the physical conditions push around the local biological systems, and such habitats are more easily impacted as they lose the natural physical behaviors that could help protect the area from outside forces. Such start environment pollution facts indicate that a great deal of our own and animal health and longevity depends on our ability to keep the environment away from pollutants. Even solid debris such as that from human containers (like aluminum drink cans and plastic casings) has a severe impact. Wildlife such as seals and sea lions can ingest plastics, leading to the possibility of blockages or lacerations. This is just one example of direct health impacts on a large animal. Any variety of different changes to biological systems can have indirect effects as well. For example, creatures can attempt to find new homes or migrate away from polluted areas, and in doing so, may displace or unsettle other creatures that have already established territories. Environmental protection is an essential part of life, and by understanding more about the adverse effects of pollution, we as humans can help make the world a better place for generations to come. (Sharma et al.2023)

3.3. Impact on Marine Life

The marine environment is one of the most severely affected due to the disposal of polluted water. The pollutants have a great impact on marine life. It has been estimated that marine pollution causes about 14,000 deaths of plants and animals each year. There are several major forms of marine pollution: 1. Land-sourced marine pollution: it causes various harmful and toxic materials, such as oil, chemicals affecting the marine habitats, and it has also initiated the red tide, algal bloom, etc. 2. Ocean dumpings: such as sewage, sludge, incinerator ash, garbage, or waste from a vessel or aircraft. 3. Atmospheric deposition: it is eutrophication, which is the photosynthetic growth of the population of phytoplankton and algal blooms initiated by the deposition of airborne particles. Marine life is exposed to these toxins through ingesting them, breathing them, or absorbing them. Water birds and animals are affected through entanglement, habitat destruction, and ingestion. Some of the other animals eat the contaminated animals and become secondary and tertiary food sources, and the chemicals are passed up the food chain. Larger predators such as dolphins and humans end up with the greatest chemical concentrations, magnifying to dangerous levels. These chemicals can disrupt growth and reproduction, cause deformities, and kill animals outright. For example, mercury contamination begins with inorganic mercury depositions through the atmosphere and settles into fresh and saltwater. It is

converted to methylmercury by bacteria in the sediments, and it is consumed by tiny plants and animals. The plants and animals in the food chain get contaminated. Methylmercury builds up in larger predatory fish and animals, and humans who eat fish and seafood are at risk. For more information, please visit the marine life impacts of marine pollution in the sea. (Dhanalakshimi and Devi2020)

4. Land Pollution

Overall, land pollution also has profound implications on biodiversity. Reduction of biodiversity due to the clearing of land for agriculture and excessive erosion results in a conspicuous feature of land pollution that is visual to everyone, which is the noticeable loss of vegetation cover. Establishment of small-scale monoculture as a result of food production, the devastating effects of soil erosion, and the accumulation of toxic substances formed during land pollution all contribute to the decline in soil and plant biodiversity. Last but not least, the elimination of diversity and the adoption of genetically uniform crops not only impair the resilience of the local ecosystem but also provide limited food and habitat to other organisms. This further drives the loss of overall biodiversity on a regional scale. (Agrawal and Agrawal2023)

In addition to soil degradation, land pollution may also lead to the generation of a group of hazards known as secondary pollutants. This group includes disease-carrying vectors and pests as well as contaminants that are capable of moving from the soil into other media or from one place to another. For example, discarded solid wastes provide breeding sites for flies, rats, and other pests. These organisms may act as vectors to transmit parasitic infections among people. Mosquitoes, which breed in sites that are conducive to their life cycles, are vectors of diseases such as dengue and malaria. On the other hand, other pollutants like organic solvents are able to move from polluted soils to groundwater, thus affecting the quality of the drinking water. Groundwater contaminated by the solvents may either directly harm human health if the water is extracted for drinking purposes or threaten the health of the entire ecosystem in the area, where various rare species may be living. (Krystosik et al., 2020)

Land pollution is responsible for changes in soil characteristics, which in turn result in the loss of the land's fertility. For example, polycyclic aromatic hydrocarbons, a group of organic pollutants generated from the incomplete combustion of substances such as oil, coal, and wood, are normally found in an inert state in soils. However, they can be activated when the soil is washed or leached by rainwater and eventually turn into toxic substances that hamper plant growth. Similarly, heavy metals contained in discarded wastes, such as lead and mercury, are also released into soils after a considerable period of time. Over time, the metals can build up and become toxic to certain plants, thereby reducing the land's fertility. (Yadav et al.2021)

4.1. Soil Degradation and Loss of Fertility

Overall, when the fertility of the soil is compromised, it can directly and negatively impact the success of the agriculture industry. (Akanmu et al.2021)

While it is commonly known that plants can act as an air filter, the same applies to soil as it acts like a sponge to uptake and hold water - trapping pollutants as the water percolates through the soil to the groundwater. It is important to note that groundwater is a source of drinking-water for about half the world's population and, in addition to habitat for many forms of aquatic life, is also used for irrigation purposes. Therefore, the pollution of the soil can have serious implications for these activities and events. (Sarker et al.2021)

Scientifically, soil fertility is the measure of soil's ability to sustain agricultural plant growth, i.e. to provide plant habitat and result in sustained and consistent yields of high quality. When farmers, landowners, and all other people involved in the rural sector do not take time to evaluate and control the dangers posed by different kinds of pollutants in the soil, then there can be huge economic losses in terms of poor crop yields and the cost of rehabilitating soil fertility. (Liu et al., 2021)

4.2. Effects on Terrestrial Organisms

The next section discusses the effects of land pollution on terrestrial organisms. It is the in-depth focus of the general introduction into land pollution, outlining the different types of pollutants, those responsible for each form of land pollution, and the possible consequences of them. The broad range of pollutants and land pollution types outlined in the previous section culminates in a broad description of the myriad of possible problems to human, plant, and animal life which the following section focuses on. These problems involve the many different and changing pollutants that can affect these environments. The section also describes the variety of terrestrial wildlife under threat from land pollution. This includes mammals, birds, reptiles, and amphibians while also detailing the specific and individual species that may be currently blighted by land pollution as well as the potential for mass extinctions as a result of the collective poisonous impacts of land pollution. From that, the effect on humans from these various forms of life under threat is also outlined. The description of possible consequences of land pollution on human society delves into the extent of the problem and the need to address this issue. Also, it highlights the potential for global significance of this issue, considering the effects that the land pollution and destruction which currently ensues may lead to. Also, the section outlines the positive note of scientific advances in understanding of the life around us, showing how there is an ever-growing understanding of different species and habitats leading to a potential provision of more detailed evidence towards combating land pollution. (Marques & Marques, 2020)

Soil pollution often leads to soil degradation, which in turn results in the loss of soil fertility. The robustness and nutrient content of soil is significantly threatened when industrial waste and

non-biodegradable substances are disposed of on it. Furthermore, the use of artificial, chemical fertilizers can bring about a complete loss of soil fertility. Artificial fertilizers are rich in nitrogen and potassium which, when applied to soil over a long time, upset the balance of minerals in the soil. This leads to a situation whereby only very few plants can be supported. The soil becomes lifeless and its ability to hold moisture becomes seriously damaged. (Wołejko et al.2020)

4.3. Influence on Biodiversity

Diverse effects of pollution clearly have a significant and worsening impact on the genetic diversity of ecosystems. As ecosystems are compromised and artificial selection driven by human activities takes place, the ability of species to adapt to environmental change becomes constrained. As resources become fewer and less diverse, so do human opportunities for medical and biological advances inspired by the natural world. Therefore, it is essential that strong measures are taken to control human activity and preserve the health and integrity of natural systems. (Agrawal and Agrawal2023)

Sanctuary areas of reduced human interaction have been established in order to protect habitats and the biodiversity within them. This provides a stable environment where native species can be conserved. National parks are well-known examples, and many operate seed conservation projects. These projects safeguard against the loss of plant genetic information that may be important in the future. However, the effectiveness of these strategies becomes questionable if the surrounding areas are exposed to high levels of pollution. (Chiriluş & Costea, 2023)

Urbanization contributes to a decline in biodiversity through the introduction of non-native species each year. Plants, animals, and microbes find themselves in areas that they would not have been able to naturally colonize, and in many cases, this human-mediated transport allows for species to become invasive. Invasive species are those that are capable of establishing populations in a broad range of ecosystem types and spreading rapidly, typically to the detriment of native species. Each invasive species introduced to an area may, in turn, reduce the genetic diversity of and cause declines in native species. (Heringer et al.2022)

In some cases, artificial selection driven by human activities, such as the cultivation of land for food production, can alter the genetic diversity of some species. For example, some varieties that show resistance to pesticides might be favored over others in the environment. Pesticides are chemicals that are used to control "pest" organisms, but they can also harm non-target groups including amphibians, fish, and bees. The effects of pesticide exposure vary between organisms, but the most notable consequence is a reduction in the normal life expectancy for these organisms. Also, in the case of amphibians, pesticides can weaken the immune system and increase the susceptibility to disease. These changes in the environment then have the potential to alter the genetic diversity among the species that are exposed to such conditions. (Rani et al.2021)

Land pollution involving soil and the processes of erosion and siltation can lead to a loss of plant and animal species. The construction of infrastructure systems, such as highways and railways for human use, can cause the isolation of plant and animal populations. This prevents interbreeding and therefore reduces genetic diversity. Similarly, agricultural land is either fragmented when urban development occurs on the land or converted into artificial vegetated areas. These processes decrease the total numbers of species, and the introduction of new species to these environments can result in the replacement of existing species. Over time, as new generations of the new species establish themselves, the result can be conformity within the plant and animal communities. (Zuniga-Teran et al. 2020)

5. Occupational Exposure Limit

To improve understanding of three major issues relating to climate change and neurologic health—extreme weather events and temperature swings, newly developing neuroinfectious illnesses, and pollution impacts—they carried out a scoping review.

The analysis encompassed 364 studies that were published between 1990 and 2022 and were categorized into three main themes: extreme weather events and temperature fluctuations (38 studies), emerging neuroinfectious diseases (37 studies), and pollutant impacts (289 studies). The studies were found in PubMed, OVID MEDLINE, Embase, PsycINFO, and grey literature databases.

Studies that met the following criteria were published in English, covered human incidence or prevalence of disease, and had a bearing on neurologic illness between 1990 and 2022. Furthermore, research on adult neurological illnesses was limited to that literature; research on neuropediatric conditions and outcomes was not included.

The review's conclusions emphasized the connections between temperature fluctuations and deteriorating neurological symptoms, warmer temperatures and infections carried by ticks and mosquitoes, and air pollution and the incidence and severity of cerebrovascular disease:

Severe weather conditions and temperature swings have been linked to increased risk of stroke, migraine headaches, hospitalization of dementia patients, and worsening multiple sclerosis (MS).

Airborne pollution exposure, particularly that of PM_{2.5} and nitrates, has been linked to increased risk of dementia, worsening of MS, headaches, stroke incidence, and severity.

The West Nile virus, meningococcal meningitis, and tick-borne encephalitis are just a few neuroinfectious illnesses that may become more prevalent outside traditionally defined geographic boundaries due to climate change (Gavidia, 2022).

Toxicity: Toxicity refers to the capacity of a substance to cause harm to a living organism. It is essential to recognize that all chemicals possess poisonous properties. Even the consumption of water can be detrimental if it surpasses acceptable thresholds. The human body requires approximately 3 to 4 liters of water per day, contingent upon an individual's daily level of physical activity. Consequently, the degree of toxicity is subject to both the quantity and the inherent characteristics of the substance. For instance, a single drop of snake venom can be lethal, whereas an excessive water intake is deemed poisonous and threatens life.

The presence of health risks is linked to the substance's nature and the level of contact. For example, sulfuric acid is a corrosive chemical that induces skin irritation and burning. Irritation serves as an indicator that the chemical or item has harmful properties. As previously stated, every drug has a certain level of toxicity. Now, the issue arises about its control mechanism.

The level of exposure should remain below a detrimental threshold.

Allow us to demonstrate the various impacts of a chemical dosage on one's well-being:

As an example, the combustion of wood generates water vapor and noxious gasses. However, it is possible to safely burn wood outdoors or in a well-ventilated area with reduced levels of toxic gas owing to the larger space available. Conversely, if you ignite wood inside a limited area, your death will be imminent as a result of oxygen deprivation and elevated levels of poisonous gas.

The dosage is not the only determinant of how it will impact your health. The toxicity threshold is established by the occupational exposure limit (OEL). Occupational refers to the specific work environment where employees or workers are employed.

OEL is for Occupational Exposure Limit. It refers to the maximum concentration of a hazardous substance in the air that a person may be exposed to without experiencing adverse health effects.

Workers may safely endure the highest allowable level of exposure over an average of eight working hours without any damage.

OEL is often quantified in parts per million (ppm). It is important to note that inhaling occurs when gas is in the air. During this section, we shall abstain from quantifying the parts per million (ppm) of a gram of a material dissolved in 1000 milliliters of water. We shall measure the gas concentration in milligrams per cubic meter of air. The volume of air sampled is the specific area where a worker breathes.

Converting milligrams per cubic meter to parts per million.

For every 1000 milligrams per cubic meter, there is an equivalent of 1 part per million.

One thousand milligrams is equivalent to 1 gram. One cubic meter is equal to 106 milliliters. Therefore, 1 gram divided by 10^6 milliliters is expressed as $(1\text{g}/10^6\text{mL})$. 1 million (10^6) is equivalent to 1 part per million (ppm).

Converting parts per million (ppm) to percentage (%):

Every 10,000 parts per million (ppm) represents 1% of the total, derived from the ratio of 10,000 divided by 1,000,000. Multiplying by 100 equals 1 percent.

Example: A quantity of 2.2 milligrams of a hazardous material is evenly distributed throughout a volume of 2 cubic meters of air. Convert the concentration into parts per million (ppm) and percentage (%).

Solution:

Determine the concentration in milligrams per cubic meter.

When we divide 2.2 milligrams by two cubic meters, the result is 1.1 milligrams per cubic meter.

Given that every $1000\text{mg}/\text{m}^3$ equals one ppm, we must determine the $1.1\text{mg}/\text{m}^3$ value in ppm.

Perform the mathematical operation of cross multiplication. 1.1 times 10 to the power of negative three parts per million (ppm)

Convert parts per million (ppm) to percentage (%).

Perform a division operation by dividing the computed parts per million (ppm) value by 10,000.

We get a value of 1.1×10^{-7} percent.

Workers may get the Occupational Exposure Limit (OEL) figures from the safety data sheet. Providing a safety data sheet is often the responsibility of the vendor who sells the material.

Furthermore, there are specific categories of health dangers in addition to those already stated. Radiation refers to energy emission as electromagnetic waves or moving subatomic particles, such as alpha or beta particles. Thermal exposure refers to the process of being exposed to heat or extreme temperatures.

Radiation: Electromagnetic radiation is a type of energy released by the sun or by industrial sources. It kills cells, producing a variety of ailments ranging from eye damage to skin cancer. Ionizing radiation is a term used to describe harmful radiation. As previously stated, the damage inflicted is proportional to the dosage. Sunburn is the most prevalent radiation-related injury. When working outside, workers are urged to use safety equipment. It is also strongly advised

to only work in the sun for a brief length of time. The symptoms may not appear immediately after the exposure. As a result, workers are only aware of the impact when discomfort occurs the following day or earlier.

Thermal exposure: Millions of people are subjected to heat during work. Although occupational heat exposure may be avoided, thousands of people fall ill each year, and some instances are fatal. Most outdoor deaths, 50% to 70%, occur during the first few days of working in warm or hot situations because the body must progressively tolerate the heat over time. Heat acclimation is the process of developing tolerance. Lack of acclimation is a significant risk factor for catastrophic results.

Heavy physical activity, warm or hot climatic circumstances, a lack of acclimatization, and wearing clothes that retain body heat are all occupational risk factors for heat sickness. (See also below for personal risk factors.)

If the circumstances are correct, dangerous heat exposure may occur inside or outdoors at any time of year, not only during heat waves. The following industries have seen workers suffer from heat-related ailments.

Heat dissipation is the process by which the human body controls itself in hot conditions, mainly while physically engaged, to expel excess heat and maintain body temperature. Sweating and increased blood flow to the skin naturally dissipate heat. Workers will cool down faster if the environmental heat and physical exertion are minimized.

Assume that heat dissipation only occurs later. In such instances, the worker's internal body temperature rises, and they may feel symptoms such as thirst, irritation, rash, cramps, heat exhaustion, or heat stroke.

The most severe heat-related sickness is heat stroke. Heat stroke causes mental dysfunction in workers, such as unconsciousness, bewilderment, disorientation, or slurred speech.

Workers may suffer from two types of heat-related diseases during heat waves. "Heat illness" is caused mainly by exertion (metabolic heat created by muscular movement in the body). On the other hand, "environmental heat illness" is caused solely by ambient circumstances such as heat and relative humidity and is linked to heat waves and mortality in the elderly, urban heat islands, and overheated motor vehicles (Buchanan, 2002). Occupational Safety and Health Administration (osha.gov): Heat - Overview: Working in Outdoor and Indoor Heat Environments

Heavy metals: Heavy metals are long-lasting elements that may harm both the environment and human health. These dangerous substances are the consequence of human activities. Heavy metals are elements having a high atomic weight or density. Examples include platinum, silver, arsenic, zinc, mercury, nickel, chromium, cadmium, and other heavy metals (Heavy Metals,

2024). Heavy metals such as lead, cadmium, arsenic, and mercury, according to Chaudhry et al., represent a high risk of gestational hypertension and preeclampsia in pregnant women and newborn babies (Chaudhry et al., 2020). These heavy metals cause oxidative stress by either producing oxygen species or interacting with the antioxidant enzyme superoxide dismutase (SOD) and lowering its concentration. Manganese, via its antioxidant capacity MnSOD, needs an optimal quantity of SOD to minimize the risk of preeclampsia. Experimental investigations have indicated that women with preeclampsia had lower levels of SOD in their blood than healthy pregnant women.

Because of its widespread usage, lead is one of the most toxic heavy metals. The widespread use of lead in industry and industrial products raises severe concerns about its adverse impact on health. According to the World Health Organization, the primary sources of lead include the earth's crust, mining, pigments, paints, solder, batteries, ceramics, and glassware. Children are exposed to lead due to their interest in breathing and ingesting lead materials. Adults are also impacted by lead exposure. Lead is a persistent toxin that may induce hypertension and cardiovascular disease (Lead Poisoning, 2023).

On the other hand, Mercury is a poisonous metal, and exposure to its vapor may result in serious health concerns, including damage to the neurological system, kidneys, liver, and immune system. Mercury is also detected in fish due to high pollution in the water body. Pregnant women are at greater risk of mercury exposure owing to ingesting significant quantities of contaminated fish items.

The current research is noteworthy because it tackles a critical public health issue: the harmful effect of harmful material usage on the environment and public health. Understanding the impact of hazardous substances on health is crucial for establishing effective preventative and intervention measures, provided by the extensive usage of toxic substances at home or workplace. This research will add to the current body of knowledge by investigating the moderating variables that may influence the association between awareness and public health outcomes. It will also shed light on the possible advantages and hazards of chemical usage for users and help inspire evidence-based recommendations for encouraging healthy and preventive programs. Using program audit measures with periodic training, which limits causal exposure to toxic substances, is challenging.

For instance, the importance of the thesis on "Pollution Chemistry and Preventive Methods" may be as follows:

- Chemical Hazard Programs can potentially change the welfare of businesses by improving healthy environmental conditions, reducing chemical-related incidents, and preventing loss prevention outcomes, thanks to the rising availability of plentiful resources and the development of robust safety data sheets. As a result, this thesis may help improve knowledge of how chemical hazard programs can be used in the

workplace and houses to increase knowledge and how they can benefit from training and monitoring.

- Chemical Hazard Programs also pose ethical and societal considerations, such as worries about privacy, algorithm bias, and the influence on associated chemical programs of industries. The thesis may give insights into the possible hazards and advantages of Chemical Hazard Programs and impact policy choices by studying these concerns.

Finally, the thesis may contribute to advancing chemical awareness programs by creating new strategies or methodologies that can be applied to chemical hazard data, which can have broader applicability in other sectors or disciplines of study.

Chapter V

Review of the Literature

1. Introduction

The Industrial Revolution witnessed a marked shift in the nature of work, characterized by the transition to large-scale industrial manufacturing. However, with the socioeconomic changes came an increased reliance on artificial materials and energy. This period of metamorphism ultimately resulted in significant pollution of both our air and waterways. Samuel Taylor Coleridge's "Kubla Khan" provides one of the earlier and romanticized descriptions of the effects of early industrialization. The famous lines 'tumultuous privacy of storm' are seen by many as a direct reference to the emerging pollution. Calveley states that Coleridge was a "pantheist" and that the pollution was threatening yet the poet could still see the beauty of nature unlike the damage Arkwright had done. An ever-increasing population which required an alimentary and sustained agricultural yield was partly managed through the increasing discoveries in chemistry. The chemist, James Muspratt, in the late 1820s, documented and visited the manufacturing chemists who were eager to speak to the lead figure of the industry at the time, Charles Tennant. Tennant was a massive manufacturer of alkali but what Muspratt would have been confronted with when he came to visit the works near Glasgow was the vast causticity of the atmosphere, damaged land and large walled courtyards to shield hazardous tank processes. Alkali manufacture was known as one of the 'big three' industrial polluters and Tennant's entrance into this field helped to develop the chemical industry as a whole. He inherited a small Bleachworks which only had around twenty workers but when he died in 1840 he was head of probably the largest chemical manufacturing establishment in the whole of Britain. (Ukaogo et al.2020)

2. Early Instances of Chemical Pollution

The Industrial Revolution witnessed a marked shift in the nature of work, characterized by the transition to large-scale industrial manufacturing. However, with the socioeconomic changes came an increased reliance on artificial materials and energy. This period of metamorphism ultimately resulted in significant pollution of both our air and waterways. Samuel Taylor Coleridge's "Kubla Khan" provides one of the earlier and romanticized descriptions of the effects of early industrialization. The famous lines 'tumultuous privacy of storm' are seen by many as a direct reference to the emerging pollution. Calveley states that Coleridge was a "pantheist" and that the pollution was threatening yet the poet could still see the beauty of nature unlike the damage Arkwright had done. An ever-increasing population which required an alimentary and sustained agricultural yield was partly managed through the increasing discoveries in chemistry. The chemist, James Muspratt, in the late 1820s, documented and visited the manufacturing chemists who were eager to speak to the lead figure of the industry at the time, Charles Tennant. Tennant was a massive manufacturer of alkali but what Muspratt would have been confronted with when he came to visit the works near Glasgow was the vast causticity of the atmosphere, damaged land and large walled courtyards to shield hazardous

tank processes. Alkali manufacture was known as one of the 'big three' industrial polluters and Tennant's entrance into this field helped to develop the chemical industry as a whole. He inherited a small Bleachworks which only had around twenty workers but when he died in 1840 he was head of probably the largest chemical manufacturing establishment in the whole of Britain. (Ukaogo et al.2020)

The Industrial Revolution began in Britain in the late 18th century and was soon felt in other countries. The revolution introduced major changes in technology, manufacturing, and transportation, which had a profound effect on the environment, especially on air and water pollution. Under the domestic or putting-out system, merchants took raw material to workers' homes, where they made the product. In and around the great cities of that time, workers toiled in the new factories that arose to take advantage of the revolution's technological advances. And eventually, these workers began to live in the cities. These newcomers to the cities could now find houses that were reasonably near their workplace and they took the jobs in the factories. With the increase in factories and urban growth, people also began to notice more pollution. Coal was the major source of power for the factories in the 19th century. With its increasing use, especially in Great Britain, there was an intensifying effect on the environment. Because the coal was so readily available, and it was a major power source, factories could be set up anywhere, not just near water. By the mid-19th century, Britain was the "workshop of the world". As supplies of raw material and labor became exhausted and too expensive in Britain, manufacturers replaced the domestic system with the factory system that produced goods for a mass market. This new system brought high-paid jobs for skilled workers and low-paid jobs for unskilled or semi-skilled labor. This revolution, which involved going from many people making goods by hands to making goods in the factories by machines, is often periodized into two distinct parts. And today historians refer to the period that preceded the revolution as the Pre-Industrial time. The Pre-Industrial period is marked by a relatively slow pace of technological advancement. For instance, a key invention that played a big part in the revolution, the smelting of iron with coke, did not take place until the early 18th century. The revolution itself is generally regarded as having begun in Britain in the late 18th century and lasted until the mid-19th century. This period brought about significant changes, including the use of steam power, the upheaval of traditional work practices, and a growth in prosperity for many but social problems too. (Stearns, 2020)

2.2. First Recorded Cases of Chemical Pollution

So, the modern legal understanding of pollution goes back to the Rivers Act 1951 and even though, as stated above, it was often criticized and held at fault during the 1980s, the 1989 Act had not improved anything either. (Wu et al., 2020)

The Act had no basis for taking into account the changing water quality and environmental standards up to 20 years from the designation of a controlled area as a water prevention zone. This act was widely criticized by key political figures and environmental groups including Friends of the Earth. This piece of legislation was amended by the 2008 CPIA and it brought into force amendments to the powers for companies to enter private land for the removal of

hazardous substances and extension of water works licenses. The act created a new civil offense of discharging poisonous, noxious, and polluting substances to the detriment of vegetation, fish, reptiles, mollusks, etc. In lieu of that, they also amassed a new offense of possession with the intent to unlawfully dispose of waste. Also, measures to prevent damage to controlled waters due to mining activities were put into place.(Wade, 2020)

The next were the British Parliament's Alkali Acts, the first one in 1863 and then another in 1874 that was concerned with the deleterious effects on the River Mersey caused by the manufacture of alkalis in St. Helens. The other major piece of legislation was the Public Health Act of 1875 which extended the powers of the local authorities to deal with river pollution. Then the Rivers Act 1951 and again in 1961 all the maximum allowable pollution levels were based on whether they were harmful to fish life and water was legislated for in this manner until the implementation of the 1989 Water Act which was based on the ECE River Basin Directive.(REED2023)

There are many written records of early chemical catastrophes. The first recorded event occurred in 1419 in the Spanish town of Alcara. A multitude of people who drank from a local river experienced vomiting, diarrhea, and many developed jaundice. The cause and origin of the condition were not known until eleven years later when a local goldsmith released small amounts of mercury and it flowed into the river. The physicians at the time quickly deduced that the mercury was the likely cause of the mysterious illness. This was widely known as the first recorded case of chemical poisoning in human history.(García-Galán et al.2020)

2.3 Consequences of Early Chemical Pollution

Additionally, it is apparent that early chemical pollution has led to certain severe consequences. For example, the pollution of water sources by the leather tanning industry during the 18th century led to widespread water contamination. This resulted in regular outbreaks of diseases such as typhoid, cholera, and dysentery. The victims of these diseases were mainly the poorer people in society who lived under unsanitary conditions. The effects of chemical and radioactive pollution persist for many generations in several cases. For example, the 1986 explosion at the Chernobyl nuclear power plant in Ukraine released large amounts of radiation as a consequent radioactive pollution which caused genetic mutations in an expanding number of humans, animals, and plants over time. As another example, the acute environmental contamination by the insecticide dichlorodiphenyltrichloroethane (DDT) after World War II led to the near extinction of the bald eagle in the lower 48 states. Such severe consequences indicate that the historical cases of chemical pollution have contributed to the shaping of various laws and regulations that regulate the use and disposal of chemicals nowadays. This point is also significant in terms of raising public awareness of the potential harms associated with hazardous chemical substances. Chemical and radioactive pollution can induce various types of cancers, asymptomatic non-fatal diseases (e.g., liver disease, renal failure), and fatal diseases (e.g., asbestosis, lung cancer). It can affect the nervous system, endocrine system, and reproductive system as well. It can cause harm to fetuses in the womb and children who are going through development. It not only can cause genetic mutations but also has a lasting negative impact on

future generations. Therefore, people should take an active role in advocating proper ways of chemical disposal and pressure relevant authorities to monitor industries and enforce related laws and regulations successfully. Public awareness should be raised through, for example, general education, mandatory high school chemistry disciplinary, and press media. (Whelan et al.2022)

3. Modern Developments in Chemical Pollution

Meanwhile, the United Nations is working with countries to create a global pact which will target a phasing out of dangerous substances, fully applying new and safer alternatives and fostering cooperation on chemical safety around the world. This agreement is hoped to create a world where by 2020, chemicals are produced and used in ways that minimise significant adverse impacts to the environment and health. Create new employment while enabling green and sustainable development and it would be openly and transparently promote the development and diffusion of environmentally friendly clean technologies. (Mingst et al., 2022)

On the other hand, the modern era has also seen health issues caused by chemical pollution escalate in severity, owing to a combination of previous exposure to well-known synthetic chemicals and the emergence of newly developed ones. According to the World Health Organization, a significant percentage of the global burden of disease is due to modifiable environmental factors - of which chemical pollution is a major constituent. The use of innovative, environmental DNA method has allowed scientists to estimate the populations of organisms in a particular area via the extraction of DNA from soil and the environment. This has led to the identification of indicators of ecological health; researchers are now able to connect species declines and their interaction with chemical pollution to assess environmental damage on a genetic level. (Manisalidis et al.2020)

In the last 50 years, the impact of chemical pollution on the environment has led to the formation of an independent environment protection industry and new ideas on how to monitor and prevent pollution. The environment protection industry, which includes ecological consultants and flood and pollution control, is now a major source of employment. Ways of monitoring pollution, such as measuring nutrient levels in water or tracking the movement of pollutants in soils, have been developed by scientists in order to effect better prevention strategies. A more recent, technological approach to pollution prevention methods is the use of remote sensing technologies, which enable the monitoring of large areas of land at the same time and improve risk estimation. Through the Remote Sensing and Pollution Control Project, specialists are able to research and apply these new technologies to areas like pest and root interactivity in soil - a highly specific, exact way of detecting and preventing pollution. Also, teams of international scientists have worked on developing sensors that can track chemicals and their movements through the environment. This will lead to a faster and more accurate response to matters of pollution. (Lohmann et al.2020)

The modern era has seen the rapid increase of synthetic chemicals, both in industry and in the laboratory. Before 1945, there were only around 1 million tonnes of synthetic chemicals

produced each year. By the mid-1990s, this had jumped to over 1 billion tonnes per year. Many of these chemicals, such as the pesticide DDT, have had a large impact on the environment and human health. DDT was banned in the United States in 1972 after a study by the Environmental Protection Agency linked it to declining eagle populations. However, because it binds to organic matter, it can linger in soil for years and has caused major environmental damage. Many thousands of synthetic chemicals in regular use have never been tested for their effects on the environment or human health because the majority have been developed since the environmental movement of the 1970s and workplaces have only recently been seen as potentially hazardous. (Okoffo et al.2021)

3.1. Rise of Synthetic Chemicals

Nowadays, the synthetic chemical industry is global, and billions of metric tonnes of chemicals are produced each year. The move to more complex molecules and materials continues apace, and this can be seen in the importance of synthetic chemicals, such as conducting polymers, in the development of new technologies for the 21st century, including light-emitting diodes, solar panels, and 'smart' materials. (Geyer, 2020)

By the beginning of the Second World War, the manufacture of plastics and the new chemical techniques and facilities developed in support of the war helped to continue to drive forward the revolution in synthetic chemicals. For example, by 1940, plastics had become the largest user of benzene - a chemical adaptogen used in the synthesis of drugs, dyes, and numerous other organic chemicals. (St2020)

One of the most famous examples of the success of synthetic dyes is the accidental discovery of mauve dye. In 1856, the British chemist William Perkin was attempting to create a synthetic quinine to treat malaria but obtained instead a sticky mass colored in a bright purple. He patented the process, and mauve dye rapidly became extremely popular, leading to Perkin making a large amount of money and pioneering the synthetic chemical revolution. (Dave et al.2022)

In the 1920s, the German chemical industry was the world leader in the development and manufacture of synthetic dyes for cloth, and most of the new synthetic chemicals at that time were pigment dyes. The popularity of synthetic dyes compared to natural dyes had arisen because, by using a range of synthetic chemicals and different chemical processes, many new and vibrant colors could be created that were either not possible with natural dyes or required additional and expensive steps, such as the use of mordants to help the dye 'fix' to the fabric and become light- or water-fast. (Stoff2021)

3.2. Impact of Chemicals on the Environment

The environment is considerably damaged by chemical pollution. Most traditional chemical pollutants, such as chemical discharges and nutrient pollution, pose a risk to aquatic and terrestrial ecosystems. Synthetic chemicals have had a particularly noticeable effect; the most well-known group of synthetic chemicals, Persistent Organic Pollutants (POPs), are of primary

concern. They are toxic to the environment, and many have the ability to bioaccumulate in food chains. Organochlorine pesticides, such as DDT, were widely used from the 1950s onwards in the United Kingdom; due to their long breakdown times, they are still periodically recorded in the environment today. Aquatic life, from fish to invertebrates, is regularly affected by chemical pollution; acute cases can result in death, whereas low-level exposure over time can lead to reproductive issues or chronic, long-term damage. In 2016, approximately 40% of water bodies in the UK failed to meet EU 'good ecological status' criteria; one of the principal reasons was chemical pollution, especially from persistent chemicals such as POPs. The introduction of many synthetic chemicals began during and after the Second World War, as technology and innovation accelerated, and the demand for new, long-lasting and highly effective products grew. Modern lifestyles revolve around the use of these chemicals: they are found in manufactured items and essential products, from food storage containers and cleaning fluids to pharmaceuticals and pesticides. Many thousands of synthetic chemicals are now commercially available, with up to 1,500 new chemicals being registered for production and use on the European market every year. During the last 70 years, over 100,000 different chemicals have been registered for production and use in the UK; approximately 18,000 are used on a larger, industrial scale. The improvement of chemical pollution in the environment is a global issue and one which is important not only for human health and wellbeing, but also for the protection of the environment and ecological systems. It is well recognized that the pollution of habitats, particularly with chemical pesticides, poses a threat to the survival and reproduction of wildlife and thereby impacts upon biodiversity. The loss of biodiversity and the destruction of healthy ecosystems may negatively impact nature's services to humanity, such as the regulation of the atmosphere, climate control, water purification, and pollination. (Posthuma et al.2020)

The expansion of the chemical industry in the 20th century and the resulting exponential increase in the amount of synthetic chemicals produced have made it possible for humans to develop products, such as pesticides, plastics, and pharmaceuticals, which have greatly improved the quality of our lives. However, the manufacture, use, and disposal of these synthetic chemicals have led to the contamination of our environment and wildlife by long-lasting toxic substances, such as heavy metals, polychlorinated biphenyls (PCBs), and more recently, perfluorinated chemicals (PFCs). (Tudi et al.2021)

4. Globally Harmonized System and OSHA

One of the most crucial abilities in Chemical Hazard Awareness Programs is training. They encounter several terminology challenges when they are well-trained on chemical hazards. Learners struggle with explaining the meanings of hazard signs and symbols because schools and educational organizations greatly emphasize teaching science and other subjects. Many course manuals do not describe the impact of chemicals on the environment or human health, and most professors do not emphasize this crucial ability in their lectures.

President of the United States of America, Nixon, established the Environment Protection Administration (EPA) in 1970 to respond to the labyrinth of perplexing and frequently

ineffectual environmental protection laws enacted by states and municipalities (*Britannica Academic*, n.d.)

The EPA is tasked with establishing and monitoring national guidelines and enforcing them. The new agency assumed the responsibilities formerly held by the Interior, Agriculture, Health, Education, and Welfare and other federal entities. The Environmental Protection Agency (EPA) was initially entrusted with the implementation of three acts: the Clean Air Act (1970), which was primarily implemented to reduce air pollution caused by industries and motor vehicles; the Clean Water Act (1972), which regulated the discharge of industrial and municipal wastewater; and the Clean Air Act (1970), which provided financial assistance for the construction of sewage treatment facilities. The Environmental Protection Agency (EPA) enforced twelve main statutes by the mid-1990s, including regulations concerning uranium mill residues, ocean pollution, safe drinking water, insecticides, fungicides, rodenticides, and school asbestos hazards.

The Globally Harmonized System of Categorization and Labeling of Chemicals (GHS) is an internationally recognized standard overseen by the United Nations. It was established to replace the several hazardous substance categorization and labeling systems that were previously used worldwide. The fundamental components of the GHS consist of established criteria for testing hazards, universally recognized warning pictograms, and safety data sheets that provide consumers of hazardous substances with consistent and organized information. The system serves as a supplementary component to the UN numbered system for the controlled transportation of hazardous materials. The UN Secretariat oversees the management of implementation. By 2017, the adoption of the system has been implemented to a large degree in the majority of significant nations worldwide (*Globally et al. of Classification and Labelling of Chemicals*, 2024)

The Occupational Safety and Health Administration (OSHA) is a public health department under the U.S. Department of Labor. Established in 1970 under the Occupational Safety and Health Act, OSHA's responsibility is to guarantee that businesses provide their workers with a work environment without known health and safety risks.

OSHA has established precise occupational safety and health standards that companies must adhere to. These guidelines include ensuring employee safety via fall protection, preventing exposure to contagious illnesses and dangerous substances, and supplying safety equipment like respirators. OSHA expands rules, conducts investigations and inspections of workplaces, and imposes tickets and penalties for failure to comply. OSHA offers a whistle-blower program to safeguard workers who report concerns about hazardous or unhealthy work environments from facing reprisals by their employers. The administration of OSHA is under the purview of the Assistant Secretary of Labor for Occupational Safety and Health (*Britannica et al.*).

The primary purpose of the Occupational Safety and Health Administration (OSHA) is to ensure the safety of individuals in the workplace. One does not anticipate sustaining injuries in

the workplace. Nevertheless, several individuals were harmed and perished as a result of the ammonium nitrate explosion, an incident that could have been prevented.

The ongoing discussion revolves around the question of whether OSHA is effective. OSHA standards have significantly reduced the incidence of employee fatalities, injuries, and diseases. OSHA is an essential need in the workplace. The establishment of OSHA directly reacted to enacting the Occupational Safety and Health Act of 1970. In 1968, President Lyndon B. Johnson received encouragement to formulate legislation focused on enhancing worker safety. President Johnson proposed a concept enabling the Labor Department to inspect firms for potentially dangerous environments. President Richard Nixon enacted the measure on December 29, 1970, establishing the History and Mission of OSHA.

OSHA aims to mitigate excessive workplace injuries, illnesses, and fatalities. Their primary purpose is to keep their staff safe. By using this approach, OSHA can potentially decrease the expenses associated with workers' compensation insurance. Additional advantages include reduced healthcare costs, diminished product losses, and heightened Efficiency.

OSHA mandates employers to provide secure working environments to safeguard their employees throughout their work duties. Employers are obligated to acknowledge and adhere to the regulations that pertain to the workplace, ensuring that their staff use safety protection equipment. Essential tools for firms to implement safety programs include accident investigation, emergency preparation, record keeping, and safety inspections. Employers are obligated to fulfill particular duties as outlined by OSHA. Additional crucial tasks are adhering to OSHA standards, monitoring working conditions, using safety equipment effectively, and recognizing hazards using signs, labels, and color codes. They also have to record injuries and report significant accidents or hospitalizations.

Employers prefer implementing safety training programs rather than complying with government-imposed safety rules. Employers can establish more tailored laws for their workers, addressing their desires and requirements in the workplace, as opposed to the broad guidelines established by OSHA.

Although precise rules bind OSHA, there are instances when these laws may legitimately demand modification based on the circumstances.

OSHA is a crucial instrument in the workplace, effectively reducing the incidence of worker deaths, injuries, and illnesses. Since 1970, occupational deaths have fallen by over sixty percent, while accidents and illnesses have declined by at least forty percent (Shuput). Both injuries and sickness significantly impact a company's profitability. The firm must cover workers' compensation and medical expenses if an employee sustains an injury. Additional costs may include training newly hired staff, the loss of productive hours, and restoring impaired equipment (Business Case for Safety and Health).

Every corporation functions with the primary goal of earning profit. However, when an employee gets into an accident, the accompanying expenditures may pile up quickly, limiting the company's potential to create Money.

My interest is sparked by the fact that companies seek advice from the Occupational Safety and Health Administration (OSHA) in order to obtain the right procedures for chemical hazards and occupational exposures when it comes to analyzing unknown unsafe scenarios. This has peaked my attention. The Occupational Safety and Health Administration (OSHA) is responsible for providing training on safety and establishing severe laws that businesses are required to adhere to in order to ensure the safety of their employees. The thing that worries me is that there aren't any organizations like OSHA in poor countries. People working together with a willing government can make a strong policy that meets world standards. OSHA must complete the examination within thirty days from the stated time. During the inspection, OSHA must solely focus on the issues raised by the workers in their complaints. Nevertheless, they can impose sanctions for any further violations they detect during inspection (Chambers). Employees must familiarize themselves with the working environment and comprehend the protocols for reporting dangerous situations. If employers strictly adhere to safety standards and workers fully comply, the workplace will remain a secure and safe environment. Suppose an employer fails to recognize or resolve a deficit. In that case, it is the responsibility of one of the workers to be ready to file a complaint to correct the problem. The synergy between employers and workers is crucial for achieving success.

Ensuring the well-being of employees should be a paramount priority for employers; if not, OSHA will use its authority to enforce necessary modifications. For OSHA to be effective, all personnel must have the necessary attitude inside the workplace. Employers and workers should be open to improving existing safety measures. Although change may be challenging, it is often necessary and widely acknowledged. As per the Fire Protection Law, firms must have readily available fire extinguishers that are suitable for use by workers (portable fire extinguishers). Ensuring the safety of their employees allows organizations to save on expenses associated with worker's compensation and medical costs. Employees may improve their working conditions by calling OSHA and requesting an inspection if they believe the workplace is hazardous. As tedious, irritating, and time-consuming as the standards are, we must remember why they exist and how safety must be the employer's priority. Everyone inside the organization must have a constructive mindset and a receptive approach toward the dynamic OSHA regulations. This will contribute to their safety and help prevent any injuries in the future. If the employer and workers agree to work together as a unified team, OSHA will likely be effective. Although it could be pricy sometimes, can we genuinely prioritize safety?

Evidence that some components were "incongruous." In France, throughout the Middle Ages and early Modern period, similar to other European countries, there was a deliberate effort to

remove dirt and move activities that generated it to the outside of cities. As the 18th century drew to a close, the use of industry by governments began to transform. The advent of the modern chemical industry coincided with the introduction of novel types of pollution. Nevertheless, pollution underwent significant transformations in the 20th century. It expanded its reach to become a worldwide issue, affecting every corner of the Earth. Furthermore, it became more severe, releasing more harmful substances into the biosphere. Lastly, it became more enduring, leading to catastrophic and cumulative effects.

4.1 Health Effects of Chemical Pollution

The issue of pollution is longstanding. Toxic waste has been a persistent problem since the emergence of our earliest ancestors. The proliferation of the human population has led to a corresponding rise in the prevalence of pathogens and illnesses. The illness spread over Europe during the sixteenth century due to the spread of bacterial diseases. The direct causes of these illnesses were garbage, manure from both humans and animals, and unhygienic surroundings. The bacteria *Yersinia pestis*, which was spread by rats and carried by fleas, was responsible for the outbreak of the bubonic plague pandemic, often referred to as the "Black Death," in the year 1347. An antagonistic environment facilitated the optimal conditions for the rapid growth of the lethal bacteria (*A Brief History of Pollution*, n.d.).

Steven Cohen states that most environmental issues are readily apparent, and there is a greater level of agreement than one would anticipate on maintaining the purity of our air, water, and land by avoiding toxins. While we acknowledge the existence of an issue, our opinions on the appropriate remedy may differ (Cohen, 2022).

Environmental Concerns are growing over time. This is because individuals grow more fretful about their health. The rise of new viruses and changes in the climate have pushed people to come up with solid answers to environmental issues. The environment is not the most essential thing in poor countries. The need for people to meet their basic needs takes precedence over the lack of funds to develop new ways to deal with environmental problems. In developed nations, the environment is a primary focus of society. Wealthy governments allocate substantial funds towards addressing environmental challenges, resulting in populations adopting stringent hygiene standards.

Environmentalists provide some suggestions for preserving the environment. These recommendations might include birth control, conservation of environmental resources, limiting the adverse effects of contemporary technology, and implementing ecologically friendly governmental and economic structures (Environmentalism et al.). It is evident that the majority of significant events seldom ever address educating the public about pollution or providing training in this area. It is time to create efficient programs that serve the community's need to learn about pollution control.

Despite the efforts to address environmental concerns and the endeavors of both governmental and non-governmental organizations to raise awareness about pollution caused by human

activities, the condition of our Earth's ecosystem continues to deteriorate. The primary emphasis of environmental solutions is on the effective management of trash, which involves recycling, reusing, and appropriately disposing of garbage via methods such as dumping and incineration. Nevertheless, the efforts to educate and train individuals remain inadequate. I believe fostering a shared understanding of the perils posed by pollution is paramount in preventing the devastation of our planet's ecology, upon which our existence depends. Utilize this definitive discovery to develop novel and efficient methods for disseminating accurate information to each member of society. Firstly, it is essential to prioritize the environment in the media and present it as a prominent topic to foster a culture dedicated to preserving the cleanliness of its surroundings. Second, studying the environment is a separate topic in schools, similar to other scientific courses. Third, efforts by municipalities to build environmental safety training facilities for the general public. Just as crucial as creating protective gear and lessening the effects of pollution is offering chances for environmental education and making it available to everyone.

Living comfortably in big cities is made possible by improving health conditions via hygiene regulations. By 1950, thirty percent were city dwellers. The percentage increased to 54% in 2014, and it is anticipated that by 2050, it will reach 70% (Stahl, 2015). The growing population needs more focus and effort to create effective pollution protection initiatives. If not, adverse effects will depress the economy and disrupt community stability.

Individuals moved from remote villages to cities due to the expansion of the industrial and economic sectors and the rise in job prospects. Some individuals lived in impoverished areas without access to essential utilities and land protection. However, wealthy cities have several well-kept neighborhoods that draw the majority of the wealthy to reside there. Above all, pollution has no bounds and cannot be isolated. A region that is contaminated will impact another. Furthermore, at some point, regional pollution may add to the overall pollution of the globe. This will allow us to begin developing robust educational chemical hazard safety awareness initiatives for each member of society. Training should not end; it should be organized routinely and consistently.

Finally, the health effects of chemical pollution are examined. This includes the impact of acute chemical incidents such as the Minamata disease and the more widespread, chronic health impacts of chemical pollution. It is noted that there is a bigger potential for widespread suffering in the case of ongoing chemical environmental destruction. It is observed that people living in close proximity to areas suffering from chemical pollution can experience very noticeable signs of illness. Sore throats, skin irritation, and breathing problems are often cited, as well as chronic conditions like impaired bodily function and even the development of cancer in the long term. Long-term chemical toxicity has been seen in cases such as 'itai-itai' disease in Japan, with harmful heavy metals like cadmium daily ingested in contaminated rice fields. Also, the chemicals can interfere with natural processes inside the body. For example, nerve gas agents like the internationally banned sarin gas have been used in terrorist attacks such as the Tokyo subway attack in 1995, targeting where there are large amounts of people. These agents operate

on the principle of preventing the breakdown of a key neurotransmitter; the human body can't 'switch off' the flight or fight response - uncontrollable muscle twitching and asphyxiation can result. Recently, there has been more concern for how everyday chemicals may disrupt natural hormones in the body. Products like atrazine, a common herbicide used in the US, and certain types of plasticisers have come under scrutiny for their roles in the increase of hormone-related cancers such as breast and prostate cancer. This area is still under investigation, and many chemicals have not been thoroughly investigated for their potential to cause such harm. With new chemical contaminants being discovered in water supplies and in the environment, it is vital that global environmental health is taken seriously in the form of ongoing monitoring and regulation. Also, the learning of the history behind chemical disasters can give insight into preventing them in the future. Research and expertise will be needed to fill these knowledge gaps in society, and working in the field of chemical pollution offers an exciting challenge to scientists. It is an interdisciplinary field and underpins the work of many global environmental health projects and non-governmental organizations. By increasing our understanding of the health impacts of environmental damage, we can make strides in the change towards a safer and more sustainable future for the world. Such a future is hoped to be free from the health issues caused by chemical pollution so far studied in this section of the essay. (Hamada & Osame)

5. Risk Management

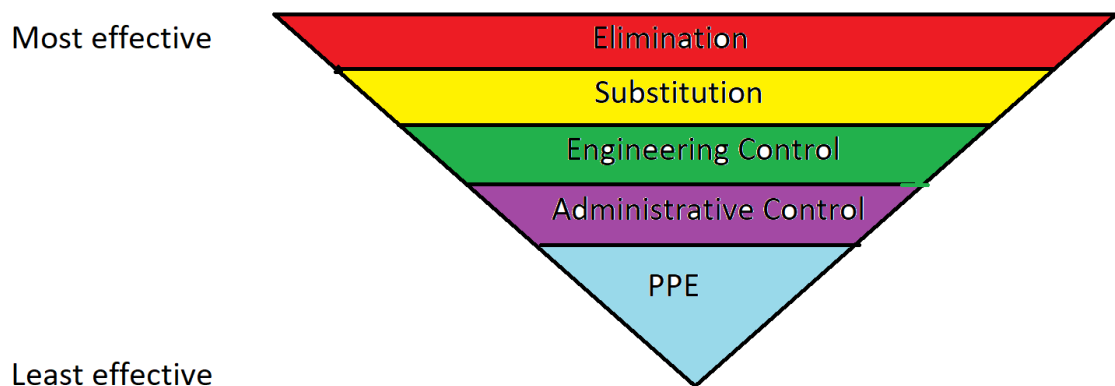
Laboratories and research institutes are two critical components of manufacturing. They play a significant role in determining the legitimacy of the process and producing new materials with improved qualities. Chemical consumption is a critical variable that prompts managers to install protective equipment that may limit workshop exposure. According to Fatima et al., using chemicals in labs creates environmental dangers that must be evaluated, controlled, and risk reduced.

Within this context, workshop monitors diligently focus on mitigating risk factors and identifying alternate approaches that have little influence on health. When examining the risk management hierarchy, it becomes evident that training significantly teaches individuals about safety.

The first step in risk management is eliminating hazardous subjects or materials from the workplace. Risk is the potential for loss, harm, or adverse consequences arising from an action or decision. Swimming in a lake inhabited by alligators poses a significant chance of being attacked by these creatures, making the lake a hazardous location for swimming. We must remove the crocodile population from the lake to ensure the area's safety. If we must eliminate a hazardous subject, we must develop something else to do the same job. This is called substitution. Another crucial aspect is to seek the expertise of experts who can create proficient designs for safeguarding the space from inhaling risks, gas leaks, and fire accidents. After securing the first two controls, the administrator becomes crucial for motivating people to adhere to safety rules by making periodic training, refresher courses, and incentives. Several fatal incidents have occurred at power plants when personnel attempt to address engine issues

without obtaining proper work permits for maintenance. The last line of protection is the use of personal protective equipment. Workers must possess knowledge of the specific equipment required for each chemical category, which may be acquired via comprehensive training. Training alone is not sufficient. The safety program should be a collection of complimentary features administered by the safety coordinator and supported by higher management in all areas.

Hierarchy of control of risk management:



In eighteenth century, people grew aware of the role of unsanitary living conditions and polluted water in contributing to disease epidemics. Major cities implemented waste and garbage management rules in response to this heightened awareness. In the mid-1850s, Disposing of trash in aquatic ecosystems leads to the spread of illnesses. Cholera is an instance of a disease that spreads along a watercourse polluted with sewage.

In my opinion, providing education to individuals on the detrimental effects of disposing rubbish in rivers and streams is a more cost-effective approach compared to the expenses incurred in cleaning up water contaminated by waste. According to Amerisafe, the cost of training an individual is nine dollars to forty dollars per hour depending on company's size (2022). Amerisafe reports that the precise cost incurred directly from occupational accidents amounts to around \$41,000. The demise of a worker as a result of a chemical mishap is a significant detriment to the organization from several perspectives. What is the expense incurred by the organization for employee development throughout their tenure? What amount of compensation will be provided for the cause of his death? Excluding the detrimental impact of the company's poor reputation on its performance. The objective of training is twofold: to minimize workplace deaths and to demonstrate the company's adherence to the regulations and standards established by international organizations. This undoubtedly elevated the company's repute over that of other firms. Allocating funding for the synthesis of environmentally friendly compounds is crucial in this particular domain. Companies are now substituting phosphates in

detergents with compounds that are environmentally friendly and aim to minimize eutrophication in water streams.

5.1 Efforts to Mitigate Chemical Pollution

The state of Massachusetts in the United States was the first place on the planet to have a policy regarding chemical pollution, back in 1977. This is an example of what has been a growing quantity of legislation worldwide aimed at tackling this drawback, as governments and world bodies start to recognize the affect that chemical pollution is having on the surroundings and, in turn, human health. One of the most necessary international treaties in current instances has been the UNECE Protocol on PRTRs. PRTR is brief for Pollution Release and Transfer Registers, and these are methods in which the quantities of sure hazardous chemical compounds being released into the atmosphere, water and soil by industrial services are measured and recorded. That is necessary because it allows policymakers, and the public, access to data on the release of these chemical compounds, and to get a better thought of what the impacts could be. The Protocol was signed in May 2003 in Kiev and came into pressure in October 2009. It was described by the then Government within the UK as a "according to the Government's technique for improving public access to environmental info through the internet. (DeMarini, 2020)

5.2 Future Challenges and Solutions

This is due to the fact that many solutions on the market are made with dangerous chemicals that can cause serious harm as well as deplete the ozone layer: lithium hydroxide, which can cause burns to the skin and eyes, indium, which can cause kidney dysfunction and work with the central nervous system, and diethyl zinc, a dangerous flammable. Ergo, the demand for a new and improved pollutant prevention has come to light. Throughout the world, there has been a consistent rise in the levels of pollution of the waters. While rising levels of industrial effluents and poisonous chemicals are the main offenders, many other factors such as improper disposal of waste oils and goods, sewage and waste water, atmosphere fallout, and silt can affect the pollution of the waters as well. (Du et al., 2022)

Most of the waters reported have low density of environmental management and protection, and the major reason for occurrence of high pollution levels of the waters. Sewage and waste waters contain nutrients that encourage the growth of aquatic plants, thus resulting in less oxygen in the water. Anaerobic bacteria that thrive in the absence of oxygen will decompose the organic materials, and in the process release the gases that deplete the oxygen in the water. This scenario will cause the death of the aquatic life due to inadequate oxygen for respiration, and the next problem after the death of the aquatic life will be the introduction of bacteria that decompose the dead materials over time. When the water ecosystem is totally disrupted or to the point of all life forms wiped out, the water is said to be totally polluted and lifeless. This is the definition of 'total pollution'. Concentrated solutions of inorganic salt can damage living organisms by altering the osmotic balance, and this will suppress enzyme and metabolic

activities. Acids can change the acidic character of the receptor water, and bases can change the basic character of the receptor water. Both acids and bases can cause death of the aquatic life and eradicate the natives from the aquatic environment. (Mohd et al.2020)

5.3 Emerging Chemical Pollutants

Given the potential widespread impact of such effects, there is a need for increased monitoring and control of the release of chemical pollutants, to try and stem their rising influence on the environment. A range of water and air purification technologies - from the use of powerful oxidizing agents to environmentally friendly, natural "bio-remediation" techniques - are being studied, and it is hoped that something will prove a suitable, large-scale solution. However, tackling emerging chemical pollution is a multidisciplinary task that requires the combined efforts of researchers, engineers, policymakers, and society as a whole. It is therefore likely that, as these chemicals continue to be developed. (Naidu et al.2021)

The effects of emerging chemical pollutants have begun to be researched, and some worrying findings have been made. For example, some researchers have published evidence that exposure to these chemicals can affect the hormone systems of animals in the environment, including humans. Hormones are the body's chemical messengers and are vital for maintaining lots of complex bodily processes like growth, metabolism, and mood. Even tiny changes to hormone levels caused by chemical pollution can have serious effects, particularly if they occur during important stages of development such as in the womb or in early life. This is known as "endocrine disruption" and has been linked to serious health problems, including birth defects, developmental disorders, and cancer. (Kasonga et al.2021)

In addition, the way we live as a society is changing in ways that could increase the impact of chemical pollution on our health and the health of the environment. For example, the global population is increasing, and there's an increasing trend towards urbanization and the creation of large cities. This puts great pressure on resources and means that more waste is generated, a lot of which contains chemical pollutants like plastics and electronics. The world is also becoming more interconnected and globalized, with more products being traded internationally than ever before. As the demand for quick, seamless manufacturing grows, it's likely that new and existing chemicals will be used unsustainably; for example, large amounts of chemicals being released unintentionally during the manufacturing process.(Saha et al.2021)

The 21st century has seen the rise of so-called "emerging" chemical pollutants. These are chemicals that have only recently become widespread in the environment, and include pharmaceuticals, personal care products like cosmetics, and flame retardants used in furniture. One of the key factors driving the emergence of such pollutants is the sheer number of new synthetic chemicals being developed. Because these chemicals are used in so many different products today, there's an increased likelihood that they will end up in the environment - and, potentially, in our bodies too. (Yu et al.2024)

5.4 Innovations in Pollution Control

The next big landmark is the Clean Air Act of 1963. The Clean Air Act was originally passed in 1963 and is often considered the first truly successful and comprehensive piece of air quality legislation on the ground that it combined air quality and auto which had been in separate legislation in the past. Provisions were added to the original 1963 version in 1966 and significantly expanded in 1970 when concerns turned to the environmental effects of pesticides that were regulated by the act. The government took a large leap forward in combating the crisis of pollution just 11 years after the Clean Air Act was first passed, with the establishment of the Environmental Protection Agency in 1970. This came off the back of months of unruly debate over the legality of creating such an agency and over President Nixon's vision for a reorganized and consolidated federal government. The EPA was given a mandate and legal ability to regulate pollution and protect public health, and it quickly emerged as a force to be reckoned with in the sphere of US federal offices. One of the first things the EPA focused on was monitoring the Clean Air Act; the modern implementation of the law is overseen by the EPA and the act has been amended and expanded many times, most notably in devastating years for air quality such as 1977, 1990 and 1997. The Clean Air Act can be seen as a shining example of the US continuing to address environmental issues as a driving force for new legislation and change. Through the use of a powerful public health law and the adoption of strict regulatory standards by the government and private industry, levels of regulated pollutants, both in the air and public spaces, have fallen significantly. As the need to address newer and emerging issues like climate change and greenhouse gas emissions becomes more into focus, the Clean Air Act and its legislative power I'm sure will continue to be a driving force for meaningful action for a long time. It can also be seen as a real step forward in innovation for environmental law in the US; although there are always going to be setbacks and challenges, the fact that the Clean Air Act has remained a legislative pillar in preventing deadly squalor and world created by pollution and its regulation gives promise for continued change and drive for a better and cleaner environment. (Zhang et al.2022)

5.5 Collaborative Approaches for a Sustainable Future

While regulatory approaches have been successful in reducing chemical pollution and its impacts on health and the environment, these approaches alone may not be enough to transition to safer, more sustainable chemical use and manufacturing. Sustainable chemistry, also known as green chemistry, provides a way to design and make chemicals in a manner that has less or no impact on the environment, and "green" the chemical manufacturing industry by developing and adopting techniques and products that are sustainable. Green chemistry focuses on innovative design processes that minimize the generation of pollution, the use of hazardous substances, and the risk of chemical accidents, with the aim to reduce the environmental and human health impacts of chemical pollution. Over the years, a growing number of scientists and engineers have conducted research aimed at finding innovative, sustainable chemical processes and products. Through these efforts, they also seek to raise public awareness of the benefits of green chemistry and develop support for green chemistry education and technology

transfer. In recent years, chemical research and development has shifted towards the idea that chemicals, whether they are a by-product of industry, used in consumer products, or drug compounds, should be designed so that they have minimal negative impact upon the surrounding environment. As a result, the chemical industry has progressed in developing new technologies and initiatives which support a more sustainable future. For example, the development and use of ultra-high efficiency separation technologies, which are used in the purification of biopharmaceuticals. These technologies have financial benefits for the companies who incorporate them into their manufacturing processes, but they can also have a "greener" advantage: they can dramatically reduce the waste products and the amount of resources required to process a drug. Such technologies are starting to be adopted by the pharmaceutical industry, which has been criticized for being slow to engage with green chemistry. (Chen & Reniers, 2020)

Chapter VI

Pollution in Lebanon

1. Introduction

The estimated pollution from street, construction sites, river and sea boats, and old car emissions, power plants, landfills, and waste compounding the waste. Whether drivers should be subjected to annual emissions tests, plus a yearly vehicle inspection, and whenever using a rental car, be certain the vehicle has a current inspection sticker or face fines. The power plants running on heavy fuel oil or diesel, and kilns and foundries producing cement or lead. Mix this all with the waste left from the civil war in the form of landfills in numerous areas. And to finalize the toxic base of heavy metals compounds embedded in the sediment in rivers and the sea from runoff water. The effects on the population's health, environmental degradation, and economic consequences. The article also suggests solutions to tackle pollution, such as implementing stricter environmental regulations, promoting renewable energy sources, improving waste management practices, and encouraging public awareness and education. (MASRI2021)

1.1. Overview of pollution in Lebanon

Lebanon is a small country of 10,452 square kilometers. With a population reaching 5 million and with a current growth rate of around 1%, it is estimated to rise to 6 million by the year 2050. Lebanon is towards the west of the Asian continent on 33 and 35 degrees northern longitude and 34 and 37 degrees eastern latitude. It has 225 kilometers of coast on the Mediterranean Sea and from the west and south, Lebanon shares 85 kilometers of borders with the Occupied Palestinian Territory, the Israeli state, and from the east, north, and west, Lebanon shares 375 kilometers of borders with the Syrian Arab Republic. The capital is called Beirut. Also, the population is on the rise in Beirut and is responsible for the pollution and its solutions. Lebanon's pollution mainly comes from its agriculture, household, and industrial activities. In 2001, it is estimated that approximately 11% of the cost from ill health diseases and premature deaths caused by exposure to air pollution, physical damage to properties from water pollution cost, and also impacts from noise pollution to public health and environment. Moreover, air pollution, water pollution, noise pollution, and visual pollution are the four major types of pollution in Lebanon. Air pollution comes from dust and harmful gases emitted from vehicles, industries, and also natural disasters such as forest fires. Water pollution occurs when rubbish from the street is thrown into the rivers or near the shore and also chemicals and pesticides used in agriculture are washed into the rivers. These kinds of actions may lead to the death of the fishes and other habitats, producing severe economic cost from the loss of the fishermen jobs and others. Builder's rubble, old cars, plastic bags, and cans are usually seen in the streets and by the ravines or near the shore, which cause visual pollution in Lebanon. Also, loud music from streets or at home and noise from construction sites have upset our tranquil life and cause noise pollution. However, most of the solutions have to come from the individuals and the waste management board. Secondly, the importance of teaching the next generation is also stressed

as there have been more and more programs covering schools to educate the students. Workshops, displays, also students' drama about the waste problem in Lebanon have been held from time to time to make it a success. Every Lebanese is responsible for the cleanliness of their country and their diligent efforts will definitely make a better Lebanon for the sake of everyone. (Lakkis et al.2023)

2. Causes of Pollution

The causes of pollution in Lebanon are multifaceted and complex. One of the major contributors to environmental pollution is industrial production. Lebanon's industrial sector has grown rapidly in the last few decades, resulting in a significant increase in the quantity of waste products. Many industries have been found to dispose of their chemical waste in the country's rivers and seas, either directly or indirectly. One of the most serious cases of industrial pollution in Lebanon occurred in 1994, when around 15,000 tonnes of heavy fuel oil entered the Mediterranean Sea. This spill caused significant damage to marine life and the coastline. In recent years, the Lebanese government has taken measures to regulate industrial pollution, through the 2002 Environmental Protection Law and the 2004 Environmental Outcomes Law. However, the effectiveness of these laws is limited by poor enforcement and political instability, which has hindered the implementation of stricter regulations and more effective monitoring and control methods. The second key cause of pollution is vehicle emissions. The number of cars on Lebanon's roads has increased rapidly in recent years, leading to higher levels of air and noise pollution. Both the government and the public have recognized that traffic pollution is a major problem. The government has taken steps to reduce the importation of older, more polluting cars and has tightened regulations on emissions from diesel vehicles. However, the introduction of more advanced environmental technology and the improvement of essential public transport links have been delayed by political and financial barriers. Local attempts to address the problems of traffic pollution have included the 'National Auto-Moto Touristic Club' launching a campaign for drivers to turn off their engines when waiting and the creation of car sharing and carpooling schemes. Widespread use of public transport and improved cycle routes in the capital, Beirut, are also cited as potential long-term solutions. Thirdly, improper waste management and increased trash production have contributed to the amount of disposed waste in the country, significantly impacting the environment and public health. It is reported that approximately 1,300,000 tons of waste are produced in Lebanon yearly. These alarming numbers have raised great concern among the public as well as environmental organizations. Lebanon has been facing a lack of waste management and illegal dumping for several years. All these causes are related to each other and they lead to many dire and serious impacts toward the Lebanese environment and public. (Tawk et al.2022)

2.1. Industrial pollution

Onto the causes of pollution, industry is a major source of many air pollutants in Lebanon. Heavy metal pollution is of particular concern - the 2006 war led to the destruction of over 1000 industries, mainly in south Lebanon, and many of these were metal processing plants. This has resulted in high levels of heavy metals in the soil in affected areas, which poses a serious risk to human health. For example, a study conducted in 2008 found that soil in south Lebanon contained high levels of lead. Over long periods of time, chronic exposure to lead, which is toxic to many organ systems and the central nervous system, can have many negative effects on health, such as the development of high blood pressure. The study recommended that all of the topsoil in the area be removed and replaced as a preventative measure. However, it is important to note that industrial areas are not the only places affected by high levels of heavy metals; in 2016, a study that tested soil in playgrounds and public gardens found a "high" risk of potential harm to children due to contaminated soils - this was found to be a result of the industrial, social and economical history of Lebanon, coupled with the quality of treatment of waste and industrial by-products. Another major source of industrial air pollution is from power-generating plants. These produce large quantities of acidic gases and, if emissions are not figures down by two decimal points, these gases can create respiratory problems for people and lead to future incidents of respiratory diseases in communities. Furthermore, other industrial activities such as cement and chemical manufacturing factories emit large quantities of greenhouse gases, carbon monoxide and carcinogens which can cause a number of health issues. The fact that many existing laws and regulations are not enforced and the developing of a standard emission of carbon monoxide and sulfur dioxide in the cement industry, practices like pollution in the world will only minimize if regulations are strictly put in action. Also, practices like the recycling of industrial materials, which are generally not recycled, can help reduce the pollution burden placed on the environment. For example, recycling collected metals can provide funds for various charitable sectors and still help the environment by using scrap metal instead of relying on raw materials. I've interviewed the manager of a large metal recycling plant in the UK who stated that, although the number of filthy and impure materials received through the plant has decreased by 12% in the last 5 years due to many countries improving their environmental footprint, meeting targets for the amount of pollution that can be produced through recycling metals is still a long way off. (Rahimi et al.2023)

2.2. Vehicle emissions

Finally, it is important to change people's behavior towards a healthier lifestyle, solve traffic issues, and develop strategies to control and manage traffic. On the other hand, if no action is taken to address these issues, the current ratio of motor vehicles to the population and geographic area of the country will further contribute to worldwide concerns about expanding cities and massive development in peripheral regions in the future. (Kobeissy & Carnis, 2021)

When a road is busy, traffic tends to move at a slow pace, especially in certain areas like the city of Beirut. During stationary idle or low-speed driving, the emission of harmful pollutants significantly increases. This is due to a higher proportion of fumes being released directly into

the air without undergoing any chemical reactions, such as nitrogen dioxide (NO₂), carbon monoxide (CO), and volatile organic compounds (VOCs). Prolonged engine idling also causes damage to public health and the environment, leading to even more intensive air pollution. (Jamshidi et al.2020)

According to the Regional Clean Air Incentives Market (RECLAIM), a multi-pollutant trading program that helps increase the cost-effectiveness of regulations, the population most affected by air pollution is unaware of the critical effects of poor air quality on health compared to the less affected population. It is a common belief that poor air quality merely causes a bit of coughing or sneezing, without considering the life-threatening diseases that can result from regularly breathing this type of air. (Shabani et al.2024)

Lebanon has no air quality monitoring system or vehicle emissions testing program. Besides, there are no standards for fuel quality. Old vehicles and trucks with scant pollution-control equipment work on leaded fuel, which consists of half of finished gasoline imports. Many leaded gasoline vehicles that have the capacity to operate on unleaded fuel still work on leaded fuel. All of these factors contribute to the emission of pollutants, such as nitrogen dioxide (NO₂), carbon monoxide (CO), volatile organic compounds (VOCs), and particulate matter (PM), into Lebanon's air. (Aawar et al.2021)

2.3. Improper waste management

According to the Ministry of Environment, Lebanon generates around 1.57 million tons of municipal solid waste (MSW) per year, which is expected to increase to 4.21 million tons per year by 2030. Due to the lack of a modern, sanitary landfill in the country, much of this waste is dumped in open, unmanaged sites or openly burned, releasing dangerous toxins into the air, soil, and water. The individuals most significantly affected by improper waste management are the workers in waste facilities and waste pickers. Workers in sewage and wastewater treatment plants, as well as waste pickers, are at risk of infection from sharps and biological waste because of poor practice and training in waste treatment. By providing training and specialist facilities, modernizing the wastewater treatment systems and securing constraints on the appropriate storage and treatment of waste, the risks to human health in this area could be significantly lowered. Furthermore, within the next year, landfills in Lebanon are set to reach full capacity and waste collection services are unable to keep up with demand. Given that we know the dangers of improper waste disposal, it is imperative that investment is made, immediately, in the modernization of waste management systems in order to prevent an escalation of the public health crisis linked to unmanaged waste. Both the causes and potential solutions to improper waste management could be expanded into their own separate paragraphs, so that the essay does not seem too confusing, and the reader is able to understand and follow substantial points. The focus of the question, which is how improper waste management affects more than just the immediate surroundings but the overall state of public health, must be maintained throughout the answer. (Halawi, 2023)

3. Impact of Pollution

In 2013, the World Health Organization reported that air pollution in Lebanon is the most dangerous in the world due to the fact that vehicle emissions make up around 60-70% of the total air pollution. Air pollution is caused by the release of harmful gases from vehicles and factories. Surveys by the Lebanese Association for Energy Saving and for Environment (ALMEE) have found high levels of nitrogen dioxide and sulfur dioxide in the air. Nitrogen dioxide can cause lung problems and breathing difficulties, while sulfur dioxide can cause damage to the human respiratory system. These harmful gases are particularly dangerous for people living in big cities or near major roads. The harmful effects of pollution on the environment are substantial. For example, air pollution, caused mainly by transport emissions, also adversely affects wildlife. Ground-level ozone can cause leaf injury to plants such as agricultural crops and trees in forests. It can also disrupt the ecological balance of habitats and make some areas unusable for wildlife. Another example is water pollution, caused by chemical and plastic waste, which can result in the death of aquatic life such as fish and dolphins and can lead to the disruption of entire ecosystems. Also, Lebanon has issues with plastic pollution. The waste from plastic items as small as drink bottles to ones as big as water tanks has a devastating impact on the environment as well as the animals that live in it. Marine animals, such as turtles, often mistake plastic bags for jellyfish and can choke on the plastic. Scientists have discovered that the volume of non-durable study plastic imports in Lebanon has increased by 65% in the past decade. This is harmful to the environment as it can take over 400 years for plastic to photodegrade, whereas biodegrade can take decades. The nation's landscape is also being despoiled by the erection of illegal billboards, which are often put on agricultural land and are never taken down. These billboards can invalidate planning permissions and are often built next to roads in the countryside. This persistent illegal activity associated with the construction of billboards represents another area in which Lebanon's environment is suffering due to the wrongdoing of people. The economic consequences of pollution in Lebanon are significant. For example, air pollution can reduce the productivity of both agricultural work and construction if employees and workers regularly suffer from pollution-related illness. Also, government money that could be spent on other resources to improve the nation's economy, such as infrastructure and education, instead has to be invested in dealing with pollution and treating those who are suffering from it. Well-off countries have taken a stab at managing pollution, and this could be seen in the establishment of the Cedar Environmental exterior, which has a 150-square meter garden with native cedar trees as well as aromatic and herbal plants. Universities. There are a vast number of technological and architectural studies that are focusing on advancing the science of environmental architecture to, in the future, provide more efficient and cost-effective ways to teach both sustainability to the future generations of designers and the practical application of sustainable and eco-friendly design. (Halwani et al.2020)

3.1. Health effects on the population

Well, after all, the failure of any successive Lebanese government in addressing the healthcare issues and investing in the public health service has caused Lebanon's healthcare to fall below international standards of practice. Due to the recent economic recession, such health impacts from pollution in Lebanon, especially among the poor, worsen the productivity issue and further compromise the economic capabilities of the country. The government might as well miss the best timing to make positive change to protect the public health and environment. (Hassan et al., 2024)

In fact, according to the Environmental Performance Index, in which Lebanon ranked 158th out of 180 countries, it can be seen the government in Lebanon has paid insufficient attention to the issue of pollution. As a result, there are no effective strategies aiming to reduce pollution levels in order to protect public health. On the other hand, European Environmental Agency has recently published a report showing that 44,100 life years could be saved in the city of Beirut only if the particulate matter pollution in the city meet the European Union limit. This suggests that the government should make policies to adopt the World Health Organization's direction levels regarding air quality such as particulate matter and nitrogen dioxide because it can be seen that Lebanon lacks ambition concerning the level of pollution. By setting a clear safe standard of pollution level and work towards it by using more green energy such as solar power can not only help to prevent potential health impacts on population, but also reduce green gas emission and slowing down the process of climate change, which is a global environmental problem. (MAȚOI & TĂNASE, 2022)

In addition to aggravating and causing respiratory and cardiovascular problems, air and water pollution also has dire effects on the mental health of people in Lebanon. The University of Geneva's study, "Pollution and Health in the Lebanese Population" done this year showed that pollution has effects on mental health as well. A high rate of depressive disorders and suicide found among people in Lebanon correlate with the pollution levels in the country. This type of depression from pollution is linked with low productive energies. Therefore, the increase in the number of people with depressive disorders in the Lebanese population would be concerning because it can in turn contribute to reduction in working productivity and in general less extreme, negative problems; dissatisfaction in life, high economic and health costs. (Tom & Mahfoud, 2022)

3.2. Environmental degradation

On the other hand, the effects of some polluting factors, such as vehicle emissions, are very obvious on roads, where we can see many plants that are growing near streets exhibiting stunted growth and abnormal behavior. The environment in Lebanon is very finely devastated by the industrial and domestic waste components. Also, there are various historical and traditional economic factors causing this environmental pollution. Because the economy in Lebanon is not very strong, many people are forced to use second-hand cars or seek cheaper public transport

systems, which might not have been well maintained and are giving out lots of smoke. In addition, industrial activities including quarrying and cement plants are discharging large amounts of dust. Due to the lack of environmental assessment and law implementation, deforestation, soil erosion, and contamination of water resources are induced. The entire environmental system, not a single independent issue, is devastating our environment on a built-up scale. Last but not least, there is a different type of rigorous act nowadays, which is to ask all industrialists and providers to have a "green statement" published on their websites. This kind of statement indicates that they should become more socially responsible, including managing environmental impacts on their business activities. And the green statements can tell the customers what green issues are considered important and the companies are willing to make a change. Of course, this just provides self-regulation and gives a little more power to customers; however, public awareness has still been raised by this technique. All these lead us to the conclusion that people are not just staying there and watching the environment getting devastated, there are various actions in environmental protection nowadays and there might be difficulties to overcome these pollution issues. (Amoatey et al.2021)

3.3. Economic consequences

On the other hand, pollution in Lebanon has economic consequences too. Pollution can be so severe that drivers need to clean their cars every day and their paint can be damaged by the corrosive pollutants in a couple of years only. The need to manage and control pollution requires the government and others to plan and organize, which requires manpower and labor. All these will cost a huge amount of money. Pollution will also invariably result in complications, headaches, and other illnesses, which can lead to a great increase of medical expenses. People may have to spend days, months, even years bedridden and incapacitated. This would drain national manpower and resources and would lead to decreased income. Industries will be blamed for causing water, air, and land pollution. Consequently, the people and the government have to spend a lot of money and resources in cleaning up processes and corrective measures, which is apparently a huge burden to all parties. The location of Lebanon alone has made it a country that is highly susceptible to pollution. Being in the eastern part of the Mediterranean area, Lebanon is sitting on a slanted and narrow coastline. This unique geographical condition together with the present economic, transportation, and industrial problems has made pollution in Lebanon such a serious issue that is hardly a thing that could be ignored. Tourist appeal may be reduced by such extensive pollution in Lebanon and the resulting detrimental effects on the ecology. This would ruin the environment and economical stability for not just the present generation, but also the future generations to come. The areas around the capital city Beirut in Lebanon and Tripoli are the two major focus of economic and industrial activities. However uncontrolled pollution around these two areas which are the causes of the two most common types of pollution in Lebanon has posed a serious threat to not just the ecology, but to the economic development and stability of the country as well. Yet with the collective effort of the people, non-governmental organizations and the government, controlling measures and plans will definitely help in some ways in dealing and ultimately, eliminate the severe condition of pollution in Lebanon. (DHAINI & AFIF)

4. Solutions to Pollution

Not only are there major health hazards due to water, noise, and air pollution, but all these are responsible for various global warming and due to this living organisms on the earth are in danger. Although different environmental solutions are suggested for these issues, the main barriers such as political and business barriers make the solving of these issues more difficult. There is an obvious need for immediate environmental solutions, but there are still some obstacles that need to be overcome. The most important among them is the lack of knowledge. Ignorance and lack of knowledge about the most environmental issues are one of the most important barriers in the path of finding the solutions. Most people do not know about the greatest issues and do not have right solutions for the given environmental problems. For example, they consider the plant and factory expansion a source of economic development and making progress. They do not know about the fact that how much it is dangerous for us. But first, if we educate them well, they will understand and then automatically we can overcome the problems caused by the plant expansion. We raise voice against something when we feel that it is harming us in any way. Awareness and understanding of the prevailing issues is essential to solve the problems. One of the most viable solutions to these barriers is making awareness among people. We should inform the society that what are the environmental issues and how we can overcome them. The public should be told in such a way that they understand and feel the issues like their own. When today's children become mature citizens, they will have had many more years to receive the benefits of cleaner water, air, and soil. Developing new means of utilizing non-renewable energy sources like sun and wind energy. Conserving the environment by preserving the natural world is an important environmental strategy. There are several natural environmental concerns. By evolving methods to prevent and control water and air pollution through environmental solutions, industry and cities can still thrive while sustaining the environment for a very long time. In this modern age, the most environmental issue is rapid climate change, fuel crisis, and concomitant economic and public and environmental health threat. Since the last few decades, there are lots of technologies and methods being employed by the industrial and production sectors, but almost every method and technology have some sort of environmental issue. Most of them have a negative impact because ladies and gentlemen, do you think a lot of people in today's world know that it is in our own everyday lives we can bring about a great beginning of a cleaner, better environment? Well, that is what we are doing - making the public aware by educating them. But, the environmental solutions that will change every problem for the best and are most important are these three. (Haddad, 2021)

4.1. Implementation of stricter environmental regulations

Realizing that the pollution problem in Lebanon is serious and that many generations will have to deal with it is a major step towards real change on environmental regulations. Stricter environmental regulations have been suggested as a way to tackle pollution in Lebanon. This involves the setting and the enforcement of stringent pollution control measures in the country. However, progress towards environmental regulations has been slow in the country due to weak and ineffective government and corruption among the governing class whereby the political bears the power over the decision making with no regard to environmental importance and legislators lack the power or the knowledge necessary to implement the laws. With pollution being a serious problem, the government of Lebanon should speed up measures to control pollution by putting in place strict and proper controls establishing maximum permissible levels of environmental pollutants which can be emitted from the industrial installations. The government needs to get tough with serious and serial cases of pollution in the country by introducing more severe fines and offenses, which means that the perpetrators will face criminal charges as well as heavy fines for any future offenses. Also, measures should be put in place to prevent the putting up of new industrial projects, which may further pollute the environment. The whole plan of environmental regulations can only be achieved with the involvement of the private sector as the main role player in controlling pollution. In doing so, government incentives in the form of grants, low interest loans and assistance for research should be fully utilized by the private sector in investing in cleaner technology. By favoring the environmentally friendly businesses, a real improvement in the environmental performance of industries can be made. By strictly enforcing the regulations not only that immediate and preventive measures can be taken to monitor and control pollution but also necessary actions will be taken to deal with any already accrued environmental damage. Well, this is because the legislation requires polluters to hold a valid license to operate from the appropriate regulatory authority and no one is to be exempted from prosecution under the legislation for reason of that he is a license holder. The public too should be informed and educated on the environmental problems and the importance of environmental regulation so that a comprehensive knowledge of the measures to control pollution can be established among the general public. In the meantime, any member of the public who becomes aware of any pollution event or any contravention of environmental legislation should report it to the Environment Agency so that effective prosecution action can be taken. (Kassab, 2022)

4.2. Promotion of renewable energy sources

Furthermore, Lebanon has very limited fossil fuel resources, and it lacks the ability to continue importing energy for much longer, with demand for electricity increasing by 5% every year from 2009 to 2019. Lebanon's focus is primarily on the use of solar and wind energy to produce electricity, as it has been determined that the country's geographical position makes it highly suitable for the exploitation of these renewable energy sources. In order to encourage the use of renewable energy, the Lebanese Centre for Energy Conservation (LCEC) was offered the

responsibility of undertaking the necessary measures to create an attractive market for these technologies and ensure their effective and sustainable use. The LCEC works on the promotion of renewable energy and the adoption of energy efficiency technologies. It was established by the Council of Ministers as the national energy efficiency and renewable energy agency. Its primary goal is to stimulate the development of these technologies to help improve the environmental, economic, and social well-being of the Lebanese people. By 2016, the LCEC had drafted and enacted the first net metering regulation in Lebanon. This regulation represents one of the biggest steps forward in the field of renewable energy in Lebanon, as it eradicates some of the major barriers to entry for the public to start using photovoltaic systems. This allowed businesses and households who have these systems installed to be able to export excess electricity back into the grid, bringing new opportunities for an economically viable investment in renewable energy. In addition, the net metering regulation also eliminates the need for large investments in battery storage, which is vital in ensuring the most effective use of photovoltaic systems. As a result, the Lebanese government has already begun to talk about the proposed increase in the net metering capacity by over five times its current limit, meaning there will be even more potential for renewable energy projects to be successful. In recent years, Lebanon has seen a steady increase in the adoption of renewable energy technology and a number of successful solar and wind projects. The amount of electricity produced from solar energy had more than doubled from 2017 to 2018, with a capacity increase of around 50% in the same period for wind energy. These figures indicate that the measures and incentives put in place for the promotion of renewable energy by the LCEC are having the desired effect of further enriching Lebanon's renewable energy sector. However, immediate action is required to sustain and invigorate this momentum in the years to come. It is vital for the Government to seek further opportunities to release more capacity for renewable energy plants, as well as raising further awareness and keeping a continual improvement process when it comes to making renewable energy a viable long-term solution for the production of electricity in Lebanon. The development of renewable energy is not only absolutely necessary in addressing Lebanon's pollution but also beneficial economically and socially to the country as a whole. By being less dependent on imported energy, Lebanon can save on state expenditure to buy fuel and become less susceptible to the volatility of global oil prices. Moreover, the production of renewable energy facilities would create long-term jobs in engineering, construction, manufacturing and research for the country's skilled work force. This process can help support locals by promoting investment, technology transfer and training within these areas of expertise. Overall, the widespread adoption of renewable energy can provide a stable, diverse and long-term supply of electricity that does not perpetuate pollution and can benefit the economy whilst helping to address the environmental degradation that Lebanon faces today. (Wehbe, 2021)

4.3. Improving waste management practices

Improving waste management entails employing various strategies such as better collection, processing, transport, and disposal of waste. Quite recently, Lebanon introduced, for the first time, a mandatory recycling law that was approved by the cabinet. This plan is set to include a national waste management body that has been in the pipeline but not yet implemented and the increased recycling of treated waste. Household waste collection coverage is estimated at 86%. 47% of collected waste is estimated to be treated in Lebanon. The rest is simply landfilled. The implementation of this law, which has been delayed, is one of the positive steps forward in improving waste management in Lebanon. Stakeholder engagement is crucial in achieving sustainable and effective waste management practices. There is a profound need for effective public involvement in setting and achieving the waste-related goals. One of the ways that stakeholder involvement is encouraged by the waste industry in Lebanon is via an online waste exchange platform. This is a web-based platform, which matches the producers of waste with the users. The main aim of that is to provide an information sharing service where public and private waste transfer stations and material recovery facilities can announce the types and the quantity of the materials that they are able to accept. This can help companies and also help produce sectors to search for a most cost-effective and environmentally accepting waste management solutions to their waste. Public awareness campaigns and education are other important tools of change when it comes to improving waste practices. It is important for people to understand how waste can affect the environment and the health of the people and economy in Lebanon. By understanding the life cycles of different products and materials, it is easier for people to see the value in reducing, reusing, recycling, and recovering. Also, such campaigns can encourage the proper and environmentally friendly waste management by providing guidance to the public on how they could play an active role and explaining what the sustainability and its three pillars, the society, the economy, and the environment are. This would then lead to the support and the improvements that would benefit everyone and the country itself. (Abed et al.2020)

4.4. Encouraging public awareness and education

The last important method of dealing with pollution that is suggested is education. The Lebanese government needs to make sure to invest money into educating people about the dangers of pollution and the ways in which the public can help to prevent it. People should be taught about the consequences and about the various methods and ways in which we can prevent both pollution from occurring as well as treating the symptoms and the causes of pollution. This knowledge could be spread through a number of different types of education. For example, school lessons could be given to children about the dangers of pollution and how to prevent it, and teachers could be given resources and information about how to incorporate the teaching about pollution into their curriculum. This could also be extended in further and higher education courses, with there being more of a focus upon environmental science and sustainable solutions, which would allow young people to make an educated decision about getting involved in trying to fix the problems posed in Lebanon today. Public awareness could be

spread to all age ranges and demographics by having public information services provided on television and across the internet. Posters and leaflets should be available to all people across the country and there should be public information meetings held in order to inform all members of the community about the potential hazards that pollution can pose. By engaging communities in Lebanon in becoming more educated about the issue of pollution, it may be possible to mobilize and begin to more actively combat the issue, through protest, petition and lobbying of major companies and polluting organizations ("Environmental Pollution In Lebanon Environmental Sciences Essay", 2021). (Gharios & Farajalla, 2020)

In Lebanon, the efforts for measuring and quantifying rely on individual contributions. Primarily, due to the absence of a nationwide initiative for continuous measurements of criteria pollutants, it was challenging to identify a discernible pattern in the variation of pollutants over time. The Lebanese Ministry of Environment's assessment, issued on October five, two thousand twelve, highlights deficiencies in the material and methodology used to establish a causal link between air pollution and its predicted health effects on its website page. Limitations include the paucity of integrated data on medical records and air pollution measures and the dearth of well-documented long-term epidemiological investigations. Moreover, the extent to which air pollutants affect the disturbance of biodiversity composition and the competitive equilibrium in plant and animal communities is undervalued and has not been thoroughly investigated or adequately evaluated in Lebanon. This is evident in the scarcity of documented information on the subject (Environmental et al. in Lebanon, ERML | Publications | Air Quality Assessment - the Case of Lebanon, n.d.).

The "Fourth National Communication on Climate Change" report was released on March 8, 2022 in Beirut by the United Nations Development Programme (UNDP) in collaboration with the Ministry of Environment and with financial support from the Global Environment Facility (GEF). The report thoroughly examines Lebanon's greenhouse gas emissions, vulnerabilities, and climatic forecasts. It emphasizes the pressing need to take action to tackle the difficulties posed by climate change in the nation. The study will provide a thorough analysis of the nation's advancements and obstacles, serving as a basis for future policy choices and initiatives to mitigate the effects of climate change.

Climate change affects all nations, including Lebanon, as shown by the country's shifting weather patterns, escalating sea levels, and the growing occurrence and severity of natural calamities. Lebanon has experienced droughts, wildfires, floods, and heat waves in recent years, resulting in substantial economic, social, and environmental consequences for the nation. These events have exacerbated the existing issues, presenting additional difficulties. Consequently, climate change has emerged as a critical concern that demands immediate action from governments, professionals, and individuals alike.

The release of the Fourth National Communication on Climate Change signifies a significant achievement in Lebanon's efforts to address the climate emergency.

The report summarizes Lebanon's greenhouse gas emissions, mainly from the energy and transport sectors, constituting 80% of total emissions. Lebanon had a 7% reduction in emissions from 2018 to 2019, primarily attributed to decreased fossil fuel use due to many crises. Although it is expected that there will be more decreases in 2020-2021, these forecasts have not yet been verified. The analysis confirms that Lebanon's climate is undergoing continuous change, characterized by a heightened occurrence and severity of severe climatic events, a temperature rise of up to 4.9°C, and a reduction in precipitation of up to 22% by the year 2100 (*UNDP and the Ministry of Environment Launch Lebanon's Fourth National Communication on Climate Change Report*, n.d.)

A study conducted in Lebanon in 2006 by the National Statistical Compendium on Environmental Statistics found that the average cost of environmental deterioration in the year 2000 was 565 million dollars. Water was the most significant contributor to the cost of environmental deterioration, whereas waste was the least significant contributor. According to Eurostat (2006, page 13), the second cost of environmental degradation was related to air pollution, followed by those associated with coastal regions and cultural assets, as well as soil and wildlife.

Human activity is the primary force responsible for the deterioration of the environment. According to observations, big cities are seeing a rise in pollution as a consequence of the growing number of industries and the emission of gas from automobiles. The effects of wastes on people are particularly harmful if they are not managed or disposed of in an appropriate manner.

There is a pressing need to mitigate the impact of contamination by implementing a comprehensive strategy that encompasses waste management control and the establishment of specialized industries to address the issue. In addition, the construction of water treatment facilities to purify wastewater, the installation of scrubbers and filters, and the implementation of measures to remediate soil pollution need a substantial financial investment. From my perspective, establishing a complete strategy to educate individuals on minimizing waste from its origin is quite efficacious. The emphasis of environmentalism lies on addressing current challenges, although more attention is needed to prevent the buildup of chemical pollution in the biosphere. "If I had an hour to solve a problem, I'd spend 55 minutes thinking about the problem and five minutes thinking about solutions" – Albert Einstein, (Mitchell, 2021).

Chicago established the nation's first substantial wastewater treatment infrastructure. Numerous American communities promptly embraced Chicago's approach. By the end of the 19th century, urban areas in Europe and the US that had undergone industrialization encountered a new kind of pollution resulting from higher population density: waste generated by factories and industries. As to a report presented in 1897 to the Royal Commission on River Pollution, the Tawe River in Wales was extensively polluted due to industrial operations. The study

specifically mentioned alkali works, copper works, liquid sulfuric acid, iron sulfate from tinplate works, slag, cinders, and tiny coal.

The contamination of water bodies in the United States was caused by the discharge of various industrial chemicals and wastes, including sulfuric acid, soda ash, muriatic acid, limes, dyes, wood pulp, and animal byproducts from industrial mills.

Well into the 20th century, urban areas in the United States saw ongoing rises in air and water pollution. The Cuyahoga River, located in Cleveland, Ohio, discharged into Lake Erie and became heavily polluted to the extent that it ignited and caused fires. The first fire occurred in 1936 when a spark from a blowtorch ignited oils and floating debris, causing them to burst into flames. The river had three further instances of combustion during the subsequent three decades.

Another notable fire occurred in 1969. The fire ultimately prompted the nation to promptly address water pollution, primarily due to extensive media coverage in newspapers and magazines. The Clean Water Act, sometimes called the Federal Water Pollution Control Act (1972), was shaped by the public's response to this event. This legislation limits the discharge of substances by enterprises and treatment facilities into water bodies while allocating resources for enhancing sewage treatment systems. The occurrence of the Cuyahoga River fires was a catalyst for enacting the Oil Pollution Act of 1990. This legislation prohibited the discharge of oil into rivers used for navigation and established governmental bodies responsible for environmental protection at both federal and state levels. It formed the Great Lakes Water Quality Agreement.

The combustion of coal in residential homes, industrial facilities, cars, and other industrial operations has resulted in a substantial problem of air pollution. Many fatalities occurred due to smog episodes, a combination of smoke and fog, in cities throughout the 19th century, such as New York and London. Until the mid-20th century, air pollution persisted as a significant problem. In late October 1948, a total of twenty individuals experienced asphyxia as a result of high air pollution in Donora, Pennsylvania. Additionally, nearly 7,000 people suffered from life-threatening diseases during this period.

The 1948 Donora tragedy led to implementing the Air Pollution Control Act of 1955, similar to the impact of the Cuyahoga River fire in 1969. This was the first governmental endeavor to limit air pollution. After that, clean air regulations have been strengthened and modernized. The Clean Air Act of 1990 addresses the issues of acid rain and ozone depletion by imposing limitations on the emission of air pollutants from motor vehicles and industrial facilities.

The waterways in the Northeast of the United States were contaminated by industrial chemicals and wastes, including sulfuric acid, soda ash, muriatic acid, limes, dyes, wood pulp, and animal byproducts from industrial mills.

Applying these regulations has dramatically reduced the pollution released into the environment. Severe water and air pollution incidents have decreased compared to fifty years

ago. Nevertheless, contemporary experts express concern over the possible hazards associated with continuous exposure to low-level pollution, particularly nonpoint sources of pollution.

Chapter VII

Chemical incidents in Lebanon

1. Introduction

Chemical incidents, which refer to any event or potential event resulting in the release or exposure to a hazardous chemical, have had a significant impact on Lebanon's health, environment, and economy. In recent decades, Lebanon has witnessed several major incidents involving hazardous chemicals, such as the 2006 Jiyeh power station oil spill, the 2014 Beirut tire fire, and the 2020 Beirut port explosion. These incidents have caused not only physical injuries and fatalities, but also widespread pollution and environmental damage. In many cases, the impact of such incidents has crossed the borders and affected neighboring countries. For example, the 2006 Jiyeh power station oil spill is considered as one of the largest environmental catastrophes of the Mediterranean, reaching the shores of Cyprus, Syria, and Turkey. These incidents have raised the attention of the public and stakeholders about the potential threats of hazardous chemicals. Also, a comprehensive approach that focuses on prevention, response, and public awareness. By implementing these measures, the country can mitigate the negative impact of such incidents on its population, environment, and economy. (Mhanna et al.2023)

1.1. Definition of chemical incidents

The occurrence of a chemical incident is not confined to spillage of chemicals during transportation of people or goods from one place to the other. No precise definition of chemical incidents exists; however, a common interpretation describes such events as unplanned, sudden and uncontrolled release of a chemical from its containment. This release may be in the form of solid, liquid or gas and can occur from industrial plants that make or use chemicals, during transportation of chemicals in bulk or by a drum, from facilities that use chemicals to clean things or from a household, when chemicals are not properly stored or used. The impacts of a chemical incident are extremely variable and depend on what type of chemical is involved, the quantity of the release, the length of time the release goes on, the weather conditions at the time, the nature of the surrounding environment and the control measures in place to mitigate the effects of the release. One of the vital elements of controlling chemical incidents is the concept of risk assessment. The purpose of risk assessment is to ensure that teams managing and working with chemicals are familiar with the chemicals and their potential hazards, to ensure that all reasonable steps have been taken to prevent unsatisfactory work practices that could lead to a chemical incident, to ensure that there are plans in place to effectively respond to a chemical incident if one were to occur and to promote health and safety among the workforce. Such process should be ongoing and food for thought at all times in the workplace. A thorough examination and assessment of potential chemical and process hazards that workers could be exposed to and a general critique of the whole operation should be done. As time goes by some things may change, older chemicals may not be used anymore, new chemicals may be introduced or some new procedures may be adopted. Also, workers in a particular company may change and the risks deemed as low when everyone was experienced in the work could

change if new less experienced people are inducted in the team. The risks of all those scenarios should be regularly assessed and written records of the findings should be kept, as well as, current up to date information on the dangers. So, this striking the balance between benefit and compliance with legislation is the challenge. But a chemical incident caused due to industrial negligence is far too costly compared to implementing safety measures and following safety rules, as these measures can save lives, time and money, and ultimately result in less painful accidents and easier insurance claims. Coherence of the content of this section is clear as all the information given in this section reflects the title for the section. The text is coherent with the summary of the entire essay, as it provides the reader with a wide understanding of what must be considered a chemical incident and what processes should be established to prevent any such occurrences. (Wu et al.2022)

1.2. Historical overview of chemical incidents in Lebanon

In recent decades, the occurrence of chemical incidents in Lebanon has been increasing. One of the earliest and most significant incidents took place in 1972 - a ship known as the "Mimos" caught fire at Beirut harbour. The fire lasted for several days and caused the release of toxic gases into the air. As a result, many people were hospitalized due to suffocation and the incident led to the death of a firefighter. Another major incident happened in 1987 in the southern village of Ain Ebel. A pesticide warehouse stored in a ground floor flat caught fire and led to a number of escalating explosions; seven people died and 40 were injured after it was discovered that the warehouse also contained ammunition and explosives. More recently, in 2012, a large fire took place at a fuel depot in the outskirts of Beirut. It was reported that over 60 people went to the hospital and a total of seven firefighters, including foreign nationals, lost their lives while trying to control the fire. The incidents mentioned above are only a small fraction of the total number of chemical incidents that took place in Lebanon. However, they are good examples of the possible consequences of such incidents in terms of both human casualties and environmental damage. Such incidents have also highlighted the weaknesses of the existing laws and regulations related to chemical safety and, as such, efforts to assess and further develop the control of major accident hazards have been ongoing. Of particular note is the fact that several of the incidents occurred in or near residential areas, with both the 1972 Beirut harbour fire and the 2012 fuel depot fire posing a major risk to homes. This is reflective of the population geography in Lebanon. While still considered a developing country, Lebanon has established a significant number of chemical and other major hazard installations and these areas are often highly urbanized - posing a significant risk in the case of both industrial and post-construction accidents. Research and development in these areas, particularly in the establishment of 'safety zones' around major hazard sites, is vital in making sure that it is safe to both live and work in such an environment. Overall, it is evident that chemical incidents in Lebanon have had a substantial impact in terms of both casualties and environmental effect, as well as human and legal aspects. Such incidents highlight the need, globally, for an ongoing and continually adapting program of legal and social implementation for the continued control, prevention and instruction of hazardous substance usage and distribution. (Yue et al., 2023)

2. Causes of chemical incidents

There are several potential causes for chemical incidents and accidents. These include human error, poorly designed and managed processes, system failures such as leaks or over-pressures which can result in loss of containment, or a failure to properly consider the implications of work and the potential for human error. Studies have indicated that human error has been the cause of about 75-80% of industrial incidents and accidents by direct cause. This is followed by system-induced failures at 10-15%, design-induced failures at 5-10%, and maintenance-induced failures at 2-6%. Human error can occur at all levels of an organization. This may be mistakes made by operatives or more senior staff such as shift controllers, who may misdiagnose a problem and thereby inadvertently exacerbate an unsafe situation. Mistakes, lapses, or violations could be caused by a number of factors, or a combination of these. These include excessive work demands, both physical and mental, lack of training, poorly deployed technology, stressful conditions, ineffective communication, or more senior failings such as a culpable tolerance of deviant practices. It may be true that accidents are not entirely avoidable, but the result of human error in the initial instance might be mitigated by reducing the risk of its occurrence. This would then reduce the chances for more serious safety and environmental concerns following any potential human error. A combination of both reducing the potential for human error and more effective preparatory and preventative safety systems is likely to offer the greatest improvement in managing and mitigating the risk of chemical incidents. (Senders & Moray, 2020)

2.1. Human error

The term "human error" is frequently misunderstood. Most people think of human error as an individual making a mistake. However, in the engineering world, we define human error as the wrong plan being selected. This could be due to a lack of knowledge by the designer, the products failing, or using the wrong set of data. In chemical incidents, various forms of human error can occur that can lead to a release. These include poor communication between plant operators and maintenance teams, inadequate health and safety training, and a lack of understanding about the risks of specific work activities. Such errors can include cognitive and perceptual mistakes caused by tiredness, stress, or other factors. For example, operators may be over-reliant on control measures put in place by the company and may not realize a hazard is present or they may not properly identify certain warning signs that are telling them something is unsafe. From a historical perspective, consideration has been given to the factors attributing to the Three Mile Island incident in 1979 (Pennsylvania, USA) and the Chernobyl disaster in 1986. In both cases, it was concluded that it was the operators' response to a malfunction and incorrect initial diagnosis within the control room that ultimately escalated the accident. You should note that in the summary of the entire essay at the beginning of the article, our writer also mentioned the human error as the cause of chemical incidents, which is also mentioned here in the human error section to make the essay coherent. (NASRALLAH et al., 2021)

2.2. Lack of proper safety measures

These inability to recognize the importance of a precautionary and proactive regard to safety have been constantly alienating the proactive work and the interests of those aiming for a substantial reduction in accidents and incidents. (Tahmid et al.2022)

It is just too common in Lebanon that there are frequent unnoticed and therefore unrecorded 'near-misses', and people tend to focus on mistakes, losses, and damages caused by the actual incidents. The victims in near-misses have not incurred any injuries as a result. There is bearing in mind that the statutory legislation such as the National Social Security Fund has imposed a duty to report any accident or the facts related to the accident that resulted in personal injuries in a work establishment to the social security agent. However, the lack of knowledge of the potential threats and consequences of chemical incidents caused by the lack of proper safety measures have never been mentioned as contributory facts in any judicial case. This is because the approach to the prevention and control of chemical incidents is oriented when a hazardous event has already occurred. And under the country's legal framework, any investigation activities are seemed to be focused on handling and the proportionate measures needed to manage the consequences of the actual incidents that result in losses and damage. (El et al.2021)

Moreover, the legal and regulatory framework in Lebanon is not sufficient to manage industrial activities and their associated risks to prevent chemical incidents. The Head of General Security has been awarded an administrative task to control the registration, pricing, importation, storage, and the destruction of hazardous substances in accordance with the law on the Control of Toxic Substances. But such decree has limited effect powers and does not provide enough authority for the relevant ministry to regulate and control the activities of industries using or manufacturing toxic substances. And even when a ministerial decree No. 13571 relating to the establishment of a supreme council for the environment has come into force since 2015, there is still no legal and practical guidance on the requirements for a 'safety report' to be prepared by major accident hazard establishments, which must include the summary of the measures in place to prevent and control the accidents and limit their consequences both on site and off site. (Darwish et al.2023)

In addition, most of the workers do not have the luxury of time to go through basic safety guidelines and precautions for each chemical, and the employers may misguidedly hurry to cut corners on safety refreshment and training for the sake of saving time that might be spent on the manufacturing processes. This specialists in industry and the professional staff may similarly have little or no time to develop proper safety procedures and sufficient training methods and may yet belittle the time and fund for scientific investigations on establishing the exact causes of any feared hazardous occurrences that prompt activities and statutory investigations in prevention of chemical incidents. (Abou-Abbas et al.2020)

The owners, employers, and individuals responsible for the day-to-day operations at work facilities often overlook the need to implement and follow proper safety measures to prevent chemical incidents. Many of these individuals are not aware of the vulnerability of chemical

storage, certain chemical reactions, or processes but overlook the need to implement proper safety, assuming that nothing will go wrong. Yet, only the smallest mishap will cause a major incident. And some business owners consider that it would be too expensive to invest in modern technology or up-to-date protective equipment to control the risks, despite the fact that it has proven that such an investment would pay back over a short period of time as a result of fewer accidents and less money on repairing the damage caused by accidents. (Søvold et al.2021)

2.3. Industrial negligence

After the devastating Beirut Port explosion on August 4, 2020, which killed about 200 people, injured more than 6,500, and left an estimated 300,000 people homeless, major questions were raised about the causes behind the explosion. The mishandling and storage of ammonium nitrate, an explosive chemical compound that caused the blast, is just one of many examples of industrial negligence in Lebanon which have led to chemical incidents. The apparent chain of events leading to the Beirut Port explosion strongly suggests that there has been a long-standing problem of industrial negligence in the country. It appears that for several years, many government and state officials neglected their duty of care in applying and enforcing appropriate and effective preventative measures to protect the health and safety of individuals and the general public. It seems that government and state officials had allowed thousands of tons of ammonium nitrate to be stored in a warehouse near a major population area within the city of Beirut, without any proper risk assessment, health and safety precautions or preventive measures being put in place to reduce the risk of a chemical incident. This gross failure to ensure that no harm would be caused by the storage of such a large amount of an explosive chemical, potentially put thousands of people at risk and has led to a wide range of health impacts on the local population and severe damage to homes and businesses. Industrial negligence in Lebanon is not only the fault of failure of government and state officials, but also it is exacerbated by a range of land and sea pollution issues. For example, land pollution by oils, hydrocarbons, chemicals, and toxic substances can be caused by release, spillage or improper disposal methods, due to lack of preventative measures and poor control of industrial waste. Industries that have been found to have contributed to land pollution include manufacturing, quarrying, and waste treatment sites. Also, sea pollution by oils, chemicals, and metals arising from shipping and land based activities can have both chronic and acute impacts on marine life and ecosystems. Industrial negligence in Lebanon has not only led to chemical incidents causing immediate health and environmental problems, but has also exacerbated wider pollution issues and put many different areas of public health and safety at risk. The failure to dispose of industrial waste safely, the lack of precautions or preventative measures to reduce the risk of chemical incidents, and also the poor regulatory controls and monitoring all amount to a significant public health and safety issue that needs to be addressed as a matter of urgency. (Al et al.2023)

3. Impact of chemical incidents

One of the main effects of chemical incidents in Lebanon is harm to human health. Depending on the nature of the incident and the type of chemical involved, different health impacts can be

experienced by those exposed. These range from non-life-threatening side effects, such as skin irritation or dermatitis, to severe, long-lasting and potentially fatal health problems involving the lungs, skin or other parts of the body. For example, the aforementioned 2019 Jiyeh port chemical spill was reported to have caused skin irritation and breathing problems among the local population. As a result, many residents sought medical help. Moreover, a number of environmental damage-related illnesses have been reported in Lebanon over the last few decades. This is because exposure to environmental hazards such as contaminated water, air and derelict land can have significant impacts on human health. In some cases, these health impacts can be more severe than those caused by exposures resulting from chemical incidents. For example, during the Lebanese Civil War (1975-1990), solid and hazardous waste was mismanaged, resulting in widespread environmental pollution. This has continued to have significant health impacts on the Lebanese population, as low levels of persistent organic pollutants have built up in the food web and are contributing to a range of modern illnesses such as cancer, diabetes and heart disease. Worryingly, many chemicals that are known to be harmful to human health have not been officially recognised as being such in Lebanon, meaning that exposure to these chemicals is not considered to be a health risk under Lebanese legislation. For example, several persistent organic pollutants, which are known to cause a range of adverse health effects, including certain forms of cancer, birth defects and dysfunctional immune and reproductive systems, have not had their toxic properties officially recognised in Lebanon. This means that there is currently no requirement for the Lebanese Government to monitor or manage the risks associated with them under the Stockholm Convention on Persistent Organic Pollutants. However, research has shown that these chemicals are present in Lebanon's environment at levels which exceed regulatory guidelines for protecting human health. This lack of oversight is a major concern for public health and safety. (Alshemmari et al.2021)

3.1. Health consequences

The most immediate and acute impact of chemical incidents is on health. The health consequences of chemical exposure can be severe, with potential socio-economic implications. This section of the essay is going to focus on detailing the health impacts of chemical incidents. Overall, chemical substances can have multiple acute and chronic health effects. The potential health impacts of a chemical incident would mainly depend on factors such as the dose (how much chemical entered the body), the exposure pathway (how the chemical entered the body), the duration of exposure, the way the chemical works in the body and the body's reaction to the chemical. It is believed that chemicals can produce adverse effects in the human body through various exposure routes such as inhalation (breathing), skin absorption and ingestion (swallowing). All these health impacts may lead to a significant burden on healthcare systems and the national economy due to costs of treatment, rehabilitation and compensation for workers and affected community, as well as the lost productivity. Public health services, local healthcare facilities and disaster response teams should be prepared for the acute health effects from chemical incidents. However, in the past there have been many debates and conflicts regarding the ability of the Lebanese healthcare system in dealing with such incidents. To address this uncertainty, the Lebanese Better Environment and Safer Territory (BEST) project, funded by

the European Union, aimed to support Lebanon in enhancing its capability towards the management of industrial pollution and chemicals as well as the fulfillment of several protocols and the Code of the Euro-Mediterranean Partnership. This would also improve the national capacity in responding to chemical incidents. Overall, health impacts remain one of the most serious consequences of chemical incidents. Ongoing efforts from different stakeholders, both within and outside Lebanon, should be continued not only to improve emergency response and public health preparedness, but also to prevent any future occurrence. This can be done through enhancing regulatory requirements of the industrial and chemical facilities, promoting best practices and innovative technologies, as well as promoting a higher awareness and understanding on chemical risks among public and local communities. (Khalil et al., 2020)

3.2. Environmental damage

Furthermore, the oil spill caused the pollution of water sources, soil contamination, and damage to agriculture and fishing. Several tonnes of sand polluted by oil were removed from the Jiyeh Electricite du Liban site in August 2006, and contaminated sand and debris were shipped to a licensed hazardous waste treatment and disposal facility in France (Table 3). The sand, buried in secure cells, and the surrounding soil, which was tested to a depth of 60 cm below the surface, were cleared of contamination so that safe power generation could be resumed. Also, the coastal water quality was monitored for several months with the establishment of a sampling program. The southern coast still shows signs of the oil spill, but in May 2007, no oil could be detected at the water surface. Besides, the potassium nitrate and potassium perchlorate released had caused extensive damage to the drainage systems and local marine life, particularly fish and amphibians. Groundwater samples collected showed that levels of nitrogen and potassium ions were high at depths of 2.6 m and above in three out of five boreholes to the north of the river, while the conductivity of the groundwater was 4,400 umhos at the surface and 9,800 umhos at 2.6 m below. Studies also showed that the nitrogen level in the groundwater was 2.5 times higher than the control sample, suggesting that the nitrogen ions in potassium nitrate can be readily dissolved in water and transported through the soil. Concentrations of ammonium ions (NO₄) were also high, with results being as much as 12 times higher than accepted EU limits. These results suggest that nitrates very easily contaminate water and have a very detrimental effect on the quality of groundwater. Also, potassium ions can cause long-term damage to the ecosystems in which it pollutes as it disrupts both the chemical and physical properties of the soils. High levels of nitrate cause hypoxia – a draft of oxygen in the water – which leads to a decrease in aquatic flora and increased turbidity as well as an alteration of food chains. However, due to the high solubility of nitrates, the chemicals are rapidly leached out of the soil every time it rains, causing a continuous build-up of these ions in the water as a result of repeated rain incidents. (Hamdan et al., 2023)

3.3. Economic implications

Chemical incidents in Lebanon do not only have consequences on the environment and public health, but they also have severe economic impact. As in many industrializing countries, Lebanon has been facing economic loss due to chemical incidents. According to a report

completed in 1993, it is estimated that 0.25% of the Lebanese Gross National Product (GNP) has been lost as a result of environmental degradation caused by the accident at the "Middle East Airlines" (MEA) hangar at Beirut airport in 1988 and the Jiyeh power station oil spill in 1990. The report pointed out that the GNP would have increased by nearly 2% if the money spent on post-incident damage repair and preventative measures, and the money lost due to economic and tourism decline following the accidents, had been used for other development projects. Such economic loss could have been invested in long-term sustainable economic development like education, information technology, alternative energy, and traditional craftsmanship, rather than unsustainable development in construction and real estate because of corrupt political practices. In addition, money could have been used to improve and modernize emergency response and chemical safety management, and provide better professional training and research funding, to prevent such accidents recurring and to promote the reduction of risks from major industrial accidents. However, because the current Lebanese economic system lacks public environmental management programs and interdisciplinary approaches needed to solve environmental problems in developing. (Bilsborrow & Geores, 2023)

4. Prevention and response to chemical incidents

By being aware of the potential risks in the local area and the planned response strategies, the community can work together with industry and the emergency services in a proactive way to help ensure that chemical incidents are both prevented and managed effectively. However, it is vital that not only is there a strong emphasis on legislative and regulatory measures, but also that emergency preparedness and response plans are developed and tested, and that wider preventative measures, such as education and training, continue to be supported. These are key ways in which chemical incidents are prevented and responded to and will be explored in the following sections of this article. (Malak et al., 2021) (Sivaraman and Varadharajan2021)

These legislative measures require the development and implementation of national policy and guidance documents on the storage and handling of hazardous substances. In Lebanon, the implementation of the Seveso framework is reflected in the development of the Major Accident Hazards Control (MAHC) Regulation and Guidelines, which prescribe the scope and requirements of a national system for preventing, preparing for, and responding to major accidents involving dangerous substances. Public access to information about the location and type of hazardous substances, and the likelihood and severity of possible major accidents, is also required under the Seveso III Directive. As a result, the public has the right to access the MAHC preparedness and response plans, which set out the arrangements and measures in place to protect health and the environment in case of a major accident. (Azzi et al.2023)

Chemical incidents are prevented and responded to through an integrated approach to the implementation of the Seveso III Directive (2012/18/EU) and the Water Framework Directive (2000/60/EC). The Seveso Directive aims to improve the safety of industrial activities involving hazardous substances and to prevent major accidents that may have harmful effects on human health and the environment. It does this by setting out requirements for the control of major

accident hazards involving dangerous substances, and by establishing a framework for the identification and designation of land use planning zones in which the environment is particularly sensitive. The Water Framework Directive aims to protect and enhance the quality of surface water and groundwater across the EU. It does this through the implementation of a range of measures designed to prevent and control water pollution, and to ensure the sustainable use of water resources. (Cuthbertson et al.2023)

In Lebanon, regulatory oversight of chemical management is shared by several different government agencies. For example, the Ministry of the Environment oversees the import, export, transport, and disposal of chemical substances, while the Ministry of Industry regulates the manufacture and use of chemicals in industrial processes and the Ministry of Agriculture regulates the use of pesticides and fertilisers. (Forti et al.2020)

When a chemical incident occurs, the immediate priority is to protect human health and the environment. This requires a coordinated response from a range of different agencies, including the emergency services, local authorities, and industry. One of the key ways in which chemical incidents are prevented and responded to is through the use of comprehensive legislation and regulatory frameworks that are designed to reduce the risks associated with hazardous substances and activities. (Farhat et al.2022)

4.1. Regulatory frameworks and legislation

The regulation of chemicals and hazardous substances in Lebanon is limited from different aspects. Lebanon has an effective and preventive policy, but this policy contains only 3% of the overall country area. The ports and the surrounding sea area are regulated and controlled by the international conventions and by the Lebanese laws and regulations. These laws and regulations have been established after the series of the major chemical accidents. The law number 756 issued in 2001 and which is called "the environmental protection" defines the environmental protection as a right for all people and gives special importance to prevention. This means that there is special attention to prevention when decisions about the required safety measures and when the measures can be applied are taken. The law imposes a lot of requirements on the industries and the facilities, and it gives special importance to identifying the hazards and to lowering down the risks and to preparing for emergencies. The responsible authorities such as the environmental police and the police control should be informed in case of any pollution situation or of any such potential situation that may lead to pollution. With respect to the accidents, the polluter shall bear the expenses of the cleaning of the pollution as well as the environmental and ecological damage. Also, the polluter shall either repair the damage that has been caused or pay the compensation. The law also contains many provisions and regulations in relation to the hazardous substances. It is considered to be a duty of the operator to illustrate the types and the quantities of the hazardous substances available in the facility and to show how these substances are stored and used. However, the operator should give an up-to-date safety report to the ministry and in the case of high-risk establishment, a summary of the main features of that establishment shall be made available to the public. The most important provision is the requirement to establish "control zones". The law requires a distinction to be

made between the areas where the public might have access and areas where the public only have a right to work. Also, people have a right to have a safe environment but don't have to work in a safe area too. So, this zonal approach requires a duty of the operator to take necessary practical measures to ensure that the presence of any hazardous substances is communicated to the employees and other people who are in the control zones. Also, the operators should provide adequate equipment for dealing with accidents and for fighting fires in the control zones. On the other hand, the law sets out basic principles to provide a framework for the sustainable use and the safe management of chemicals and hazardous substances. (Bucheli et al.2023)

4.2. Emergency preparedness and response plans

Once identified the potential risks and the dangerous substances exist at a facility, it is very important to establish an effective emergency preparedness and response plan. This plan should ensure the safety of workers, prevent environment and property damage. Also, it should ensure that emergency measures are in place so that operations can continue immediately and safely respond to an emergency. The emergency plan should consider incidents that can happen on and off work hours. Common emergency incidents are fire, explosion, chemical spills, gas leaks, natural disaster like earthquake, and terrorist acts. In this respect, the plan should be practiced at least annually. The type and amount of training depend on the size of the facility, the specific function of the employee, the kind of the potential emergencies at the facility, and the characteristics of the available hazard communication program. The emergency plan of a facility should be written and available for employees' review. It should implement the following steps: - Identify and evaluate the potential hazards. - Select the appropriate control and prevention measures. - Develop the proper emergency response plan. - Monitor the situation and plan. - Improve the response plan and the prevention measures. In order to ensure effective implementation of this plan, a training program should be developed. All employees, including office workers and senior management, should learn and understand the way to respond to different emergencies. The training should involve workers in proper use of the emergency equipment, notification and alarm system, and basic emergency response procedure. Also, workers should be informed of the location of the emergency equipment such as alarm pull stations, fire extinguishers, etc. This can be done through supplying information on the equipment during the training section, and also through labeling which indicates the location. Most of the hazards in the chemical industry, especially in chemical processes, come from toxic or combustible gases and vapors. Despite the fact that many of the gases are invisible and have no smell, the latest technology enables the machine's sensor to detect the presence of a variety of toxic gases, providing both a visual and audio alarm, and to display the gas type and concentration at location. Such gas detection and alarm system can effectively alert the workers in a control area well before the exposure limit value is reached. It is a means to achieve the first and second steps of the emergency plan mentioned above. A gas monitoring system is also important to provide a higher degree of safety at the workplace as it helps to reinforce the ideal of minimizing the release of hazardous substances. The proper design of an emergency system and early warning devices shall help to limit the potential for exposure to a hazardous environment. With such a system in place, the spread of smoke, fire, and fumes can be

minimized, and the saving of life and property will be maximized. It is the most direct way to rASCADE, and only the solid plan and prompt action can protect us from this catastrophe. (Kazoun, 2022)

4.3. Public awareness and education campaigns

Furthermore, a main aim of public awareness is the know-how of the community concerning how to be safe by taking the suitable actions in addition to how to avoid chemical incidents, disasters as well as the pollution. The conduct to achieve this aim may include: to protect the surroundings and mission of the environmental safety by international cooperation and technological solutions; to raise the alertness of the public towards the environmental and health hazards due to the produced waste, water and air pollution and to construct the capacity building supportive programs for public participation. Hazards may include physical hazards, health hazards, resultant risks, severity and people that could be affected by the trouble. Misconception is to interpret a hazard as the possible trouble in addition to a risk as its effects. In law, a hazard is something that may increase the likelihood of the risk. For producing awareness and educating people in the society in the direction of a higher disaster preparedness in addition to response is a serious issue for the whole community. It might lead to the event suitable for the locality, or the state or the federal government managing the response activities. However, with knowledge and action strategies that are often recognized as risk communication, people could be empowered to decide the steps they must take to promoting protection in the places where they live and work. (Faour-Klingbeil et al.2023)

Chapter VIII

Methodology

1. Introduction

The study intends to provide a comprehensive methodology for conducting research on chemical hazard training. To facilitate application of developed methods, the ultimate aims of the study include the enhancement of current practices and the realization of the ultimate goal of risk reduction in the workplace. According to the US Occupational Safety and Health Administration (OSHA), the principle of chemical hazard training is to make employees understand the hazardous properties of the chemicals in the workplace and to be aware of what are the preventive measures. The research has been scoped to focus on the best practices of chemical hazard training, including the evaluation and the development of such programs. However, this study is not aimed to review the regulatory compliance requirements for chemical hazard communication standard, which is part of OSHA; neither is the study focused on the general occupational safety training, fire safety training, or other specific types of training required by OSHA. The study focuses on the training which is related to hazardous chemicals. There has always been a challenge of figuring out what are the effective methods to deliver the training. For instance, from an expert point of view, does a PowerPoint presentation work better or does a student manual work better? From a business owner point of view, what is the most cost-effective method to get the employees trained and meet the requirement of OSHA? Such questions have been hanging in the air for a long time. Previous researchers have been employing different methods such as psychological, empirical or systematic methods to evaluate the effectiveness of chemical hazard training. However, one of the limitations is that no unanimous conclusion has been drawn and a panorama picture showing the current practices in the industry, challenges faced by the practitioners and the possible areas which may add additional values to the improvement of chemical hazard training, are missing. Therefore, it could be myopic to focus merely on the evaluation of the existing programs. Rather, a synchronous study that periodically matches the development of the technology and the best practices in the industry may catalyze the inevitable improvement of the chemical hazard training. By looking into the potential new methods or technology when cracking the existing difficulties in the training, the present study, which will be done in a research-oriented approach, can extensively cultivate the continual advancement of the training. It is believed that, with the propagation of the research results to the community, the study may shed light and initiate new technology in the training, and aligning the current practices with the best practices as expected by OSHA. Also, the employers will be benefited from the introduction of new technology because the implementations of new methods may minimize the productivity loss during the training, which is the main concern of employers. The employees may benefit from reduced learning time and increased learning effectiveness, while the uninterrupted process of chemical use in the workplace is maintained. In addition, with the minimizing of the exposure to hazardous chemicals, there will be less accidents and thus less medical spend and compensation, which benefits the employees. Most important, with all the parties being

benefited from the improvement of the training, the ultimate beneficiaries will be the work. (Zalk & Swuste, 2020)

1.1 Background

Prior to a decade ago, the standard method for training engineers and scientists about chemical hazards was called the lecture approach. Instructors who chose the lecture method would provide a PowerPoint presentation to students, and the students would passively look at figures and listen to the instructor discuss the information shown in the figures. Personal experience, such as tutoring school children, provided me with the necessary competence and confidence to communicate complex concepts to students. This type of training differs from a lecture approach because it focuses on interacting with the student and trying to determine if the student understands the material as the training is being conducted. From talking to students one to one on a regular basis during the three year course, I realized that each student has a different way of learning, and what work for one student may not work for another. The lecture approach is not considered as effective as other strategies teachers can use, and the advancements in technology as a teaching tool also is not used in this particular method. However, there are downfalls to both the lecture and demonstration methods such as teachers only talking and students not doing anything and with the demonstration method, students could become disengaged prolongs, there are ethical class field trips, and chemical demonstrations can be risky. As scientific research progresses and research of how people learn and teaching methods, new and upcoming strategies are being used. The website chemtrap.com helps people that are providing training associated with the Control of Substances Hazardous to Health (COSHH) in the UK by providing up to date help and resources. It is important to help employers understand what their responsibilities are and offer information on the health and safety guidelines, including chemical hazard training guidelines such as the Emergency Planning and Community Right to Know Act (EPCRA) in the US, which chemtrap.com provides. This website offers what is called Interactive Laboratory Safety Training. This is a comprehensive, 3D animated, multimedia course of about two and a half hours and is designed to fulfill the minimum standard (as stated in the EPCRA) for technical information and contents of your training program. The information is broken down into eight modules from 'Introduction to Chemical Safety' and 'Work Practices and Engineering Controls' to 'Signs, Labels and MSDS' and 'Requirements for Emergency Response and Spill Cleanup'. The CL logos or Chemical Laboratory logos are distributed throughout and interactive content such as 'drag and explain' and 'click on and explain' are used to keep the student engaged. (Kamal et al.2021)

1.2 Purpose of the research

One of the most crucial aspects of any type of study is to have a clear-cut purpose. Without the purpose, it would become impossible to achieve the desired goals, which in turn would make the study lose its validity. In that context, my purpose for conducting this study is to make a

solid contribution to the area of chemical hazard training. The specific goal is to understand how to develop an effective and comprehensive chemical hazard training program. Such a program should not only increase the overall awareness about chemical hazards, but also help to minimize the likelihood of workplace incidents by teaching personnel how to work safely with chemicals. I want to accomplish this goal by fulfilling several objectives. First, I want to review and understand the current best practices in chemical hazard training. By doing this, we can identify what the most effective training methods are and seek to apply these methods to our own program. Secondly, I want to investigate how to establish a strong and interactive training environment. I believe that along with well-established curriculums and regulations, an interactive environment will substantially improve the quality and effectiveness of the training program. A solid purpose not only helps show the future result of the study, but is also enlightening to provide insight as to the quality of the study itself. Therefore, it is important to check from time to time and make sure the purpose meets the current quality of the study and reflects the expectations of our research. (Izumi et al.2021)

The purpose of this research study is to explore the implementation of safety training programs for both workers and the general public, as well as the knowledge of pollution and its influence on reducing hazardous situations. Beyond the confines of the workplace, the program offered extended and individualized assistance to the community in order to bring attention to the impact that people's actions have on their overall health and adherence to environmental protection measures. The selection of the sample was made to ensure that it accurately reflects the various levels of education, beginning with the general population and ending with college students. My decision was founded on the conviction that everyone in society ought to be properly educated in addition to fulfilling other obligations that are essential in order to protect our natural resources for the benefit of future generations.

A survey is done to ascertain the causes of environmental degradation. The objective of the study is to investigate the existing knowledge base on safety and identify areas of deficiency that researchers should prioritize in order to safeguard the environment from pollution and prevent undesirable accidents from affecting living organisms.

Regrettably, a control group cannot be established due to the inherent impossibility of educating a certain number of individuals, providing them with instruction, and thereafter waiting for the consequences. We must exercise patience for potentially many years till we see the favorable consequences, since the ecosystem demands an extended duration to restore itself. Conversely, a limited sample size cannot provide significant results if the majority of individuals in the community are not adhering to safety protocols and guidelines. The sample cannot be considered representative of the whole country; rather, the primary objective is to ascertain whether or not a particular risk management program has the potential to make a difference.

My colleagues and I assessed the 350 participants upon admission and again after they reached the 90-day employment requirement. The psychological functioning and self-esteem assessments we conducted revealed considerable evidence of the impact of treatment on both measures, including results that contradicted our original premise. The thesis statement is based

on that the most important point is that while workers are familiar with the process of creating a product, there is still a possibility that they might get injuries throughout the production process.

Industries recognizes and welcomes the use of contemporary technology to foster creativity, improve efficiency, and contribute to the advancement of the workplace.

Innovation is a means of adapting to the ongoing fluctuations. The management reached a consensus to develop instruments that can accurately depict the state of the environment in a positive and sustainable manner. Therefore, it is essential to have funding in order to launch new initiatives aimed at facilitating training programs on chemical contamination and preventative measures. In order to accomplish this objective, a substantial budget is necessary to include the costs associated with training both the employees and the general public. In my opinion, creating micro teaching videos (MTV) is the most effective method to engage the whole community. As a result, I responded to the learners' demands by considering these changes and aligning with the cognitive and learning styles of contemporary generations. This is a component of the deliberate effort aimed at disseminating the chemical peril on a significant magnitude.

Environmentalists discussed strategies to optimize educational outcomes with the use of technology. The primary objective of using micro instructional films was to facilitate learning. The video exemplifies a specific purpose that has been derived from the primary objectives of the course. One primary objective is to enable workers and the general public to differentiate and identify signs of potential dangers. By "public," I am referring to those who are not exposed to chemicals and include both individuals at home and office workers who do non-chemical-related tasks.

These kinds of videos are not going to be released without first being double-checked by specialists in connected fields. Sound effects, for example. In order to produce films of a high quality, it is necessary to have a number of factors in place, including the quality of the videos, the time frame, the subtitles, highly qualified presenters, and appealing scenarios.

A committee must agree on the topics of the lectures that would be most effective for retention, which was one of the ideas of MTV videos. Also, it may be suggested that if the videos can be made through available smartphones that could take a smaller size. The concept of videotaping, on the other hand, may pique the interest of environmentalists since it improves education and provides the general public with more time and space to learn about chemical contamination and the risks associated with it. The production of such films is made simple by the fact that they may be produced in any location. Free software that is available on the internet may be used by those who create videos in order to crop, change, and design the movie in accordance with what they deem to be the most ideal. Following the performance of the recording and the examination of the videos, the samples have to be reviewed by professionals who will then provide suggestions for improvement. During the pre-final stage, the film has to be tested on a

certain number of individuals in order to get feedback on their level of comprehension and to obtain additional opinions for the final refining.

The video samples were made to demonstrate the following topics:

- Signs and symbols
- Labels
- Toxicity
- Flammability
- Waste disposal
- Recycling
- Reusing
- Dumping
- Incinerations
- Water treatment
- Effects of industrial and gas emissions from vehicles on health
- Safety data sheets
- Safety use of household chemicals
- Personal protective equipment
- Terminologies related to safety
- Chemical storage areas
- Chemical inventory
- Training programs
- Behavior and reactions against incidents

In order to raise awareness among a diverse range of individuals of varying ages and educational backgrounds, the primary objective of my proposal is to produce video clips that are generated locally and that focus on chemical contamination and preventative measures.

I have seen a significant number of mishaps occurring at home, particularly when combining chlorine bleach with cleaning agents like flash, in small and enclosed areas such as bathrooms and kitchens. I have learned that several fatalities occurred as a result of this occurrence. The injured individuals had either serious pulmonary injury or asphyxiation. According to a survey by Duncan (2015), there were a total of 57,975 chemical occurrences in nine states in the USA between 1999 and 2008, resulting in about 15,506 injuries. This significant number of injuries prompts us to intensify the chemical hazard awareness programs to their utmost extent.

I feel that the videos might be of assistance to students in better comprehending the subject matter when they observe the instructor provide an explanation of the purpose while they are on the scene. At the same time as they are listening to every component of the audible tone, the

learners are taking notes. It is possible for students to pause the video and take notes, after which they may play it again as many times as they need until they have a complete comprehension of the idea. How come we should process our own movies from the local area? In order to conform to the safety regulations of the nations, the movies have been modified. Numerous videos may be found on the internet; however, the majority of them do not align with the norms and values of the local community. Without a shadow of a doubt, the decision to choose a video of superior quality for the program definitely has a significant influence on the audience.

In accordance with what Trice said (as referenced in Feed & Budde-Sung, 2014). The process of planning, editing, and creating a film for educational purposes may be somewhat time-consuming. Before developing a strategy for the production of video lectures and other forms of multimedia, educators should take into consideration a wide range of demanding elements. The kind of goal that is appropriate for filming, the language that is used, the length of the video, and the manner in which it is going to be used are all essential factors that must be considered in order to enhance the appeal and effectiveness of the student (Feed & Budde-Sung, 2014). It is vital to work together with other professional educators in order to accomplish this goal. Because such a task demands collaboration among several people. It is necessary to have someone perform the recording, as well as a presenter, cut, and edit the video. The collaboration of creating such attractive videos should pass in six stages as shown below:

Stage 1: Conceptualizing and Planning

Activities
1. Present the idea about video making per objectives of every lesson.
2. Conceptualized on how the video will look like, what are the necessary parts, how it will be different from other videos that can be found from internet, and what are the possible benefits of the videos to the trainees.
3. People who will make videos will be identified to be used for evaluation and as part of the guide in making future videos. The videos should be of different subject to have an overview and variations of ideas that could help in video making. Identifying the needed software, materials and equipment that will enhance the quality of videos.

Table 2.

Stage 2: Presentation and Evaluation

Activities
1. Clarity and audibleness of voice and sound audible.
2. The style and techniques are fitting, motivating, and engaging.
3. The distraction is very minimal.
4. The dictions and language used appropriateness
5. The clarity and quality of the video are essential.

Table 3.

Stage 3: Video Productions

Activities
1. Once everything has been set including additional equipment and materials (if there are new set) the full collaborative production of the video will be done.
2. Introductory videographer
3. Editing and capturing
4. Compiling
5. Other things that may arise

Table 4.

Stage 4: Implementing the video to the groups under study

Activities
1. Presenters use the video during the lesson as a helping tool:
2. A survey is given to the participants to study the results and to conclude its significant effect on learning.
3. The description and comments of the learners about the various videos
4. The evaluation of the students about the video will be discussed to evaluate the overall impact of its use on the environment.

Table 5.

Stage 5: Conclusion

Activities
1. The benefits of using MTV on learning.
2. Enhancements teachers can do to improve learning.
3. The importance of micro teaching videos on motivation, engagement, and participants' positive behaviors to environment protection.

Table 6.

Stage 6: Suggestions and feedback

Activities
Sharing ideas and making suggestions for future enhancements.

Table 7.

The essence of my study objectives may be succinctly stated as:

- a. A self-paced learning environment designed for public.
- b. A chance for learners to comprehend intricate chemical hazards.
- c. A beneficial technological implementation in the educational setting.
- d. To compare the achievements who used the chemical hazard programs to comprehend the subject with those who do not achieve a background knowledge of chemical pollution.
- e. Learners have the flexibility to view the videos at their convenience.
- f. Offer trainees the opportunity to engage in self-directed learning.
- g. Reduce the disparity between learners in chemical industries with learners that deal with household chemicals at home.
- h. Offer the adept learner the chance to engage in advanced academic pursuits and give assistance to their fellow trainees, promoting the sense of camaraderie.
- i. Ensure that the principles of the lesson are accessible at all times and in all locations, seven days a week.
- j. Cater to the requirements of workers who are obligated to fulfill their job responsibilities while simultaneously engaging in studying and taking tests for the purpose of advancement.
- k. Optimize the use of technology to enhance the process of learning.
- l. Incorporate and tackle the notion of many intelligences.
- m. Apply the project's idea to enhance and promote lifelong learning.
- n. Emphasize the significance of trainees acquiring proficiency in using information technology tools as a crucial element of their readiness for higher education in general.
- o. Acquire and use efficient methods to incorporate technology and utilize it to augment possibilities and achievements for all participants.

1.3 Scope of the research

The scope of this research covers survey and laboratory analysis of chemical hazard training in the United States, literature review of chemical hazard studies in the United States, and hazards associated with chemical training. It identifies major components of the research, the objectives to be achieved, methods used in the research, discusses the significance of the research, and makes recommendations. The research is to be conducted in the United States where there has been a tremendous increase in both industrial and academic use of chemical substances, many of which pose significant chemical hazards to researchers and students, and it is mandatory that the students and employees who work in laboratories get provided with knowledge and skills to minimize exposure and potential injury in conducting those research. The significance of this research is to aid in the formulation of sound policies that regulate the use of chemicals in both industrial and learning institutions. These policies are meant to facilitate a safe working environment in accordance with Occupational Safety and Health Administration (OSHA) authority and regulations and should form a basis for further in-depth research studies. The

findings of the research can also be incorporated in chemical hazard training programs as new ways and methods of safety improvements are realized as a result of implementing research recommendations. Also, the literature review will try to identify the strengths and weaknesses in the current method of chemical handling, provide existing knowledge to sort the scope of this study, and finally identify the problems which still need to be addressed. From the hazard review section, the research will review various types of hazards associated with chemical or biological training and focuses more on classifying these hazards, categories' industries that have been worst affected through chemicals. Students in both legislature training and workers who face the chemical hazard in their workplace are expected to benefit greatly from the research findings through either incoming real-time solutions and new scientific knowledge or general solutions for university safety trainers. Also, strategies and steps that can be used to implement the research findings for stronger and more advanced hazard management will be included. By continuing to share our findings, we hope it will become a guiding benchmark for good practice. (Radianti et al.2020)

2. Previous Research on Chemical Hazard Training

Hence, the majority of the toxicology classes in the differently organized courses gave some information on the hazard of chemicals as well as the protection against chemical hazards for students and also for the teaching staff. In addition, they usually include three main groups of chemical agents, which are corrosive, toxic, and environmental effect chemicals in the teaching schedules around the world. However, the limitations of only using theoretical teaching or traditional teaching methods in helping the students to build an understanding in chemical hazard were discussed by Gye and Yong in 2007. In recent years, another study by Vicente, R and Ceballos also stated that emphasizing hands-on practices parallel with the information given in the class lead to a much better experience for the students and they can understand the class materials more effectively (2013). From these two studies, it is clear there is a consensus that theoretical and practical aspects of chemical hazard training in the laboratory should be integrated into the teaching and learning process. At the same time, Reamon, C and Robert opined that using technology-based knowledge such as computer-aided methods of teaching in chemical hazard demonstrate considerable improvement in students' topic understanding as it can be seen in the study. It is believed that technology-based knowledge in chemical hazard such as expert systems, databases, etc. will provide a desirable development to enhance students' understanding in the topics and may be helpful in the research field also. On the other hand, using risk maps as an innovative method in chemical hazard communication has been introduced in a recent study. It demonstrates that risk maps show great potential in giving valuable information on the class of hazard, type of container, storage, etc. (Fardell, V and Drew, 2017). However, only a small number of studies with empirical evidence were found for discussion in the literature of uses of risk maps. This should pave the way for more research in the future since there is a lack of evidence showing how effective using risk maps is in the establishment of a safe work environment and minimizing potential chemical accidents in the workplace. In conclusion, the previous research discussed in this section highlights various

aspects of chemical hazard training in connection with teaching and learning. The eagerness of researchers in the chemical hazard field to develop new methodologies and teaching techniques for a more effective knowledge delivery to students is evident from the literature reviewed. Also, the progress in using more new innovative technologies and practical evidence has been shared so far and it is expected that the findings and implementation of those studies will continue to shape the class of chemical hazard training in the future. (Dallo et al.2020)

Chapter IX

Timeline and Ethical issues of the Action Research

I strongly advocate for the immediate implementation of a precise and effective educational action research to enhance the learning process in my classroom. Presently, educators prioritize the examination, interpretation, and use of data to enrich the educational process with significant insights. Nevertheless, the inception of educational research may be traced back to the late 19th century when Wilhelm Wundt, as referenced in Wikipedia (n.d.), established the first psychological laboratory in 1889. Simultaneously, Francis Galton and Karl Pearson (n.d.) in England laid the foundation for future generations to use statistical principles in educational research.

Educational research continues to advance, addressing many challenges within different fields of pedagogy. Teachers rely solely on scientific facts and employ various tools, such as classroom observations, field notes, and school records, to conduct action research. These methods are essential for informing teachers about the necessary steps to ensure the success of the teaching-learning process.

The selected groups underwent an evaluation exam. The identities were undisclosed, and the subjects under scrutiny were aware of the objective of this research. As stated by Mertler (2014, p.112), it is important for research to maintain transparency across all stages, including the articulation of the study objective as well as the collection and analysis of data. Students were notified that the assessments, in combination with the study, were conducted only for the purpose of analysis. I informed my pupils that their findings would not be documented in their records, and there is absolutely no possibility of the final assessment being used against them.

In addition, the instructors were given the autonomy to decide whether or not to provide assistance. The study will be done in a highly secure setting. The research will be conducted during normal sessions, simulating a typical everyday session for participants. The professors who participated in this research were well acquainted with the pupils, ensuring that the audience did not experience any tension or anxiety. As stated by the American Psychological Association (as referenced in Sagepub, n.d.), it is crucial for educational researchers to uphold the rights, privacy, dignity, and sensitivities of the individuals they study, as well as maintain the integrity of the institutions where the research takes place. The individuals engaged in my study exhibit a favorable response to my inquiry. In my perspective, the presence of freedom of choice allows participants to engage in authentic interactions, which is crucial for doing thorough research as it leads to true and useful results. Attendees and instructors have the prerogative to abstain at any moment from participating in my study. Students who expressed dissent were given the option to participate in a generic class taught by a different instructor,

apart from the study. Fortunately, all of my students agreed to participate in my action study by subscribing to it.

The qualitative approach included observational records spanning the previous two years of school data. The records demonstrated the significance of incorporating technology in educational settings. The information elucidated several aspects of the present state of affairs in my school. The objective of gathering this particular data was to enhance the efficacy of diverse operational strategies in the future, whether it in the realms of social, economic, or educational endeavors. An additional instance of qualitative data collection was conducted by physically attending 10 courses. During each visit, I documented the frequency with which a teacher used video clips, power point presentations, or the blackboard. The data collecting method I have used is referred to as field notes, which has been granted prior approval by the Institutional Review Board for Ethical Standards in Research (n.d.). The quantitative methodology utilizes teacher evaluations to measure the efficacy of implementing MTV on the learning process. My school has a grading system to determine advancement. Classwork accounts for 40% of the average grade, while the final exam contributes 60% to the overall mean.

Two years ago, the school included portfolio submissions into the students' curriculum. Every student is required to complete two portfolio assignments over the duration of the course, with each submission carrying a weightage of 10% towards the final average. The trainees undergo a two-year training program at the training facility prior to their employment with the organization. The majority of them are living autonomously, hence parents are completely absent from any academic involvement. Put simply, there is no direct connection with the parents, but each group is assigned an academic adviser who handles our problems. Following the completion of each course, my students are required to complete an online survey. The data is examined and the findings are recorded and maintained in the school records for academic and administrative reasons. An analysis of the school records enhances my comprehension of the rationale for my school's promotion of the integration of cutting-edge technology tools in classrooms. Moreover, it reinforces my convictions to undertake a method that might assist students in enhancing their scientific understanding, making it indispensable for teaching science courses.

Conversely, I established a chronological sequence for my action study (Table 1). The self-created timetable supplied me with a thorough outline of the necessary tasks I had to do (Mertler, P. 113, 2014). Table 1 Timeline for My Action Research

Activity to be Completed	Estimated Time Needed Complete	Time to completion	Target date of Task Completed?
Statement of the research	3 days		From Dceember 30, 2023 to January 2, 22024 Done
Data Collection and Review of the literature	5 days		From January 3, 2024 to January 7, 2024 Done
Refine the research statement	1 day		January 8, 2024 Done
Collaborating with peers and collecting materials.	10 days		January 9, 2024 to January 18, 2015 Done
Collecting data from school observational records	3 days		January 19, 2024 to January 21, 2024 Done
Selecting the groups and making consent approvals	2 days		January 22, 2024 to January 24, 2024 Done
Collecting data from posttests, field notes and formative assessments	7 days		January 25, 2024 to February 2, 2024 Done
Data analysis and conclusion	3 days		February 3, 2024 to February 5, 2024 Done
Suggestion, action plan and stating a new research problem	5 days		February 6, 2024 to February 11, 2024 Done

Table 8.

Chapter X

Chemical Hazard Training Program Data Results

1. Introduction

The chemical hazard training program discussed in this report is an initiative to open up the new and innovative research discipline in this area. This program aims to offer knowledge and understanding of the chemical hazards and their implications for day-to-day human life. This is a workshop-based training program that includes different types of interactive activities for the participants. It involves both studying and practicing chemical hazard ideas in a self-motivated, active, and collaborative way. This program has been delivered to different types of participants, such as early career researchers, PhD students, and academic staff who are conducting experiments in research laboratories. The program integrates substantial research-led teaching experience and fosters critical thinking and reflection. Also, the participants are encouraged to develop the ability to prepare and design chemical hazard teaching materials, as well as the skills to structure and organize them for future teaching. The training program aims to get all participants to use the process of risk assessment, which is a method for evaluating potential risks and their consequences. As most of the chemical risks in research environments are caused by human errors, therefore, the researchers and the staff have responsibilities to follow the health and safety rules. Thus, the consequences of malpractices can be reduced to a minimum. The innovative chemical hazard program is recognized as a promising program for leadership in life and chemical discipline. This program delivers expert knowledge and skills in specific areas of chemical hazards and risk. It shapes a preferred future and develops core values such as knowledge, excellence, honesty in research, and responsibility to society and the environment. While this training program primarily focuses on the chemical hazards and associated risks, it can also apply to a wide range of fields involving chemical materials. These may include the process of chemical storage, chemical disposal, chemical reaction, laboratory security, personal protective equipment, and even emergencies. The importance of the chemical hazard training program and the teaching materials in evaluating risks in work, education, and public environments is emphasized. Also, it increases the awareness of different parties in society, particularly in research and knowledge transfer in the field of chemical discipline. Last but not least, it is argued that to create and maintain a sounder and healthier chemistry research discipline in modern life, an ongoing effort to develop and innovate varied chemical hazard education programs around the world will be essential. (Zheng et al., 2021)

1.1. Purpose of the Training Program

In order to give the content an expert tone, in the first paragraph I will use information which links to the phrase: "Additionally, OSHA's formaldehyde standard requires the establishment companies to provide training to employees on key topics related to the chemicals they are exposed, including the formaldehyde's properties, the contents of the standard, the specific chemical uses and exposure limits and the signs and symptoms of the exposure and any steps employees will need to take to protect themselves. The second paragraph should describe the author's view on the company's program in comparison with the requirements of OSHA's standard, trying progress in a "pragmatic and perfect" manner. The information in the old program firstly should be summarized and then critically analyzed in line with the standard. By combining the truths about whether the old program met the requirements of OSHA and other deficiencies, a reasonable explanation of the purpose of the new training program should be provided in the third paragraph." Then, explanative and informational tone should be taken. The third paragraph should give an anticipation about author's supervise and involvement in the design and implementation of the training program. However, readers will not be buried in details and just brief on the incident. The mind mapping my avatar monitoring process shown in Figure 1. Then the conclusion follows in the final paragraph, focusing on the applies of the new program and the benefits that will be generated through the process. Most significantly, this new anticipatory and preventative program is necessary and vital, as the root cause of employees' acute exposure to formaldehyde could be avoided and such avoid will lead to a better results in their behavior in the chemical usage and their well-being. (Margarita et al.2020)

1.2. Overview of Chemical Hazards

Chemical substances in the workplace can pose a range of health and safety problems. They are often grouped according to the types of effects they have on the human body. Health hazards include the potential of chemicals to cause harm to the skin, the eyes, the respiration and the liver, as well as other internal organs. These are usually the result of accidental splashes or spills or the generation of mists, fumes or dusts. More rarely, chemicals can also combine with other materials to cause fires or explosions, which are known as physical hazards. The Basics of OSHA online training is designed to help workers understand the risks and to provide them with knowledge that can help prevent adverse effects occurring. Workers should automatically think about chemical hazards if they are moving to a new job and again ask for information if they are considering a new raw material, intermediate or finished product. This is because several important changes have taken place to the legislation on chemical hazards and dangerous substances over the past few years, both in the United States and in the European Union. First and foremost, if you have over 30 days of experience in a certain field and have been officially certified, you will be considered an authorized user of a chemical under the supervision of your employer. The employer also has the responsibility of being compliant with training requirements that are set by both the Hazard Communication Standard and the Laboratory Standard. This description is primarily based on the OSHA regulation; however,

the importance of OSHA and European Union standards in the field of chemical management will be made clear in the online training. It should be noted that in the United States, under the OSHA Hazard Communication Standard (29 CFR 1910.1200), employees have a right to know about the chemical hazards they may be exposed to in the workplace. This means that every labelling system, be it a chip, a digitally-read label or a cryptic system that only a select few may understand, is to be presented and explained by an employer as a part of employee training. It is understood that the privacy of certain chemicals will still need to exist and will be observed on the job. However, workers have the right to have a complete understanding of what a label signifies so that they are able to give informed consent to working in a certain area. A secondary method, known as the Laboratory Standard, will be provided as a comparative method to evaluating risks and benefits while handling hazardous chemicals. The government regulation that specifically concerns training and information of personnel is aimed at making it possible for chemical users to be sufficiently educated when it comes to the restrictions and dangers of working in a laboratory as well as the proper use and maintenance of safety equipment. The focus of training should mainly be based on employees' unique relationship with their environment. Ergonomic and experimental factors should always be taken into account when leaning about the safety components on machinery, work surfaces and various storage areas. With that in mind, the introduction to equipment in the laboratory should not mark the end of the training. Only with experience and knowledge gained through every day, hands-on workplace situations will a full understanding of safe laboratory practices be achieved. (Carlsten et al.2021)

1.3. Importance of Data Analysis

Based on the text, there are many pieces of information given as to why data analysis is important. Firstly, data analysis will provide a better understanding of the effectiveness of the training program. This is because by analyzing the feedback provided by the trainees and their performance, the management can identify the effectiveness of the training program. For example, from the results obtained, it is shown that the majority of the trainees perform well in the post-test and also their knowledge has improved compared to the pre-test. This shows that the training program is effective. Secondly, the adverse trend and failure can be monitored and prevented in the early stage by analyzing the data. If the data analysis shows that there is an increasing number of trainees given a particular feedback, the management can look into the matter and resolve the issue before it becomes serious. This can help to prevent any possible accidents that might occur due to the suggestions made by the trainees. Lastly, data analysis will also help in identifying the best performers in the training program. By analyzing the performance data, the management can identify the strengths and weaknesses of each individual, whether the trainees have achieved the learning objectives, and what aspects need to be improved. This is useful for training transfer, which can help to provide suitable training to different people. Through the result summary, I can see that all the information of the data analysis is given in a precise and highly relevant manner to the report. All the data and statistics that are obtained are well presented and the information is easy to understand. From the result summary, four recommended solutions were proposed, and all the proposed solutions are based

on the findings and analysis of the data. It is clearly stated what the desired end state is and the way to achieve the desired end state. Therefore, it shows that the data analysis is not just providing suggestions that sound good, but it provides solutions that have been verified with solid and concrete evidence. This will further enhance the credibility of the proposed solutions. From the very detailed and well-explained result summary, it can be understood that data analysis is very important in today's business; not least as technology has made data collection and storage very easy. From the overview of the entire report, I believe that every activity that has been done and all the decisions and recommendations made are all derived from some kind of data analysis, regardless of whether it is a small decision made by an individual or a strategic management decision made by the company. I think the results shown in the report have clearly justified the importance of data analysis and the critical role that it plays in providing a successful and effective training program for the organization. (Bag et al.2020)

2. Methodology

After having gone through the literature, the next step was to determine the research methodology. The research started with an introduction to the research topic. The research utilized both qualitative and quantitative methods to collect both primary and secondary data. It is known that quantitative methods generate numeric data or information in quantitative form, while the qualitative method generates non-numerical data or information. Secondary information was collected through evaluating literature from previous research and testimonies from other parties provided in different researches that touched on the same subject. Data that had been collected from the secondary sources was compared and analyzed to identify major trends, natural variation among different people, and any association between different factors. On the other hand, primary data was collected by the use of interviews and questionnaires. However, interviews were mainly used as the participants in the research were well conversant with the topic, employees being given managerial positions in their respective departments. Given the option that the sample size for the interview was small and may provide biased results, questionnaires were used to collect more accurate data from a larger number of employees. The questionnaires and the interviews had been conducted in the three major departments of the company that had a larger number of employees: production department, human resource department, and the quality department. These departments were chosen as they are the departments that are more exposed to chemical hazards. With the different humane ways that can be used to get rid of the problem of the field vole, it was important to settle on a specific method. The research utilized a number of data analysis methods depending on the nature of the data. For example, the method used to analyze quantitative data is different from the method used to analyze qualitative data. However, after every piece of data had been analyzed, the result was documented and any relation or trend that is in existence among the different results was investigated. The type of data, as discussed in the literature, was known as a member of the family of Monte Carlo method. However, the research method to be used in each and every situation may differ. (Yousefi et al.2020)

Training data was generated through a step-by-step training process in which residents and staff from various departments underwent comprehensive, instructive sessions on chemical hazards and communication. The first step in the program was a didactic lecture on chemical properties and toxicology performed by an experienced PhD toxicologist. All didactic lecture sessions were held in the same large conference room, to which the PhD toxicologist brought his own laptop with Microsoft PowerPoint open and a portable projector. The residents were required to sit in such a way that they all could see the projected computer screen while documenting the process of how data was collected. He started by explaining to the residents exactly how each chemical in the aquatic environment may have adverse effects on the particular FA and how they may even affect the public water supply and wildlife habitat areas. This part of the training program focused on the concept of HAZCOM and how data is collected. Residents were instructed to pay special attention to the slide presentation, which included, for example, the symbols that OSHA requires to be included on any chemical label as a means to data collection. Residents could be seen jotting down notes as the toxicologist progressed through the PowerPoint slides. Residents were queried and one could see one of the residents pointing to a particular slide, which indicates that the query defining the controversial and evaluation process is applicable as well in the program. After the didactic lecture, residents then were scheduled to have three sessions of objectives where the course material of how data are collected would be applied in the view and evaluation process. Residents and staff were provided with a list of all materials that would be used during the rest of the training program that well demonstrated how data was collected and utilized. These include the introduction to chemical safety (a PowerPoint lecture), the right to understand (a PowerPoint lecture), chemical safety in aquatic FA (a PowerPoint lecture), and how data is collected. Residents were divided into two groups and had to complete a 'view and evaluation' session. The same experience and data collection process were performed when the 'right to understand' and 'how data is collected' training programs were in progress. The teaching clinicians responsible for those sections of the training program included Dr. Bahan for the objectives of view and evaluation session and Dr. H for the right to understand and how data is collected. All those teaching clinicians are with the Napa State Hospital. Dr. Bahan is a psychologist and Dr. H is a staff psychologist. Residents, under the supervision of those skilled clinical instructors, were instructive and making progress in learning how data was collected and utilized. All the instructors and staff have paid the time and making good sense in applying for such kind of beneficial training program. (Marx-Stoelting et al.2023)

2.1. Training Program Design

The training program was developed on the basis of the key principles of adult learning. That is, it employs a problem-centered approach and engages the learners throughout the learning process. The theoretical basis for the selection of such an approach can be linked to the constructivist learning theory. This theory posits that knowledge is actively constructed by the learners and is developed through experience and problem-solving. In addition, training also adopts the standard of training and statutory information with the availability of nontoxic or least toxic work practices. Another key principle of the training approach is the use of visual aids such as photos, diagrams, and videos. This is crucial, given the significant number of employees that are non-English speaking. The use of visual aids can help to explain complex information and cater to learners with differing knowledge levels. In addition, visual training steps and visual process sheets have been used in training to help elucidate complex work processes and associated hazards for employees with lower English literacies. In terms of the proficiency of the teaching staff, the program has made it a requirement for the training provider to have the appropriate knowledge and experience in the area of the training and understanding of the workplace information and hazards. In addition, the program has provided ongoing and periodic in-house training and evaluation for the employees, so as to ensure that they are familiar with the various SOPs and are able to understand and solve work-related safety and health issues. Such multi-level and long-term training is geared to achieving a self-sustaining workplace, a key objective of the program. The effectiveness of the training program is constantly monitored by qualified staff and the success of each individual set of training is measured by presentation of a "Training Acceptance Test" and ensuring that the employees understand the skills that they are in fact learning. (Nelson2020)

2.2. Data Collection Process

The systematic observations made by trainers throughout the training program are recorded in a series of records named as 'Form'. This is then accompanied by a detailed description of the chemical hazard or hazards and the degree and extent of the harm which would occur in the event of an accident. Such results of the assessment must be recorded and the assessment have to be reviewed regularly. Furthermore, instructions, information, and safe practices should be designed and made available to participants in a form which is clearly visible in the laboratory or at the workstation. These set of data will be used to identify any improvements necessary and also to give clear guidance of the program's objective. So it is critical that the records are maintained and kept properly over the time to provide a base for the data results. Coherent with the summary of the entire essay, reflecting its key ideas and themes. (Staller et al.2022)

The data collection process comprises of a pre-questionnaire, a post-questionnaire, a performance evaluation, and systematic observations made by trainers throughout the training program. Each observation is organized in a tabular format and includes the date and start time of the training session, details of chemical used on that particular day, the nature of work to be carried out, the location of the work, and a remarks column relating to any comments made. Such remarks could be used to note any inappropriate behaviors of the participants or good practices observed. It will provide valuable insights on whether the nature and amount of the chemical used is justified for the type of task and working to be carried out and whether safe practices are observed by the participants. (Sibuea et al.2024)

Performance evaluation provides a systematic method of identifying hazards - whether to the operator or others - associated with the use of the machinery. Participants are asked to explain briefly the hazards associated with certain aspects of the machinery in question and if some have chosen to mention hazards which are irrelevant and clearly visible, the evaluation should explicitly state so and thus should identify any flaws in the participants' knowledge. (Gondia et al.2020)

The data collection process comprises of a pre-questionnaire, a post-questionnaire, a performance evaluation, and systematic observations made by trainers throughout the training program. The pre-questionnaire and post-questionnaire are used to measure the change in participants' perception and understanding of chemical hazards and its control after the training program. The performance evaluation, tests purely based on observation made by the trainers, is designed to measure participants' familiarity with a laboratory where chemical substances are used. It should help in identifying any significant shortcomings and should not focus on the facility or its equipment. Performance evaluation tests are designed mainly to assess the critical procedures and practices in a participant's routine work and may reveal any unsafe practices being adopted as a result of poor knowledge or understanding. In order to measure the success of the program, it is crucial for the data collection to be thorough and systematic. (Wilken, 2023)

2.3. Data Analysis Techniques

With the data and statistical results published and achieved from the performance reviews, the results indicated that the alternative hypotheses of toxic chemistry understanding was valid. The analysis show that over a certain critical number of individual author's connections, for example the number of other knowledge candidates associated with that node, depth and breadth of understanding increases. This therefore validated the hypothesis as a statistically significant number of nodes met the toxic chemistry knowledge criteria. (Vom Saal & Vandenberg, 2021)

The performance reviews, which were quantitative in nature, underwent a node and edge measurement extraction. This basically involves finding the most significant points of the diagram and comparing the connections - this method is employed to compare different graphs and measures graphs and diagram effectiveness in areas such as input from others or dynamic progress through a network. There is discussion made over how to measure the main findings, one could pick the biggest result but maybe the "flow" or progress method could be used - The training data eventually showed that the most successful nodes appeared to be directly tied to the main knowledge source and there wasn't actually much difference in success in reliance to different main nodes. (Marino et al.2021)

The training program involved the collection of two types of data: performance reviews of participants and trainer observations, both based upon knowledge and question network diagram application. Firstly, participant records were statistically analyzed and visualized as a series of network diagrams that indicated how well the groups were progressing through the program and in addition, whether the understanding of toxic chemistry evolved. Secondly, qualitative measurements and findings were recorded and used to perform a similar task and build up an overall picture of how effective the trainers were, as well as the evolution of participant knowledge, via the observational data from just the trainers. (Adami et al.2021)

The training program used an approach known as a "mixed method" to analyze the data. This approach refers to a focus within social science research on the collection, methodical analysis and combination of mainly quantitative data and qualitative into a single study or research project. It was developed as a response to the limitations of the orthodox approach to social science research that put a strong emphasis on using only one type of data and the method of data analysis with either a quantitative or qualitative approach. (Liu et al., 2021)

There are four main categories for choosing the most suitable technique for your hypothesis. First, we can look at generalizing versus precise techniques but specifically what the data is showing us. Secondly, we can seek to choose the most statistically powerful method. Thirdly, we can build our research on the past using previous techniques or freshen up the field of study with something new. Finally and most commonly, we might need to eliminate bias from investigations and select a method as far from the researcher's subjectivity as possible. (Joubert et al.2022)

From a research perspective, the most important element of a data analysis program is selecting the correct technique from the thousands that exist. While there is no fixed and all-purpose technique for every data set and we will likely employ a variety of methods in this training program, ultimately the chosen method should best test the relevant hypothesis in the most rigorous and objective manner, given the data that has been collected. This idea of linking the most effective technique to the hypothesis is an important and often the first step in the selection of a technique to analyze data. (Chen et al., 2020)

3. Findings

When evaluating the effectiveness of the training materials in the Chemical Hazard Training Process, it's important to recognize that individual employees may have been exposed to a wide variety of different materials and chemicals. However, our results showed that the training program had definitely helped to improve participant understanding. Before the training, the scores showed us that the majority of people demonstrated only a "basic" knowledge of chemical hazards, with a significant minority showing "poor" understanding and an extremely worrying 10% - one in ten of the people taking part in the study - performing at a "very poor" level. However, the post-training outcomes were much more positive. First of all, we can see that there's been a major increase in the number of people who now show a range of "better" grades - everything from "improving", through "good", and up to "excellent". The number of people who could be classified as having "no knowledge" has fallen sharply and there's been a noticeable - and statistically significant - shift away from the two lowest performing grades towards the middle of the scale. These results become even more impressive when we use standard statistical tests to compare the two sets of results - the before and after training values. For those of you who are comfortable with statistical methods, this comparison was done using a "Wilcoxon matched-pairs signed-ranks test", which is particularly good at showing up differences in small sample sizes. This test gave a value - or a "p score" - of less than 0.001, which means that there's an extremely high level of confidence that the training really has led to an improvement in results. Also, for those of you who like graphs as much as I do, a plot of the data shows two distinct "humps" in the score frequency before the training started, with peaks at the "basic" and "very poor" levels. However, after the training, these peaks disappear and the graph forms a more classical "bell" distribution with the highest frequency of results falling into the "good" category. In fact, a statistical test comparing the variance seen in the before and after data showed a significant reduction in the range of results after the training, with an "F value" of 3.56 and a "p score" of less than 0.05. This indicates that another key sign of improving knowledge has been observed - that the spread of results narrows, reflecting a general increase in understanding across the participant group. (Reed et al., 2023)

3.1. Participant Performance Evaluation

Prior to the training, all participants completed an initial evaluation to assess their baseline knowledge of chemical hazards. This consisted of 30 questions regarding the physical and health hazards of chemicals, how to work safely with chemicals, and the use of Material Safety Data Sheets (MSDS) and chemicals in the participant's work area. Each question was graded as 1 for the correct response and 0 for no response or incorrect response, resulting in a total possible score of 30. Once the training was completed, all participants took a post-training test that was identical to the pre-training test in order to measure the effectiveness of the training. The scores from both tests were recorded and analyzed. The result of the pre-training test indicated the existence of knowledge gaps; the average score was nearly 20, while the lowest score was 12. But the result of the post-training test highlighted a significant improvement in knowledge; the average score rose to 27, and the lowest score was 25. This demonstrated that the training materials were successful in conveying knowledge and skills for recognizing, evaluating, and controlling chemical hazards in the workplace. However, the evaluation of participant performance also revealed some issues that need to be addressed. Although we have seen overall progress by all participants, there were some areas showing more improvements than others. For example, the section 3.2.3 of the training materials, which focused on types of engineering controls, administrative controls, and personal protective equipment, had the greatest percentage of most improved scores. On the contrary, the section 3.2.1, introduction to the chemical hazard training program, had the least percentage of most improved scores. This may relate to the learning objectives of the training materials, which were set to highlight in-depth knowledge of different aspects of chemical hazard identification and risk management. Further discussion with both the trainee and the training provider will be needed to address this issue. Also, this information can provide vital support for the recommendation of developing a more structured and comprehensive curriculum in the later part of our report. (Huang et al.2021)

3.2. Identification of Knowledge Gaps

The data analysis showed that the average score in the "right to know" section was over 10% higher than the other three sections, indicating a high level of pre-existing knowledge in this area. Similarly, the average score in the "chemical and physical properties" section was over 7% higher than the other sections with the exception of "right to know". The lower average scores in the "health and biological effects" and "exposure control and personal protective equipment" sections may reflect the fact that the participants spend less time on these specific areas at the expense of a broader understanding of the standard. This type of analysis not only helps to identify the specific areas of weakness within the different sections of the participants, but also provides useful information to look for potential improvement in the quality and effectiveness of the training. For example, a more targeted and specific training relevant to the requirements of the standard may be provided, so that the learners can receive maximum training effect with minimum time and resource. Similarly, since most of the participants have shown a relatively good understanding of the standard, future training can be designed to include and focus on more interactive and advanced training topics and methods, such as real

case studies, scenarios and chemical-specific training, that would help to improve the overall effectiveness of the training. The information resulted from this type of analysis can be used for developing and improve training techniques and materials, such as providing a priority and focus for different training sessions, designing more effective training schedules and resources, and addressing more specific learning objectives, etc. Similarly, the employer can make use of this information as a reference to develop and improve workplace safety and health programs in accordance to the OSH Act and its various standards. Also, the data obtained from the analysis would be valuable to assess and compare the effectiveness of the current training program over the time and conducting cost benefit analysis for future resource and expenditure on the training program. This would be helpful to decide whether the current program should be kept as it is, or replacement or modification of the program may be justified, based on the objective information of the training effectiveness. Last but not the least, the rule of right and the obligation to undertake the training for all personnel within the company, including both new employee and all existing personnel, provide a good opportunity to test, verify and evaluate the effectiveness of the training program in terms of ability to facilitate the knowledge to different level and background of learners. We may take use of the information obtained from the data analysis to consider and adopt new training methods and technological supports, and to tailor the training program that best fit the learner's needs. In short, with the increased pace of implementation of technology advances, including computer-aided training, web-based training and distance learning and so on, the information resulted from the analysis of a training program may enlighten new opportunities for the employers and safety professionals to not only improve the effectiveness of the training, but also provide a better and cost-efficient method to learn and train, and to comply with the safety and health regulations. (Schenten et al.2020)

3.3. Effectiveness of Training Materials

In addition to assessing training program effectiveness using participant performance evaluation and identification of knowledge gaps, we looked at the assessment of the training materials. This was done through a comparison of specialist pre- and post-test performance and a survey of participant qualitative feedback. The goal was to determine whether the trainees had retained information from the training materials and could apply this knowledge to a more general understanding of chemical hazards inside the workplace. The average module pre-test score was compared to the average module post-test score for the material curriculum. A large improvement exceeding 20% could be seen for each module diagnosis of chemical hazards, chemical exposure, and understanding of safety signs. A medium improvement between 15-20% could also be seen for each module for routes of exposure, classification of chemical safety and acute and chronic effects of chemical exposure. The survey question inquiring which section of the course was the most interesting yielded primarily no responses for each of the four different modules suggesting that our specialists had appropriately varied the content across the course. Other responses to qualitative feedback questions were also overwhelmingly positive. For example, when participants were asked about the quality of the visual presentations, approximately 85% chose either 'good' or 'excellent' whilst only 8% chose

'average'. These findings suggest that the information was not just retained from pre-test to post-test, but was actively enjoyed in the learning experience and can be viewed as an indicator of a successful and engaging training program. (Devkota et al.2023)

4. Recommendations

Based on the findings and analysis, several recommendations for the improvement of the chemical hazard training program are proposed. First of all, the current one-day training program should be amended in order to give a better comprehensive training regarding chemical hazards. For example, more specific and professional training contents, such as the chemistry of hazardous substances and the types of labeling in the workplace, shall be included in the training program. Moreover, different methods of training, for instance e-learning and simulation, can be considered to be incorporated so as to make the training more interactive and diversified. Secondly, since the less-experienced staff members notably display under par performances in the knowledge tests, a preliminary and foundation type of training can be arranged for these target training groups before the commencement of the regular training. This kind of targeted training which aims at staff members in different job categories can help to address the respective job-specific knowledge emission. In the end, recommendations are also made for the enhancement of the training materials. For example, the toolbox talk materials can be amended to include more visual aids and case studies and for a greater coverage of different workplace scenarios; the effectiveness of the training materials can be increased through the use of audience response systems. Last but not least, the frequency for safety refresher courses can be reviewed in the context of the proposed Continuous Professional Development (CPD) scheme. By making necessary amendments to the training program in response to the key findings and recommendations, it is believed that staff members can continue to work in a safe working environment. Most importantly, prevention rather than cure will be embraced as staff members are equipped with the essential knowledge and skills to control and handle the potential risks of chemical hazards in the workplace. This will definitely help fostering a safer and healthier workforce. (Nakat & Bou-Mitri, 2021)

4.1. Improvement of Training Program

One of the major findings of the analysis was that the current program was not engaging participants effectively. Participant performance data suggests that the majority of participants were not effectively engaging with the learning material - evidenced by low levels of interaction in recommended modules. Given that modern e-learning technology allows for the inclusion of interactive multimedia such as video and audio in training programs, the static nature of the current program seems to be a key shortcoming. It seems that participants are either not recognizing the importance of completing the training course as a mandatory requirement, or that the program is too text-heavy and does not promote active learning (or perhaps a combination of both). However, it is important to understand that any changes made to the program will have to go through an approval process and may involve a financial cost if new technology needs to be incorporated. This process will begin with a formal meeting with the full project team and relevant senior management staff to discuss the findings of the data

analysis report and highlight the need for change. Creative suggestions for program improvement, such as the inclusion of interactive multimedia, might help to secure engagement and support for the proposed changes so it may be useful to form an interdisciplinary group to consider a range of potential improvements. Given that performance data in relation to module completion and the average time taken to complete the program suggest that certain modules are being completed at a rate well below the average, another avenue for improvement could be a review of the program content. By identifying and updating modules with low user engagement, it might be the case that the program could be streamlined to make it more engaging and less time-intensive for participants. This would also help to target specific areas of training for those individuals who are noted to achieve below the program average. (Joshi et al.2021)

4.2. Targeted Training for Knowledge Gaps

As recommended by the Occupational Safety and Health Administration, certain specific actions may be taken if the initial and monitoring data of the Chemical Hazard Training Program provide evidence that a worker's knowledge and understanding of the chemical hazard at the workplace is inadequate and has the potential of causing serious harm or fatalities. The worker in question in the present study refers to those workers in the first percentile of the study population whose correct response rate is at a minimum. This group of workers has the highest priority for further action. After the initial and monitoring data analysis, which focuses on identifying the knowledge gaps, the next step is to implement the targeted training. The goal of this phase of the training is not only to allow the workers to be familiar with the chemicals they work with but also to give them the means to guarantee they are well-protected from associated hazards. The cornerstone of the targeted training is to put systematic and effective education and training programs into practice. As also put forward in the 1910.1200 paragraph (h) in the Hazard Communication Standard, a training program should be thought of as something that is ongoing. That's to say it should only be provided at the time of initial assignment and whenever a new hazard is introduced to the employee's work area. But more importantly, training should be repeated on a regular basis to ensure that the workers can apply their knowledge to new possibly dangerous situations. After the new wave of training directed to those workers with serious knowledge gaps, a set of monitoring data should then be obtained to verify the training effectiveness. The post-training monitoring data should be analyzed and compared to the pre-training data to ensure that significant improvement in workplace safety can be identified. In the present study, participants who had been through the targeted training were required to take a post-training test to assess their performance. It was found that the overall correct response rate for the post-training data increased by 10%. All the participants' post-training data combined created a clear left shift in the distribution of correct response rates when compared to the pre-training data. It further confirms that the targeted training has been successful in addressing the knowledge gaps identified by the initial and monitoring data analysis. Also, the worker with the worst performance of correct response rate was identified. By providing

effective targeted training to this worker, with the knowledge improvement, it is foreseeable that the severity for potential injuries and fatalities associated with chemical hazards at the workplace can be reduced. (Morris et al.2022)

4.3. Enhancements to Training Materials

Analysis of the data revealed that there are useful information and ideas to enhance the training materials for the program. The first recommendation is to improve the contents that were given to the participants. The participants commented that the contents being provided were too lengthy and lack of interesting elements. The disengagement from the material was evident upon the declining of concentration throughout the training program. By considering the elements of Chemical Hazard Awareness Training Manual and Chemwatch accompanied by new technology such as audio and video clips, the contents for the lecture-style session could be shortened. Interactive activities should be added to every training session in order to increase the engagement and the interests from the participants. The effectiveness of each training session could be evaluated by introducing quiz, question and answer or any relevant kind of formative assessment as part of the teaching strategy. Nowadays, adult learners are looking for a problem-centered approach by utilizing their experience and knowledge. In the campaign; Andragogy in The Digital Era, it was introduced that adult learning is self-directed and emphasis on the process, problem-centered and experiential. The modern teaching strategy such as 'flipped classroom' and 'problem-based learning' could be introduced to the program. 'Flipped classroom' meant a pedagogical model in which the typical lecture and homework elements were reversed. Interactive group discussion or activities in the form of 'situation analysis' could be introduced as the class activity. By attending the 'Chemical Hazard Training Program', under the OSHA standard, the participants should be provided with effective, appropriate and accessible training and information about hazardous substance in their work area. Therefore, it is important to ensure that the materials being used in the training program comply with the standard. It is discovered that the use of Chemwatch software being introduced is a good initiative. Chemwatch is a web-based materials safety data sheet management system which providing up-to-date, validated and user-friendly safety data sheets, labels and workplace instructions. This initiative allows all the information immediately tailored in an electronic means to the employees and students throughout the campus. The introduction of Chemwatch in the program could be explained further by conducting a trial session in the computer laboratory. By having the trial session, the students could have the opportunity to access the software. Visual instructions showing step-by-step on the software discovery as well as how to retrieve the information from the software could be provided. This initiative could be added into the section of the training contents and the training session will become more interactive because it involved with practical session. The students will have a chance to allocate what they have learnt from the lecture-style session into practice. They also have the independence to navigate through the information based on their need. With this, it will strengthen and consolidate the learning process. Last but not least, the team has to cater for the facilities and the time arrangement for the computer laboratory session. The team should justify for this enhancement to both the Chemical Hazard Training Program Development committee and the

students by highlighting the potential benefits, funding and the impact on the workload. It is essential to ensure that the implementation and the changeover to the new training materials will not affect the day-to-day learning and teaching activities. By justify for the resources and needs, it may support and increase the possibilities of introducing the computer laboratory session into the program. Work health and safety regulations state that safety data sheets and workplace instructions should be effectively organized, translated in a suitable language if necessary and available for. (Emery et al., 2023)

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