Case Study of Potential Hazards of Pb (lead) Lining inRadiation Laboratory on The Employees & Public

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Abstract

In today's modern world radiation is utilized in medical, industrial and military sectors. X-rays and gamma radiation are both forms of electromagnetic radiation commonly used in laboratory settings. X-rays are produced by accelerating electrons and directing them onto a target material, while the decay of radioactive isotopes emits gamma radiation. Despite the benefits of radiation, prolonged exposure can affect employees and public health. Thus, Pb (lead) shielding has been utilized as an effective mitigation strategy for mitigating the health hazards associated with radiation. Due to its large atomic number and density, Pb is effective for mitigating x-rays and gamma rays. However, even though lead provides protection from radiation it can also affect human health. This research focuses on the effect of the lead pb on employees and public health. The study proposes measures and controls to reduce lead associated health hazards.

Keywords
Lead, Radiation, Shielding, Lead exposure, Lead Poisoning, and Occupational exposure.

1. Introduction

Radiation exposure is a growing concern in contemporary society, attributed to its increasing use in medical, industrial, and military settings. In the laboratory setting, it is utilized for various purposes, such as material science, medical research, and nuclear physics. However, compared to the public, cardiovascular interventional laboratory employees such as technicians, physicians, and other workers are exposed to higher radiation levels (Rogers & Brodt 2018). Therefore, although the utilization of this approach in the clinical setting is associated with numerous benefits, its increased utilization puts clinical staff at risk of harmful radiation exposure. Additionally, although all forms of radiation pose significant health hazards to the public, gamma radiation is associated with more adverse outcomes. Gamma radiation is one of the physical agents that previous studies have identified as carcinogenic (Basu 2018). Despite its effectiveness in sterilization in the clinical context, the exposure of these rays to the patients and the public may lead to various alterations in different cells that may cause body damage. The damage linked with gamma-ray exposure includes DNA damage, radiation sickness, cell death, and cancer incidence (Ahmed et al. 2020). Additionally, this type of gamma radiation is more penetrating than X-rays and can pass through thicker and denser materials, leading to reconsidering its use. Furthermore, gamma rays are more prone to ionization due to cobalt-60, a primary source of its radioactive isotope, which exposes lab employees to various health hazards. Therefore, gamma rays present various health hazards to the public that need to be investigated to formulate potential solutions which will complement existing shielding strategies such as Pb shielding. Pb (lead) shielding has been utilized as an effective mitigation strategy for mitigating the health hazards associated with radiation. In the laboratory setting, operators should utilize ceiling-suspended shields combined with Pb eyeglasses and protective side shields (Christopoulos et al. 2016). However, the approach for Pb shielding varies in other sectors, such as the surgical unit. For instance, various research has recommended that surgeons and other radiation professionals wear 0.5 mm Pb-equivalent apronsduring fluoroscopy (Lakhwani et al. 2019). This approach of Pb shielding varies from that recommended to laboratoryoperators presenting the varying utilization of Pb for radiation shielding. Furthermore, lead line plywood and drywallshave been utilized in laboratory construction for shielding (AbuAlRoos et al. 2019), highlighting its utilization in construction. Generally, this strategy is applicable in different settings and can be effectively utilized asa mitigation strategy. This research paper aims to propose methods and recommendations to reduce the health hazardsassociated with lead (Pb) on employees and the public who get exposed to radiation for prolonged periods. The study indicates different measures and precautions that can be implemented.

Objectives
Despite its effectiveness in radiation shielding, Pb is associated with health hazards for employees and the public. Strong justification has been aired for using alternative materials due to the hazardous nature of Pb (Abdullah et al. 2022). Although measures have been incorporated to mitigate the weight and density issues associated with this shielding strategy, there are limited insights on the effect continuous exposure to lead through this strategy will haveon employees and the public. Kumar (2018) argues that this component is hazardous and can affect fetal development,multiple body organs, and young children. The lead (Pb) presence is disastrous for the public, especially children, whoare in crucial development stages. Therefore, exposure to lead in the clinical setting negatively affects the general population, which needs to be addressed. Additionally, employees in these sectors have chronic exposure to lead dueto their continuous use of protection gear made with this component. With the continuous endorsement of this strategyby studies, which fail to outline its negative impacts on the health of employees in radiation sectors, these employeesare more exposed to health hazards. Therefore, based on these findings, this research will aim to assess the potential health hazards associated with the usage of Pb as a shielding material against radiation, calculate the concentration oflead in air coming from lead shielding and compare it to the PELs & regulations and finally propose control measuresto mitigate these hazards.

Literature Review
This literature review begins with a discussion of three previous studies that examined the relationship between lead exposure and cognitive performance. Balbus-Kornfeld et al. (1995) examined the evidence for a relationship between cumulative lead exposure and cognitive performance by analyzing data from 1976 to 1991. The authors discovered that cumulative dose biomarkers were not utilized in any of the 21 relevant studies. Moreover, the researchers discovered that the four longitudinal studies had small sample sizes, low follow-up rates, and short follow-up durations. These limitations led scientists to conclude that there was insufficient evidence in scientific literature to determine whether protracted lead exposure impairs cognitive function. Goodman et al. (2002) may have been fundedby the German Batteries Association in anticipation of Germany's reduction in blood lead levels for lead employees. (Seeber and Meyer-Baron 2003). To determine the relationship between moderate blood lead levels and the outcomesof neurobehavioral tests following occupational lead exposure, this study analyzed 22 publications published between1974 and 1999. The studies considered in the analysis provided mathematical means and measures of variability for test results of exposed and unexposed workers, the number of exposed and unexposed workers, and central trends of blood lead levels below 70 g/dL.

The authors of the study concluded that no single study provided sufficient or convincing data on how lead affects cognitive function. It was suggested to conduct prospective investigations comparing cognitive performance before and after exposure. Despite the assumption that cumulative lead exposure has the greatest impact on cognitive function, the authors did not address whether concentrating on the relationship between blood lead levels and cognitive performance was the most critical issue. In addition, the authors did not specify how epidemiologic data may be used to evaluate the acute and long-term effects of lead. Meyer-Baron and Seeber (2000) performed a meta-analysis of 12 trials employing analogous criteria to those used by Goodman et al. (2002). They did, however, require that the dependent variable means and standard deviations be disclosed. In orderto completely comprehend the current state of research on the relationship between blood lead levels and cognitive performance, both studies will be analyzed in this literature review. In addition, we will discuss the limitations of thesestudies and the need for additional research to fill in the knowledge voids regarding the effects of lead exposure on cognitive function. In the preceding literature review, three studies examining the relationship between lead exposureand cognitive performance were included. In the following section, a 2000 study by Meyer-Baron and Seeber will be evaluated. This is the first study to examine epidemiological studies that differentiate between the chronic and acute effects of cumulative exposure. The purpose of the investigation was to determine if moderate blood lead levels and neurobehavioral test results following occupational lead exposure are related. In contrast to other studies, Meyer-Baron and Seeber used selection criteria that accounted for the available means and standard deviations of the dependent variables in the articles under consideration. The authors did not investigate the most significant lead biomarker for assessing the possibility that protracted lead exposure may impair cognitive function. Instead, they focused on the relationships between blood lead levels and other variables. Lead poisoning can result from consuming tainted food or water, as well as unintentionally imbibing lead-based paint, soil, or dust. Absorption of lead can cause injury to the immune, cardiovascular, central nervous, and renal systems. Numerous pharmaceutical companies have imposed a maximum daily lead consumption restriction of 1.0 g/g because even short-term exposure to low levels of lead can be detrimental to human health. Blood lead concentrations that are elevated due to occupational exposure have been linked to delayed puberty in females.

Exposure to even small quantities of lead over an extended period oftime can have devastating effects on children's cognitive development. In older homes, children are at risk of unintentional lead poisoning due to the hazards of lead-based paint, particularly if they inhale dust from the removal of old paint. Traditional remedies, particularly Ayurvedic ones, have been found to contain lead and other heavy metals, which have been linked to a number of well-known diseases. Forty-six percent of 115 individuals who took these medications had elevated blood lead levels, according to recent research. Several factors, including lead-contaminated soil and Chinese traditional remedies, have been linked to lead poisoning's adverse effects. Taking conventional medications that are high in lead or lead compounds can have negative health effects. The Centers for Disease Control and Prevention have issued warnings against ingesting these treatments. Also posing a threat to humanhealth are fruits and vegetables grown in soil containing a high concentration of lead. Due to factors such as pipelines,lead paint, and residual emissions from leaded gasoline, lead may accumulate in the soil. To prevent lead poisoning in homes, it is essential that the public understands the disease's primary causes. Lead poisoning from water pipelinesentering homes is a major cause, particularly for newborn children who are more susceptible to lead absorption.

In addition, lead exposure on the job could place nearly 3 million American workers at risk, particularly those employed in critical industries such as the production of circuit boards, aircraft engines, plumbing, surgical equipment, radiation shielding, and weapons. Depending on the duration of lead exposure, the severity of lead poisoning symptoms varies, and some individuals may have an excessive amount of lead in their bodies without displaying any symptoms. Organic lead may be more dangerous than inorganic lead because it disrupts the central nervous system rapidly and is lipid soluble. However, it is still unknown at what lead concentrations symptoms and signs begin to manifest. Lead exposure can cause a variety of symptoms, including behavioral abnormalities, neuropsychiatric symptoms, digestive issues, short-term memory loss, melancholy, and anemia. Blood lead levels above 100 g/dL can cause severe symptoms, such as encephalopathy and coma, whereas blood lead levels between 25 and 60 g/dL may cause neuropsychiatric symptoms.

These symptoms may appear in children exposed to lead concentrations of 70 g/dL or higher. Anemia, short-term memory loss, depression, vertigo, cramping, lack of coordination, numbness and sensation in the extremities, fatigue, sleep problems, migraines, stupor, and short-term memory loss are among the long-term health issues caused by chronic lead exposure. Lead contamination is a significant global public health concern. Lead exposure can occur through the consumption of contaminated food or water, inhalation of lead-containing particles orvapors, and skin contact with lead-containing objects. Particularly in children, whose developing minds and nervous systems are particularly susceptible to lead's deleterious effects, lead poisoning can cause serious health problems. This literature review includes lead paint, lead pipelines, Chinese traditional medicine, and residual emissions from leaded gasoline as sources of lead exposure. The review also highlights the importance of public education in preventing lead poisoning in homes, as well as the grave dangers of lead exposure for workers in a variety of industries,such as those that produce circuit boards, jet engines, plumbing, surgical equipment, radiation shielding, and weapons.Organic lead compounds may be more hazardous than inorganic lead due to their solubility in lipids and ability to disrupt the central nervous system rapidly and readily, according to the review. In addition, it emphasizes that even modest levels of lead exposure can have negative effects on development and health. The study also discusses the numerous symptoms of lead toxicity, including neuropsychiatric disorders, anemia, gastrointestinal issues, and centralnervous system and neuromuscular symptoms. This literature review emphasizes the significance of preventing lead exposure and the need for additional research to better comprehend the mechanisms and effects of lead toxicity in thehuman body.

Long-term lead-exposed children frequently display aggressive behavior and may refuse to play. When exposed to lead (Pb), humans are at risk for a variety of health problems, including kidney, neurological, and developmental issues, as well as an increased risk of cancer. In radiation laboratories, lead is frequently used as a linear barrier to protect personnel and the public from ionizing radiation. However, lead consumption may also pose dangers to the

public and personnel. The installation, maintenance, and removal of Pb shielding in radiation laboratories may expose employees to Pb particles and fumes. Inhaling Pb particles can cause respiratory problems such as chronic bronchitis, wheezing, and shortness of breath. In addition, contact with Pb may result in skin irritation, dermatitis, and rashes. Lead can also be absorbed through the epidermis and enter the circulation, where it can affect the body as a whole. In addition, research indicates that employee exposure to Pb may impede cognitive function and exacerbate mood disorders. In addition to occupational exposure, the use of Pb lining shields in specific areas has the potential to contaminate the environment with Lead, jeopardizing the general population. According to studies, those who are exposed to lead have an increased risk of cardiovascular disease, stroke, and death. Pb exposure can also worsen in children, as it can interfere with the development of their nervous systems and cause behavioral and cognitive problems. The disposal of Pb-containing products may endanger the environment and the general public's health. Lead can accumulate in soil and water, contaminating the food chain and endangering both fauna and humans. To reduce the likelihood of lead exposure to the public, lead-containing materials must be disposed of appropriately. Steps should be taken to ensure the safe handling, disposal, and monitoring of Pb materials to reduce any potential hazards associated with Pb shield linings in radiation laboratories. Other shielding materials, such as concrete or steel, should be considered if possible.

So, clearly, there are health hazards related to Pb but how to determine the actual levels of Pb as doses or even in air and who are the most exposed people to Pb? So, before clarifying the available ways to determine the Pb exposure to employees or the public, we should address who can be exposed to Pb or any other chemical in the workplace.
Initially, based on ADNOC COP V3-08, people who are exposed to any risk including Pb are Employees, contractors, visitors, and other people present in the area. In addition, there is another category that requires further notice, which is people identified with increased risks. This category contains pregnant women, nursing mothers, untrained staff, employee working in poorly ventilated spaces, workers with pre-existing illnesses, and smokers.

Applying both categories to our case study, people who are exposed to Pb are employees, visitors, and contractors. And regarding people with increased risk, the list is as follows: untrained staff, workers with pre-existing diseases, and smokers.

In addition, to identifying the people who are expected to be exposed to Pb in the case study of the radiation laboratory, and based on the literature review, the paper will outline the exposure level of Pb by providing the following assumptionregarding the estimation of Expected Pb exposure in the Radiation Laboratory:

1. The magnitude of exposure.
2. The exposure route: which is mainly inhalation and probably skin contact or digestion in case of not following the safety recommendations.
3. The frequency of exposure.
4. The duration of exposure.
5. The likelihood of an increased level of exposure during normal operation or in case of emergency or abnormal condition: In the case study the only probability of getting exposed to a higher level is that Pb covering shields get damaged and exposed Pb sheets for surface area to be directly reacted with.

These five parameters will support the estimation of doses. Nevertheless, to determine and quantify Pb in air especially, or to determine the exact exposure requires further evaluation.
Based on the International Labor Organization (ILO), the magnitude of exposure is a way to measure the level of risk employees, or a group of workers are expected to be exposed to from potential hazards in their daily work, which includes dangerous chemicals, potentially unsafe equipment, and any other related risk. Such measurement is critical to mitigate the risks in order to protect the workers in the workplace.

For example, based on OSHA, an employee working in a chemical plant is expected to get exposed to toxic fumes, which results in respiratory illness and issues, skin diseases, and probably cancer. In our case study, we are going to focus on Pb, which in the previous sections covered Pb's health hazards and risks.

The next step is to identify the exposure route and based on the Center of Disease Control and Prevention (CDC), it is theway that the toxic substances enter the body, and can be through inhalation, ingestion, or absorption through the skin. Identifying the exposure route is important to identify the control measure that can be applied. For example, an employee can be exposed to lead through inhalation by breathing the fumes or dust contaminated with Pb in the workplace, a countermeasure is to have a special mask that can be worn to avoid such passing of substance to the body.

The third assumption that requires to be identified is the frequency of exposure and in this case, it will be through how many days per year, which isrelated to the fourth assumption which is the duration of exposure. The duration of exposure can be in terms of hours in a day.

The last assumption is regarding identifying the cases that could lead to an increase in the exposure of the substance to the workers or the public and can be in terms of emergencies or spills.
Therefore, this section will focus on the ways to evaluate the Pb levels and doses that employees or the public are getting and based on these findings, the paper will focus on the most suitable method for our purpose, which is to have an assessment of the Pb in Radiation Laboratory in terms of health hazards.

The first method to estimate the exposure level is based on relevant data, experience and or modeling.
Basically, considering modeling as a choice then the usage of the Estimation and Assessment of Substance Exposure (EASE)model created by UK health and safety executives is a choice, this is a model that provides a framework and a way to estimate and assess the exposure of toxic substance in workplaces. The use of such a model will involve different stepsthat include the definition of the problem, selecting the model inputs, starting the model, and finally interpreting the outcomesand is used to calculate the expected exposure from inhalation to support the selection of control measure. As stated by UK HSE, it is preferable to use the model in compliance with other methods of exposure assessment to have a clearpicture of exposure.

Another option is to use relevant data and experiences available in the literature review or from other institutes, this step is to extract data similar and related to the current scope based on the assumption that will be discussed in the next section and especially focusing on the usage of lead shielding or lead apron in laboratories or hospitals. This step should include the gathering of information from published references and resources from academic journals, books, and reports to help develop the needed understanding and to compare the matter of interest according to the case study. In addition, it will help identify the gaps between what has been done and our case study. This option can lead us to the next method that most of the findings in the literature review are focusing on, which is the direct measurements.
So, on the other hand, there is the quantitative evaluation of exposure by direct measurements, which is an actual measurement of Pb or a toxic substance to evaluate the exposure to the hazardous material. This type of assessing exposure should be taken into consideration, under these circumstances. If there are doubts that the exposure exceeds the limit, or to provide justification for implementing countermeasures to protect the employees, or based on legal requirements, and finally these steps all move toward the safety of employees. So, based on the literature review regarding addressing Pb levels in the part the paper will address some significant publications that can support the method to evaluate Pb level in the case study.

Based on the study conducted by Jafari, Pourmahabadian, Kianizadeh, and Poursafa in 2018, this research emphasizes the assumption that Lead (Pb) shielding could effectively reduce exposure to ionizing radiation.However, it could increase the exposure to lead poisoning if it was not handled with care and with propercountermeasures. Therefore, the authors emphasize the need to assess the lead exposure of radiology workers to provide the best countermeasure. So, to assess the lead level, the study designed a method where there was a collectionof environmental samples including soil, dust, air, water, and food, as well as 68 blood samples from radiation workers.All these samples were analyzed for Pb concentration. Out of the 68 workers, 34 workers were to not use lead shieldingand the rest were wearing lead aprons. As a result of the whole screening, the lead concentration of soil and dust washigher than the limits of the World Health Organization (WHO). On the other hand, air, food, and water samples results were within and below the permissible limits. The most significant findings are that the results show that lead concentration in blood was higher in radiology workers than in the general population and that younger unskilled workersshowed a higher frequency of exposure to lead due to lack of experience.

Another review paper supports the same findings above. According to Bhagat et al. (2019), more than 60% of the aprons had a quantifiable quantity of Pb in the dust of the external surface of the aprons, which can be inhaled or digested if the employees are not aware of the measurements.

Therefore, both research papers explained that lead dust is noticeable and is above the recommended levels based on WHO Lead concentrations. One further step is to establish a table comparing the different Lead concentrations stated by WHO, OSHA, NEBOSH, and UAE regulations.

Table 1. Allowable concentrations and permissible exposure limits for lead

Agency/Organization	Allowable Concentration of Pb (air)	Permissible Exposure Limit of Pb (air)	Permissible Exposure Limit of Pb (blood)
WHO	0.15 µg/m³	N/A	5 µg/dL
OSHA	50 µg/m³ (TWA)	50 µg/m³ (TWA)	40 µg/dL
NEBOSH	50 µg/m³ (TWA)	50 µg/m³ (TWA)	N/A
UAE Regulations	0.2 µg/m³ (TWA)	0.15 µg/m³ (TWA)	10 µg/dL

Note: TWA stands for Time-Weighted Average, which refers to the average concentration of a substance in the air over a specified period of time.

Furthermore, regarding determining lead in air, Hirano et al. (1993) have conducted research to analyze lead isotopes of airborne particulates, the most important takeaway from this research paper is the way the sampling was conducted. Since air sampling can quantify the amount of lead in the air. The authors used a high-volume air sampler with filters made of glass fiber. The samples were collected every 24 hours from each point of interest with a flow rate of 1.13 m^3 /min.

3. Methodology

Based on the literature review regarding building the methodology to identify the risk of the radiation laboratory shield of exposure we need to clearly identify the assumptions about the case study.
The case study covers a radiation laboratory that is enhanced between 2022 and 2023 and implements an extra level oflead shield to enhance the safety of the public from any trace of radiation on them. This laboratory is expected to implement around 4 mm lead shield on all the walls surrounding the radiation laboratory and in contact with non-radiation related areas. The employees in this laboratory are males and they are mainly five employees, one contractor, andtwo subcontractors. Visitors visit the laboratory on rare occasions that are meant for maintenance or training. However, in this laboratory, the people with increased risk are untrained staff or trainees, staff with diseases or above 40, and smokers. Therefore, table 2. Table 3. Explain further information about the case study.

Table 2. Employee Health Information by Role in the Case Study

Role	Smokers	Age > 40	With Disease	Normal	Total
Employees	2	2	2 (1)	0	5
Contractor	0	1	0	0	1
Subcontractor - Cleaners	1	0	0	1	2
Total	3	3	1	1	8

Table 3. Summary of Exposure Assessment for Lead in the Workplace

Exposure Assessment Factor	Value
Magnitude of Exposure	Breathing zone and opportunity for skin contact
Exposure Route	Inhalation, skin contact, and ingestion (in case of not following safety recommendations)
Frequency of Exposure	5 days/week
Duration of Exposure	8 hours/day
Likelihood of Increased Exposure	Damage to gypsum board, moisture or water damage, age and wear and tear, and incorrect installation

Based on the finding from the literature review, the proposed methods that can be used in the case study are relevant data comparison, direct measurements, and EASE modeling of UK-HSE.
Due to the availability of similar data from the covered research papers in the literature review, in this paper, we are going to adopt the findings of the previous work done by other entities with similar activity to assume that the same concentration of lead is going to be present in the laboratory. This can be implied in our case study by providing further details relevant to the actual measurements of lead that have been done.

However, there are two additional steps that would support the findings of the paper but due to the time scale of writing the paper, it cannot be performed. Therefore, we are going to mention the two steps in methodology, and it will be in detail in the recommendation section in what is related to the case study.

So, the second step is to collect samples of air and dust from the laboratory, which is under construction, to assess the current concentration of lead. However, this step depends on two main factors the time to submit the paper and the availability of calibrated sampling machine. Therefore, due to the first factor, which is time, this will be performed in future research. In addition, the third step would be after collecting exact measurements and applying them to the EASE model to run a simulation to observe the actual data we got from the direct measurements and probably to compare it to the findings of the literature review.

Therefore, in this paper the focus will be on similar case studies and the findings of the papers and case studies will be considered. So, this case study finding will rely on three different and previous case studies and extract their data about the effect of lead shielding, which will be implied in our case study to provide recommendations.

4. Data Collection and Discussion

Based on Manocchio et al. in their research in 2023, a survey of Radiation Protection Aprons (RPAs) was conducted in 2021 in one of the radiology departments in one hospital to measure the amount of lead dust. The focus on lead dust isbecause of its ability to pass to the body by different pathways including inhalation, digestion, and through the skin. In this research, the survey covered a total of 69 aprons, which were distributed on full-length aprons, frontal aprons, thyroid collars, and a mix of thyroid collars and frontal aprons. The samples were quantified with a rapid method of fluoroscopy. Therefore, the finding of this research was that 60.9% of RPA contained lead dust contamination, and it was higher on thyroid collars around 78.8% than on aprons where the contamination was around 44.4%. In their conclusion,they emphasize the existence of lead dust on the RPA and that there is no safe level of lead on aprons has been identified.

In this case study, in addition to the lead lining of the laboratory, the employeesare using lead RPA and specifically aprons, which seem to be partially old aprons. This increases the chances ofhaving lead (Pb) dust on the aprons and in the workplace environment. Based on the similarity of the usage of aprons,the case study is suspected to have higher lead dust as compared to other locations where the radiation laboratoryexists and especially on the aprons and in the surrounding area. As suggested by the research, further monitoring ofthe dust is required. Applying it to the case study, it is suggested to have a confirmation measurement of lead dust. Based on NIOSH in their publication on Lead in 2018, it is confirmed that dealing with lead in the workplace will increasethe amount of lead in blood especially if not properly maintained or covered as it will create an excessive amount of leaddust. This applies to radiation workers who are working in a laboratory lined with lead, wearing lead aprons, and usinginstruments shielded with lead. As a result, OSHA has set a permissible exposure limit (PEL) for lead in the workplace of (50 $\mu g/m^3$) for an 8-hour workday.

In addition to the study previously mentioned in the literature review, which is conducted by Jafari et al. in 2018, there is a clear increase of Pb in the blood of the workers wearing aprons. This finding was also supported by another study done by Morgan et al. in 2005, showing that wearing lead aprons increased the lead (Pb) in the blood of the workers in arange of 7-10% on average, and for some individuals, the level of increase reached around 27%.
Therefore, these studies are suggesting that lead poisoning can be a real concern, especially for radiation workers that are being exposed to lead on different scales, from protecting themselves from radioactive materials and protecting the public from the radiation activities handled in the laboratory. Gamma or x-ray types of radiation are a hazard and a concern, but this does not exclude the hazardous effect of excessive exposure to lead even if it is a countermeasure to radiation. Based on the findings of the literature review, lead poisoning is a real threat to employees' health if the exposure is not monitored and dealt with precautions.
The current location of the laboratory, which is before shifting, does not have a lead lining around the premises. However, the obligations of shifting to the new location imply an extra level of public protection from radiation. As a

result and based on the safety assessment conducted to protect the public from radiation, the laboratory is getting around 4 mm of lead shielding on each wall, including the ground. Nevertheless, excessive usage of lead, which is not necessary for the protection of employees and the public, can result in serious health issues for exposed employees. This suggests further safety assessment to assess the risk of lead (Pb) and radiation in the laboratory.

5. Recommendations

Based on the findings regarding the case study laboratory it is strongly recommended to have the following countermeasure and further investigations based on the finding and the results:

1. The administration of the laboratory must have a complete safety assessment that includes the assessment of lead exposure to the employees and public in addition to the safety assessment conducted for radiation exposure.
2. To support the finding, it is strongly suggested to conduct an actual measurement of lead in the laboratory and compare it to the results found in the literature review.
3. Biological monitoring is extremely recommended to measure any increase of lead in the blood of the employeesto investigate unwanted exposure to lead.
4. Based on the finding of Kang et al. in 2019 that to protect employees a non-lead radiation-shielding fabric can be a replacement for lead aprons used in the laboratory.
5. It is suggested to conduct monthly sampling of air to measure the amount of lead dust in the laboratory.

However, there are further general recommendations to reduce the effects of lead (Pb) exposure on employees and the public, the following measures and precautions can be taken:

1. Implement engineering controls, such as ventilation, air filtration systems, and enclosures, to prevent the spread of lead particles or vapors.
2. Provide employees with PPE, such as gloves, masks, and eyewear, to protect them from lead exposure.
3. Encourage employees to frequently cleanse their hands and make hand-washing facilities accessible. In addition, establish policies prohibiting dining, imbibing, and smoking in lead-contaminated areas.
4. Conduct periodic training and instruction: Instruct employees on the hazards of lead exposure as well as how to use PPE and practice proper hygiene. Inform the public about the dangers associated with lead and how to avoid exposure.
5. Implement a monitoring program to assess lead levels in the workplace and public areas on a regular basis. This will aid in identifying any potential exposure hazards and enable swift action.

By implementing these methods and secure practices, the risk of lead exposure to employees and the public can be reduced, protecting their health and safety.
Finally, the most recommended action is to have further research to be conducted after the completion of the laboratory, where the three stages explained in the methodology can be applied by taking actual measurements and applying the findings and new parameters in the EASE simulation to a stronger output assessing the lead risk tothe employees and public.

Conclusion

In radiation laboratories, it is evident that exposure to lead can have negative impacts on human health. Therefore, in order to identify the risk of radiation laboratory shield exposure, it is crucial to implement effective methods to assess the concentration of lead. To identify the concentration of lead in the laboratory, data comparison, direct measurements, and EASE modeling of UK-HSE are the proposed methods. In addition, collecting air and dust samples and using the EASE model would further support the findings. Thus, it is recommended to implement further monitoring of lead dust contamination in the laboratory environment. In conclusion, this paper emphasizes the importance of implementing effective solutions to identify the risk of radiation laboratory shield exposure to prevent negative impacts on human health. Consequently, precautions should be taken to reduce the likelihood of lead exposure. To protect employees and the public from Pb exposure, alternative shielding materials and responsible storage, disposal, and monitoring of Pb materials are required.

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