RESERCH ARTICLE Open Access

Gema Lingkungan Kesehatan
Vol. 22, No. 2 (2024), pp 140-148
e-ISSN 2407-8948 p-ISSN 16933761
Doi: https://doi.org/10.36568/gelinkes.v22i2.183 Journal Hompage: https://gelinkes.poltekkesdepkes-sby.ac.id/

The Effect of X-ray Radiation on Malondialdehyde Levels in Radiology Workers in Selected Hospitals in Indonesia

Y Denny Ardyanto W[1], Abdul Rohim Tualeka[1*], Rizaldy Fathur Rachman[1], Tamilanban Thamaraikani[2], Velu Perumal[3,4], Ahsan Ahsan[5], Pudji Rahmawati[6], Suardi Zurimi[7], Salsabila Novianti[1]

[1] Department of Occupational Health and Safety, Faculty of Public Health, Airlangga University, 60115, Surabaya, East Java, Indonesia
[2] Department of Pharmacology, SRM College of Pharmacy, SRM Institute of Science and Technology, Kattankulthur, Tamilnadu, India 603203; Department of Occupational Health and Safety, Faculty of Public Health, Airlangga University, 60115, Surabaya, East Java, Indonesia
[3] Jabatan Rekabentuk Perindustrian Fakulti Rekabentuk dan Senibina, Universiti Putra Malaysia 43400 Serdang Selangor Darul ehsan;
[4] Department of Occupational Health and Safety, Faculty of Public Health, Airlangga University, 60115, Surabaya, East Java, Indonesia
[5] Faculty of Nursing, Brawijaya University, Malang, Indonesia
[6] Department of Development of Islamic Society, State Islamic University Sunan Ampel, Surabaya, Indonesia
[7] Politeknik Kesehatan Kemenkes Maluku, Indonesia

*Correspondence: abdul-r-t@fkm.unair.ac.id

ABSTRACT

The use of ionizing radiation in radiology units is essential for disease diagnosis. However, the energy of this radiation is sufficient to ionize the atoms and molecules in the substance it moves through, potentially posing health risks. This study aimed to analyze the effect of an effective dose of X-ray radiation on malondialdehyde (MDA) levels, a marker of oxidative stress, in radiographers. With an observational design, this study was conducted cross-sectionally at hospitals X and Y from January to April 2023, involving 19 radiographers exposed to X-ray radiation. MDA levels were measured using the Thio Barbituric Acid Reactive Substances (TBARS) method, and data were analyzed using SPSS, including descriptive, bivariate, and multivariate analyses. The results showed that all respondents had abnormal MDA levels, but the effective dose of radiation did not significantly affect MDA levels ($p > 0.05$). In contrast, working hours showed a significant influence on MDA levels, where an increase in working hours correlated with an increase in MDA levels. Thus, although the radiation dose received is considered safe, there is evidence of significant oxidative stress in radiographers, which requires further attention regarding the management of radiation exposure in the work environment.Ionizing radiation sources are used by the radiology unit for diagnosing diseases. When radiation contacts an element with sufficient energy, the atoms and molecules can become ionized. The research aims to examine how effective X-ray radiation doses affect malondialdehyde (MDA) levels. The methodology of this research is observational because no intervention is used—just the observation of the variables. In recognition of the type of data and analysis, the study is quantitative. While during the study, data from the dependent variable is only collected once, it is cross-sectional in design. Nineteen radiographers who deal directly with X-ray radiation exposure participated in the study, which took place in hospitals X and Y between January 2023 and April 2023.Based on the data shown in Table 3, every respondent has blood levels of malondialdehyde (MDA) that are abnormal. MDA levels are not impacted by the radiation's effective dose. More details about MDA and its connections to radiation exposure and oxidative stress can be found in the search results. All respondents show abnormally high levels of MDA in their blood; working hours have an impact on MDA levels; and effective radiation doses do not affect MDA levels. All radiation doses received have been considered safe.

Keywords: Radiation, Ionizing, X-rays, MDA

INTRODUCTION

The radiology unit is one of many departments at hospitals that deal with health and disease-related issues. These responsibilities include care, treatment, and diagnosis. To diagnose diseases, the radiology unit uses sources of ionizing radiation, such as X-rays (Tuasikal *et al.*, 2022; Akrimah, Wardana and Tualeka, 2023; Ruzi *et al.*, 2023). According to a study (Ardiny, 2014), Ionizing radiation contains sufficient energy to cause ionization processes by ionizing molecules and atoms of the material it moves through. Neutrons and beta (β), gamma (γ) rays, alpha (α) and beta (β) particles are a few examples of ionizing radiation that can actively ionize matter (Yatulaini *et al.*, 2021; Yudisianto, Tualeka and Widajati, 2021; Rachmah *et al.*, 2022). Though possessing mass and electric charge, X-rays, gamma rays, and cosmic rays are classified as ionizing radiation due to their ability to induce indirect ionization (Nurmianto *et al.*, 2020; Rahma, Safitri and Tualeka, 2020; Shahidin, Jalaludin and SYAZWEEN, 2021).

Based on the study (Ardiny, 2014), because the effects of ionizing radiation might be stochastic, cells can be harmed by even very small radiation doses that enter the body. X-ray radiation is one of the primary sources of ionizing radiation found in hospitals; ionizing radiation has a high energy and can result in ion production, according to the Nuclear Energy Regulatory Agency (2011) (Hidayat, Rahayu and Tualeka, 2020). Although small quantities of this energy can be advantageous to people, prolonged exposure can be hazardous (Bestari *et al.*, 2020; Hanifah, Rahman and Tualeka, 2020; Rachma, 2020).

Even at effective dosages, X-ray radiation is typically regarded as safe for medical diagnosis, but current research indicates that even at these levels, there may be subtle biological consequences that are not fully understood. In particular, not much research has been done on the connection between low-dose X-ray radiation and oxidative stress indicators such as malondialdehyde (MDA), particularly in work environments where radiology personnel are frequently exposed. Although the levels are considered safe, this begs the question of whether present safety regulations provide sufficient protection against long- term oxidative damage.

According to (Simanjuntak, Camelia and Purba, 2013), Using radiation for health reasons contributes to 20% of all sources of radiation exposure, making it the second greatest source. Overexposure to radiation can result in skin responses, hair loss, cancer, damage to pulmonary function (such as radiation pneumonitis), and adverse genetic effects (Ayu, 2020; Febrianti *et al.*, 2020; Ningrum *et al.*, 2020). Both direct and indirect cell damage can result from X-ray radiation. Certain targets, such as the DNA and RNA in the nucleus, sustain direct damage (Asiah, Tualeka and Denny Ardyanto W, 2020; Putra *et al.*, 2020; Tualeka, Jalaludin, Widiyanti, *et al.*, 2020). Free radicals cause indirect damage. A large amount of free radicals can have several adverse consequences, including pathogenic diseases and a defect in cellular communication. It is also thought to play a role in cell death Radiation acts as a free radical when it enters the body (Kartika *et al.*, 2020a). The body's metabolism of antioxidant enzymes can affect free radicals (Kimura *et al.*, 2020; NS *et al.*, 2020; Suaebo, Dewi and Tualeka, 2020).

A deficiency between the total number of free radicals and the ability of the human body to eliminate them causes oxidative stress. A marker of increasing oxidative stress is increased body levels of malondialdehyde (MDA) (Kartika *et al.*, 2020b; Kuncoro, Dwiyanti and Tualeka, 2020; Sutanti *et al.*, 2020). One consequence of unregulated oxidative stress inside the body is oxidative damage, which can harm many types of cells, tissues, and organs (Arfandi Setiawan *et al.*, 2020; Sulistyanto *et al.*, 2020). Liver dysfunction represents an example of harm to the body's cells, organs, and tissues (McKee and McKee, 2003).

According to (R, 2006), When the levels of blood sugar increase, the liver's vein damage vessels will filter out sugar from the blood and supply it, where it will be stored as glycogen. If the levels of blood sugar collapse, the liver will release the sugar that is held in glycogen into the circulation (Hisamuddin *et al.*, 2020; Ningrum, Kurniawati and Tualeka, 2020; Tualeka, Guan, *et al.*, 2020). Based on these data, more investigation is required to ascertain whether effective radiation doses have an impact on hospital radiographers' liver function and levels of malondialdehyde (MDA).

The research aims to examine if malondialdehyde (MDA) levels are impacted by effective X-ray radiation doses.

RESEARCH METODOLOGY

Because no intervention is used and only the variables are observed, this study design is observational. The study is quantitative due to the type of data and the analysis. The dependent variable's data is cross- sectional since it was collected just once during the study's duration. Study participants included nineteen radiographers who deal directly with X-ray radiation exposure. The study was conducted between January 2023 and April 2023 in hospitals X and Y.

Variable measurement methods

The hospital provided the following primary and secondary data for this study: The Health Facility Security Agency (BPFK) Surabaya provided the findings of personal monitoring measurements (Film Badge), which were used to obtain secondary data. Direct interviews regarding worker characteristics, working hours, age, and duration of service were conducted with eligible workers using a questionnaire. Workers' testing for malondialdehyde (MDA) was received from the Faculty of Public Health's integrated laboratory.

Data analysis

The study's data analysis was performed using SPSS. The following tests for data analysis were applied:

1. The frequency distribution table was used to do a descriptive analysis of each study variable to determine its distribution and proportion. The information displayed includes the percentage or proportion for categorical data, and the coefficient of variation, standard deviation, lowest and maximum values, mean, median, and such for numerical data.
2. To find out how one independent variable affected the dependent variable, bivariate analysis was performed using a typical regression analysis.
3. To investigate the impact multivariate analysis was used to examine the relationship between two or more variables that are assumed to affect one another. Assuming a significance standard of ɑ < 0.05, this analysis was done to find out how independent factors affected the dependent variable. Statistical tests for logistic regression were utilized in the analysis

RESULT

Identification of Effective Radiation Dose

Table 1.
Effective Dosage Results for Radiation Exposure of Radiographers.

Variable	Category	Frequency	
		(n)	(%)
Effective Dose	Safe	19	100
	Not Safe	0	0
Total		19	100

Table 1 indicates that the safe range of 100% is preserved by the effective dose of blood. The following are the findings of the yearly effective dose assessment in the blood performed on 19 radiologists at hospitals X and Y:

Table 2.
Results of the Annual Maximum Dose Examination.

Annual Effective Radiation Dose	Value
Frequency (n)	19
Minimum	0.7
Maximun	0.746
Mean	0.707
Std. Deviasi	0.0412

Table 2 suggests that radiographers at hospitals X and Y had the greatest annual effective dosage in their blood, measuring 0.746.

Identification of the Blood Test for Malondialdehyde

Table 3.
Results of the blood examination by radiologists.

Variable	Category	Frequency	
		(n)	(%)
Malondialdehyde (MDA)	Normal	0	0
	Abnormal	19	100
Total		19	100

According to Table 3, all respondents had significantly high levels of malondialdehyde (MDA) in their blood, according to the results of the examination. Table 4 shows the findings of the blood analysis for malondialdehyde (MDA) carried out on 19 radiographers at hospitals X and Y.

Table 4.
Results of a Blood Malondialdehyde Test.

Malondialdehyde (MDA)	Value
Frequency (n)	19
Minimum	3.620
Maximun	5.741
Mean	3.593
Std. Deviasi	1.404

Table 4 shows that the radiographers at hospitals X and Y had the highest blood levels of malondialdehyde (MDA), measuring 5.741 nmol/ml.

Table 5.
Assessment of the Results of Individual Determinants on MDA Levels.

	Unstandarized Coeffisients		Sig	Information
	B	Std. Error		
Age	0.080	0.70	0.252	No effect
Working hours	0.620	0.574	0.280	No effect
Gender	-1.200	1.515	0.428	No effect
Work period	-.044	0.294	0.881	No effect
Education	-22.481	40192.977	1.000	No effect

For the purpose of analyzing the impact of specific characteristics on MDA levels, using backward Wald logistic regression analysis, features on MDA levels were used. Based on Table 5, it can be inferred that the MDA levels were not significantly impacted by variables of an individual's characteristics, including age, gender, education, work period, and working hours, as evidenced by a significance value > 0.05. This indicates that the levels of MDA and these factors are not correlated.

Table 6.
Analysis of Radiation Effective Dose on MDA Levels.

	Unstandarized Coeffisients		Sig	Information
	B	Std. Error		
Age	0.080	0.70	0.252	No effect

Table 6 shows that, as shown by a significance value > 0.05, the effective radiation dosage variable had no obvious effect on MDA levels. This indicates that the levels of MDA and these factors are not correlated

DISCUSSION

Effective Radiation Dose

Radiation dose monitoring is an activity carried out to determine the level of radiation exposure to each radiation worker while working in the Radiology Installation. The dose monitoring of personnel is carried out using film badges or TLD badges, and direct-reading personal dosimeters that have been calibrated. These tools function to measure the dose received by radiation workers. If workers do not monitor their dose, they will not know how much radiation dose they have received while working (Tualeka, Jalaludin, Salesman, *et al.*, 2020). Hospitals X and Y have monitored individual radiation dose using TLD badges for radiographer personnel. TLD badges function to measure the dose received by radiation workers. If radiation workers do not use TLD badges, they will not know how much radiation dose they have received while working. This dose monitoring aims to ensure that the radiation exposure received by workers is below the NBD, and the hospital must provide individual dose monitoring tools. Radiology installations at hospitals X and Y perform individual dose monitoring using TLD badges, where readings are done indirectly and must be sent to the Health Facility Security Agency (BPFK) for evaluation. The results of the dose monitoring evaluation are received by radiation protection officers from the BPFK and are communicated to each personnel member. This aligns with recommendations in the literature that emphasize the importance of routine dose monitoring to mitigate the long-term health risks associated with occupational radiation exposure (Abuzaid et al., 2024).

Radiographers in this study received an average dose of 0.70 mSv per year, which is much lower than the minimum annual dose limit set by the International Atomic Energy Agency (IAEA) of 20 mSv. However, this should still be monitored due to the stochastic effect, where stochastic effects are related to low-dose radiation exposure (0.25-1000) that can cause cancer (somatic damage) or genetic defects (IAEA, 1996). In stochastic effects, there is no known threshold dose, and any radiation dose received by the body, no matter how small, can cause cell damage. The effect occurs long after exposure and is only experienced by some of the exposed group (Ahsan et al., 2020b). The severity does not depend on the radiation dose, and there is no spontaneous healing (Akhadi, 2000; Mahfudz et al., 2020). Therefore, even though the radiation levels observed are below the IAEA threshold, continuous monitoring and protective measures are crucial.

The workload is calculated based on the number of examinations performed. The more examinations performed by a radiographer, the higher the radiation dose received (Sigurdson et al., 2008; Sugiharta & Tualeka, 2020). This is consistent with findings from previous research that show a direct correlation between workload and radiation dose accumulation (Sharkey et al., 2021). The radiation dose received by radiographers and other radiation workers is an accumulation of small daily doses received each working day in performing examinations. Although weak, daily radiation exposure can result in cumulative chromosomal translocation. If a radiographer works in a department that uses high radiation, such as CT-Scan and interventional radiology, then rotation or shift changes are necessary (Bhatti et al., 2008; Mulia et al., 2020). Such findings underscore the importance of implementing rotational work schedules and regular breaks to minimize cumulative radiation exposure, which is a critical component of occupational health policies aimed at protecting healthcare workers in high-exposure environments.

Malondialdehyde (MDA)

Blood samples from 19 radiographers were used in this study to measure the MDA levels. The samples were then analyzed utilizing the Thio Barbituric Acid Reactive Substances (TBARS) method. A spectrophotometer based on the color absorption produced by the TBARS and MDA reaction is used in this procedure. The MDA level test was administered at Airlangga University's Nutrition Laboratory. The MDA level that was measured in this investigation ranged from 2.779 nmol/ml to 5.741 nmol/ml, with an average of 3.93 nmol/ml. Human MDA levels typically range from 1.076 nmol/ml.

According to this study, MDA levels were abnormal for all radiographers and > 1.076 nmol/ml for all workers. Because age can have an impact on a person's physical and physiological state when exposed to chemicals, age can have an impact on the adverse health effects of chemical exposure (Almadiana & Tualeka, 2020). A study by (Fatimah & Warno Utomo, 2020) found that employees over the age of 32 are more likely than those under to have higher MDA levels. According to (Suherdin et al., 2020; Suma'mur, 1996), Age also has an impact on the body's ability to tolerate harmful substances. Aging results in a gradual rise in the risk of disease as well as a decline in both physical and mental ability (Rahman & Tualeka, 2020b; WHO, 2018).

A dialdehyde molecule called malondialdehyde (MDA) is produced when the body develops lipid peroxidation (Ayala et al., 2014; Rahman & Tualeka, 2020a). Increased levels of MDA suggest that cell membrane oxidation activities are occurring. MDA concentrations in plasma and erythrocytes have occurred utilized as indicators of adverse effects on the tissue brought on by free radicals that act in vivo (Oktavia et al., 2020; Seçkin et al., 2014). Compared to other molecules, MDA is more frequently utilized as a warning sign of oxidative stress due to its more stable chemical characteristics. MDA is a trusted and efficient part of the evaluation of lipid peroxidation, as demonstrated by many studies, and it has assisted in the perception of oxidative stress's impact on some disorders, including skin conditions (Grotto et al., 2009; Muliatna & Tualeka, 2020).

Oxidative stress can be described as a contradiction between pro- and antioxidant-oxidants. This results from either an excess of ROS generation over the capacity of the antioxidant defense system or from a decline in or maintenance of the antioxidant capacity. Under physiological settings, the body's defensive mechanism, antioxidants, can shield cells and tissues from harmful ROS (Ahsan et al., 2020a). The 'Free Radical Theory' speculates that certain biochemical and cellular systems start to function abnormally as a result of the build-up of oxidative stress and free radical damage (Nuttall et al., 1999; Rahman et al., 2020). The body can produce an increase in MDA when its amount of free radicals is greater than its level of antioxidants.

According to the study's findings, every worker had MDA levels greater than 1,076 nmol/ml, and those who had levels higher than the median of 3.593 were primarily those who had worked for longer than ten years. Long-term employees in adverse conditions run a higher chance of developing health issues. This is supported by research conducted by (Yanti et al., 2019) that chronic getting exposed to radiation from X-rays increases the chance of receiving total radiation exposure while working, which may have an impact on health. Research by (Nishi et al., 1986) indicated that the levels of lipid peroxidation increased in plasma after two hours, seven days, and fourteen days after radiation and at seven days after X-ray exposure, there was a rise in malondialdehyde in the submandibular gland of Wistar rats. Exposure to radiation can produce too many free radicals and make the body unable to fight them off, which can lead to oxidative stress and increased MDA levels (Saridewi & Tualeka, 2019; Suherdin et al., 2020).

A discussion of how the effective dose of X-ray radiation affects MDA levels.

Ionization is a result of radiation passing through media or tissues. A quantity that is solely dependent on the level of radiation energy received per unit mass of the radiation-exposed material rather than the specific type of radiation and the absorber's characteristics, or any combination of these must be introduced to find out how much energy from radiation the medium has absorbed. The total volume of energy given through radiation or the quantity of energy that a substance absorbs relative to its mass is known as the "absorbed dose." One gene implicated in the process of cell death is the p53 gene, or apoptosis, can become activated when the body receives a radiation dose that damages DNA. The goal of programmed cell death, or apoptosis, is to maintain the stability of the cell population.

Oxidative damage is the result of unregulated oxidative stress in the body, which harms a variety of organs, tissues, and cells. Among the effects of oxidative stress on the human body is liver injury. High MDA levels in the body are one indicator of higher oxidative stress (Junaidi et al., 2019; McKee & McKee, 2003). Increases of MDA indicate an increase in the body's free radical count. Eating fruits and vegetables containing vitamins C and E on a regular basis can help the body's antioxidant levels, which can help combat an increase in radicals (Dwicahyo, 2020).

The study's findings demonstrated that MDA levels were not affected by effective X-ray radiation exposure. Results from studies carried out by (Khoshbin et al., 2015) in three radiation treatment phases, with a uniform protocol provided by the Phoenix radiotherapy machines that involved giving 54 Gy of radiation was given to each patient in the supraclavicular and abdomen walls. There was no discernible change in MDA levels during the three treatment phases in the starting sample, which had already been taken beginning chemotherapy, the 2nd case, which was obtained prior to receiving radiation therapy, the final sample, which was taken following radiation therapy.

When assessing cell damage and lipid peroxidation, malondialdehyde (MDA) is a frequently used marker. Elevated reactive oxygen species (ROS) concentrations, which are free radicals that are crucial to the physiological functions of the body's organs, can raise MDA levels. Research conducted by (Al-Nimer & Ali, 2012) showed that the plasma malondialdehyde (MDA) levels of radiology workers were significantly more than the non-irradiated control group. Up to 500 Kev of X-ray radiation is used for each exposure, and the radiation dosage is estimated immediately for each exposure. This suggests that radiation can raise plasma levels of oxidants, such as MDA and hydroperoxides, and that radiation may have potential as a biomarker in bio dosimetry considering its large dose range

CONCLUSION

This study's objective was to assess radiographers' levels of malondialdehyde (MDA) and radiation dose response while they worked at the Radiology Installation. The findings found that all respondents had abnormal MDA levels, indicating severe oxidative stress, even if the radiation dosages they received were within safe parameters. This study also discovered a relationship between working hours and MDA levels, with higher MDA levels being found during longer workdays. Nevertheless, there wasn't any obvious impact of radiation that is effective dosage on MDA levels. In order to minimize the implications of oxidative stress in workers exposed to radiation, more research is required to examine the association between MDA levels as well as additional elements of the workplace.

ACKNOWLEDGEMENTS

The authors acknowledge thanks to Airlangga University's rector. The Effect of X-ray radiation on Malondialdehyde Workers in the Hospital Radiology Room is acknowledged by the authors.

REFERENCES

Abuzaid, M., Noorajan, Z., Elshami, W., & Ibham, M. (2024). Monitoring Occupational Radiation Dose In

Radiography Students: Implications For Safety And Training. *Safety*, *10*(2), 35. [Crossref], [Publisher]

Ahsan, A., Tualeka, A. R., Rahmawati, P., Russeng, S. S., Susilowati, I. H., & Jalaludin, J. (2020a). Factores Dominantes Que Afectan La Autoeficacia De La Enfermera Del Departamento De Emergencias En La Implementación De La Reanimación. *Opción*, *36*(Special Edition 27), 1562–1575. [Publisher]

Ahsan, A., Tualeka, A. R., Rahmawati, P., Russeng, S. S., Susilowati, I. H., & Jalaludin, J. (2020b). Factors Analysis Affecting Nurse Efficacy In Implementing Resuscitation In Cardiac Arrest Patients. *Opción: Revista De Ciencias Humanas Y Sociales*, *27*, 20. [Publisher]

Akhadi, M. (2000). *Dasar-Dasar Proteksi Radiasi*.

Akrimah, W. D., Wardana, I. W., & Tualeka, A. R. (2023). Mental Workload And Work Factors As Predictors Of Stress Levels In Port Sector Employees. *The Indonesian Journal Of Occupational Safety And Health*, *12*(1), 124–135. [Crossref], [Publisher]

Al-Nimer, M. S. M., & Ali, N. H. (2012). Assessment Of Nitrosative Stress And Lipid Peroxidation Activity In Asymptomatic Exposures To Medical Radiation: The Bystander Effect Of Ionizing Radiation. *International Journal Of Applied And Basic Medical Research*, *2*(1). [Crossref], [Publisher]

Almadiana, C. S., & Tualeka, A. R. (2020). Determination Of Safe Benzene Concentration At Ciputat Gas Station. *Indian Journal Of Forensic Medicine And Toxicology*, *14*(1), 124–129. [Publisher]

Ardiny, K. (2014). *JUMLAH SEL PADA ISOLAT MONOSIT SETELAH PAPARAN TUNGGAL RADIASI SINAR X DARI RADIOGRAFI PERIAPIKAL*. Universitas Jember. [Publisher]

Arfandi Setiawan, M., Bagus, H., Rahmania, A., Suci, C., Agustin, C., & Tualeka, A. R. (2020). NOAEL Benzene In White Mice As The Basis For Determining The Safe Limit Of Benzene Concentration In The Pulogadung Shoe Industry Home In Jakarta. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(2). [Publisher]

Asiah, S., Tualeka, A. R., & Denny Ardyanto W, Y. (2020). The Effect Of Chromium Exposure On Creatinine And Bun Level Of Tanners In Leather Industry In Magetan. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(3). [Publisher]

Ayala, A., Muñoz, M. F., & Argüelles, S. (2014). Lipid Peroxidation: Production, Metabolism, And Signaling Mechanisms Of Malondialdehyde And 4-Hydroxy-2-Nonenal. *Oxidative Medicine And Cellular Longevity*, *2014*, 360438. [Crossref], [Publisher]

Ayu, P. S. (2020). Relationship Between Toluene Concentration, Malondialdehyde (MDA) Level And Health Complaints In Workers Of Surabaya Printing Industry. *Indian Journal Of Forensic Medicine And Toxicology*, *14*(4), 3389–3395. [Crossref], [Publisher]

Bestari, M. A. D., Tualeka, A. R., Alayyannur, P. A., Arini, S. Y., Russeng, S. S., Rahmawati, P., & Susilowati, I. H. (2020). Relationship Between Benzene Concentrations With Erythrocyte, Hemoglobin, And Health Complaints Of Workers In Surabaya Printing Industry. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(4), 3112–3119.

Bhatti, P., Doody, M. M., Preston, D. L., Kampa, D., Ron, E., Weinstock, R. W., Simon, S., Edwards, A. A., & Sigurdson, A. J. (2008). Increased Frequency Of Chromosome Translocations Associated With Diagnostic X-Ray Examinations. *Radiation Research*, *170*(2), 149–155. [Crossref], [Publisher]

Dwicahyo, H. B. (2020). *Hubungan Paparan Toluena Dengan Kadar Eritrosit, Ldl Dan Mda Serta Keluhan Gangguan Saraf Pada Pekerja Bengkel Pengecatan Mobil Di Surabaya*. Ii–Xi. [Publisher]

Dwicahyo, H. B., Sulistyorini, L., & Tualeka, A. R. (2020). Risk Analysis Of H 2 S Gas Exposure At Benowo Landfill Surabaya. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(2). [Publisher]

Fatimah, R., & Warno Utomo, S. (2020). Stres Oksidatif Pada Pekerja Yang Terpajan Benzena Melalui Pengukuran Plasma Malondialdehid (Mda) (Studi Kasus Pada Pekerja Bengkel Sandal/Sepatu Di Desa Sukajaya, Kecamatan Tamansari, Kabupaten Bogor Tahun 2018). *Hearty*, *8*(1), 9–19. [Crossref], [Publisher]

Febrianti, R. R., Tualeka, A. R., Jalaludin, J., Russeng, S. S., Rahmawati, P., Ahsan, A., & Susilowati, I. H. (2020). Correlation Of Safe Benzene Duration (Hours/Day) And Blood Profile (Leukocytes, Hematocrit, Hemoglobin) In The Osowilangun Shoe Home Industry. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(4).

Freitinger Skalická, Z., Zölzer, F., Beránek, L., & Racek, J. (2012). Indicators Of Oxidative Stress After Ionizing And/Or Non-Ionizing Radiation: Superoxid Dismutase And Malondialdehyde. *Journal Of Photochemistry And Photobiology. B, Biology*, *117*, 111–114. [Crossref], [Publisher]

Grotto, D., Maria, L. S., Valentini, J., Paniz, C., Schmitt, G., Garcia, S. C., Pomblum, V. J., Rocha, J. B. T., & Farina, M. (2009). Importance Of The Lipid Peroxidation Biomarkers And Methodological Aspects FOR Malondialdehyde Quantification. In *Química Nova* (Vol. 32). Scielo . [Crossref], [Publisher]

Hanifah, S., Rahman, Z. F., & Tualeka, A. R. (2020). The Relationships Of Temperature And Humidity In Airconditioned Room To The Occurrences Of Sick Building Syndrome. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(4), 3486–3490. [Publisher]

Hidayat, N., Rahayu, M., & Tualeka, A. R. (2020). Relationships Of Service Response With Service Quality In Emergency Department Of Rsud Dr. Loekmono Hadi, Kudus, Indonesia. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(4). [Publisher]

Hisamuddin, N. H., Jalaludin, J., Yusof, A. N., & Tualeka, A. R. (2020). Genotoxic Effects Of Exposure To Urban Traffic Related Air Pollutants On Children In Klang Valley, Malaysia. *Aerosol And Air Quality Research*, *20*(12), 2614–2623. [Crossref], [Publisher]

IAEA. (1996). *International Basic Safety Standards For Protectionagainst Ionizing Radiation And For The Safety Of Radiation Sources* (Safety Ser). IAEA. [Publisher]

Junaidi, E. S., Jalaludin, J., & Tualeka, A. R. (2019). The Evaluation Of Exposure To Benzene Among Children In Indoor Environments: A Review. *Malaysian Journal Of Medicine And Health Sciences*, *15*(3), 151–155. [Crossref], [Publisher]

Kartika, A. P., Budiarti, V., Kuncoro, A., Kimura, C., & Tualeka, A. R. (2020a). Determination Of The Health Costs Of Effective Detoxification Based On Effective Doses Of Benzene Exposure To Workers In Oil And Gas Mining Companies, Central Java, Indonesia. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(2). [Publisher]

Kartika, A. P., Budiarti, V., Kuncoro, A., Kimura, C., & Tualeka, A. R. (2020b). Safe Concentration Of Benzene Exposure Based On Safe Human Dose Of Workers In The Paint Manufacturing Industry Sidoarjo, East Java, Indonesia. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(2). [Publisher]

Khoshbin, A., Mohamadabadi, F., Vafaeian, F., Babania, A., Akbarian, S., Khandozi, R., Sadrebazaz, M., Hatami, E., & Joshaghani, H. (2015). The Effect Of Radiotherapy And Chemotherapy On Osmotic Fragility Of Red Blood Cells And Plasma Levels Of Malondialdehyde In Patients With Breast Cancer. *Reports Of Practical Oncology And Radiotherapy*, *20*(4), 305–308. [Crossref], [Publisher]

Kimura, C., Goddess, L. S., Rahman, Z. F., & Tualeka, A. R. (2020). Relationship Of Hot Work Climate With Employee Blood Pressure In Binat Installation, Dr. Sardjito. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(2). [Publisher]

Kuncoro, A., Dwiyanti, E., & Tualeka, A. R. (2020). Control Of Risk In The Process Loading/Unloading In. Pelindo Iii Surabaya. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(2). [Publisher]

Mahfudz, M. A., Alayyannur, P. A., Haqi, D. N., Tualeka, A. R., & Sugiharto, F. M. (2020). The Implementation Of Hiradc Method In Computer Laboratory. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(1), 216–220. [Publisher]

Mckee, T., & Mckee, J. R. (2003). *Aerobic Metabolism II: Electron Transport And Oxidative Phosphorylation In: Biochemistry The Molecular Basis Of Life.* (3rd Ed.).

Mulia, S. A., Rahman, Z. F., Sugiharta, A. M. B., Susanti, L., & Tualeka, A. R. (2020). Evaluation Of Benzene Threshold Value In Benzene Exposed Work Environment: Case Study At Ciputat Gas Station. *Indian Journal Of Forensic Medicine And Toxicology*, *14*(1), 359–364. [Publisher]

Muliatna, I. M., & Tualeka, A. R. (2020). Risk Assessment, Risk Management, And Risk Communication Of Welding Work At PT DOK And Perkapalan Surabaya (Persero). *Indian Journal Of Forensic Medicine And Toxicology*, *14*(1), 113–117. [Publisher]

Ningrum, D. A. K., Kurniawati, A., & Tualeka, A. R. (2020). Climate Relationship Work With Fatigue Employees Working In Laundry Plant Dr. Sardjito. *Indian Journal Of Forensic Medicine And Toxicology*, *14*(2), 1225–1228. [Publisher]

Ningrum, D. P., Tualeka, A. R., Jalaludin, J., Russeng, S. S., Rahmawati, P., Ahsan, A., & Susilowati, I. H. (2020). Correlation Of Toluene Safe Duration (Hours/Day) And Glutathione Concentration, Malondialdehyde And Neurotoxic Symptoms In Osowilangun Shoe Home Industry Workers. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(4).

Nishi, M., Takashima, H., Oka, T., Ohishi, N., & Yagi, K. (1986). Effect Of X-Ray Irradiation On Lipid Peroxide Levels In The Rat Submandibular Gland. *Journal Of Dental Research*, *65*(7), 1028–1029. [Crossref], [Publisher]

NS, F. S., Levinrarian, T., Oktavia, B., & Tualeka, A. R. (2020). Health Costs For Detoxification Benzene Exposure Workers In The Mining Oil And Gas Pt. A Balikpapan. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(2). [Publisher]

Nurmianto, E., Ciptomulyono, U., Kromodihardjo, S., Setijono, H., Arief, N. A., & Tualeka, A. R. (2020). Working And Resting Period Based On Inclination, Loads, And Lift Methods On Manual Material Handling In Mining Environment. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(4). [Publisher]

Nuttall, S. L., Dunne, F., Kendall, M. J., & Martin, U. (1999). Age-Independent Oxidative Stress In Elderly Patients With Non-Insulin-Dependent Diabetes Mellitus. *QJM - Monthly Journal Of The Association Of Physicians*, *92*(1), 33–38. [Crossref], [Publisher]

Oktavia, B., Suratna, F. S. N., & Tualeka, A. R. (2020). Determination Of Safe Benzene Concentration In Tank Car Crew At Pt Pertamina Patria Niaga. *Indian Journal Of Forensic Medicine And Toxicology*, *14*(1), 164–169. [Publisher]

Putra, A. A., Ni'matu Zuliana, Z. F. R., Widajati, N., & Tualeka, A. R. (2020). Factors Affecting The Incidences Of Needle Stick Injury On The Nurses Emergency Department Of Hospital East Java. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(3), 1799–1803. [Publisher]

R, A. (2006). *Fisiologi Dan Biokomiawi Hati, Dalam: Buku Ajar Ilmu Penyakit Dalam* (Jild II Ed). Balai Penerbit FKUI.

Rachma, E. Y. (2020). Correlation Of Toluene Safe Concentration, Malondialdehyde And Glutathione

Levels In Osowilangun Shoe Home Industry Workers. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(4), 950–958. [Publisher]

Rachmah, Q., Martiana, T., Mulyono, Paskarini, I., Dwiyanti, E., Widajati, N., Ernawati, M., Ardyanto, Y. D., Tualeka, A. R., & Haqi, D. N. (2022). The Effectiveness Of Nutrition And Health Intervention In Workplace Setting: A Systematic Review. *Journal Of Public Health Research*, *11*(1), Jphr-2021. [Crossref], [Publisher]

Rahma, S. N., Safitri, M. R., & Tualeka, A. R. (2020). *The Analysis Of Differences In Body Temperature And Blood Pressure Before And After Exposure To Hot Work Climates Analisis Perbedaan Suhu Tubuh Dan Tekanan Darah Sebelum Dan Sesudah Terpapar Iklim Kerja Panas*. [Crossref], [Publisher]

Rahman, Z. F., Mulia, S. A., Sugiharta, A. M. B., Susanti, L., & Tualeka, A. R. (2020). Coal Dust And Acute Respiratory Infections In South Kalimantan PT 'X'coal Mining Workers. *Indian Journal Of Forensic Medicine And Toxicology*, *14*(1), 444–447. [Publisher]

Rahman, Z. F., & Tualeka, A. R. (2020a). Risk Assessment, Risk Management, And Risk Communication In The Carpet Industry: PT.'X'Pandaan. East Jawa. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(1), 385–389. [Publisher]

Rahman, Z. F., & Tualeka, A. R. (2020b). Work Safety Risk Assessment At Container Load Unloading Jobs At PT. Pelabuhan Indonesia II (Persero) Palembang Branch 2017. *Indian Journal Of Forensic Medicine And Toxicology*, *14*(1), 375–378. [Publisher]

Rahmania, A., & Tualeka, A. R. (2020). Determination Of Safe Level Of Benzene Concentration In Mechanics Workshop "X" Tembalang Semarang. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(2). [Publisher]

Ruzi, I. I., Ishak, A. R., Abdullah, M. A., Zain, N. N. M., Tualeka, A. R., & Aziz, M. Y. (2023). Assessment Of Heavy Metal Concentrations In Penang, Malaysia's Wastewater Treatment Plants: A Wastewater-Based Epidemiology Approach. *Trends In Sciences*, *20*(5), 6523. [Crossref], [Publisher]

Saridewi, N., & Tualeka, A. R. (2019). Determining Benzene Concentration Safe Level At Gas Stations In Pancoranmas Depok, Indonesia. *Indian Journal Of Public Health Research & Development*, *10*(12). [Crossref], [Publisher]

Seçkin, H. Y., Kalkan, G., Baş, Y., Akbaş, A., Önder, Y., Özyurt, H., & Sahin, M. (2014). Oxidative Stress Status In Patients With Melasma. *Cutaneous And Ocular Toxicology*, *33*(3), 212–217. [Crossref], [Publisher]

Shahidin, F. S. M., Jalaludin, J., & SYAZWEEN, E. (2021). Associations Of Exposure To PM10 And PM2. 5 With Respiratory Health Symptoms And Lung Function Status Among Children Living Near Palm Oil Activity In Semenyih, Selangor. *Journal Of Sustainability Science And Management*, *16*(6), 165–179. [Crossref], [Publisher]

Sharkey, A. R., Gambhir, P., Saraskani, S., Walker, R., Hajilou, A., Bassett, P., Sandhu, N., Croasdale, P., Honey, I., & Diamantopoulos, A. (2021). Occupational Radiation Exposure In Doctors: An Analysis Of Exposure Rates Over 25 Years. *The British Journal Of Radiology*, *94*(1127), 20210602. [Crossref], [Publisher]

Sigurdson, A. J., Bhatti, P., Preston, D. L., Doody, M. M., Kampa, D., Alexander, B. H., Petibone, D., Yong, L. C., Edwards, A. A., Ron, E., & Tucker, J. D. (2008). Routine Diagnostic X-Ray Examinations And Increased Frequency Of Chromosome Translocations Among U.S. Radiologic Technologists. *Cancer Research*, *68*(21), 8825–8831. [Crossref], [Publisher]

Simanjuntak, J., Camelia, A., & Purba, I. G. (2013). Penerapan Keselamatan Radiasi Pada Instalasi Radiologi Di Rumah Sakit Khusus (RSK) Paru Provinsi Sumatera Selatan Tahun 2013. *Jurnal Ilmu Kesehatan Masyarakat*, *4*(3 SE-Articles). [Publisher]

Suaebo, N. M., Dewi, K. A., & Tualeka, A. R. (2020). Relationship Between Fatigue And Musculoskeletal Complaints On Pedicab Drivers In The Pedicab Association Solo Balapan Station. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(2). [Publisher]

Sugiharta, A. M. B., & Tualeka, A. R. (2020). Evaluation To Identify Benzene Safe Concentration In Oil And Gas Processing Facility In East Java Area Due To Process Fugitive Emission. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(1), 142–147. [Publisher]

Suherdin, N. W., Kurniawati, R. D., & Tualeka, A. R. (2020). Risk Assessment, Risk Management, And Risk Communication At Drug Industries PT. Kimia Farma (Persero) Tbk. Plant Bandung. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(1), 423–428. [Publisher]

Sulistyanto, R. A., Kusumaningrum, D. A., Suaebo, N. M., & Tualeka, A. R. (2020). Safe Concentration Of Benzene Exposure To Worker's In Gas Station At The Area Of Diponegoro University, Semarang. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(2). [Publisher]

Suma'mur. (1996). *Higene Perusahaan Dan Kesehatan Kerja*. PT. Toko Gunung Agung.

Sutanti, L., Rahman, Z. F., Masruroh, N., & Tualeka, A. R. (2020). Relations Exposure To Dust Inhalation Against Impaired Lung Function In Worker Unloading At The Port Of Manado. *Relations Exposure To Dust Inhalation Against Impaired Lung Function In Worker Unloading At The Port Of Manado, North Sulawesi*, *14*(2), 1310–1314. [Publisher]

Tualeka, A. R., Guan, N. Y., Russeng, S. S., Ahsan, A., Susilowati, I. H., Rahmawati, P., & Ain, K. (2020). Relationship Of Benzene Concentration, ECR Benzene, Malondialdehyde, Glutathione, And DNA Degeneration In Shoe Industrial Workers In

Osowilangun, Indonesia. *Dose-Response*, *18*(2), 1559325820921023. [Crossref], [Publisher]

Tualeka, A. R., Jalaludin, J., Salesman, F., Wahyu, A., & Daika, N. (2020). Correlation Between Age, Working Period And Work-Related Musculoskeletal Complaints With Nordic Body Map Among Fishermen. *Iranian Journal Of Public Health*, *49*(3), 601–602. [Crossref], [Publisher]

Tualeka, A. R., Jalaludin, J., Widiyanti, P., Russeng, S. S., Rahmawati, P., Ahsan, A., & Susilowati, I. H. (2020). Determination Reference Of Concentration (Rfc) Xylen Exposure Based On Xylen NOAEL In White Rats And Workers' Body Weight And Height In Surabaya Car Painting Area, Indonesia. *Indian Journal Of Forensic Medicine & Toxicology*, *14*(3), 1709–1715.

Tuasikal, I. Z., Tualeka, A. R., Widajati, N., Mahmudiono, T., & Rachman, R. F. (2022). Evaluation Of The Exposure To Benzene And Spma Using The Urine Of Workers In The Shoe Home Industry In Surabaya. *The Indonesian Journal Of Occupational Safety And Health*, *11*(3), 436–444. [Crossref], [Publisher]

WHO. (2018). *Penuaan Dan Kesehatan*. [Publisher]

Yanti, K. K., Ma'ruf, F., Musyarrafah, & Setyowati, E. R. (2019). Hubungan Paparan Sinar-X Dengan Jumlah Limfosit Pada Radiografer Di Rumah Sakit Umum Daerah Provinsi Nusa Tenggara Barat. *Fakultas Kedokteran, Universitas Islam Al-Azhar*. [Publisher]

Yatulaini, F., Tualeka, A. R., Jalaludin, J., & Russeng, S. S. (2021). The Relationship Between Duration Of Benzene Exposure With Liver Enzymes In Car Painting Workshop Workers Hubungan Antara Durasi Paparan Benzena Dengan Enzim Hati Pada Pekerja Pengecatan Mobil. *The Indonesian Journal Of Occupational Safety And Health*, *10*(3), 361–370. [Crossref], [Publisher]

Yudisianto, I., Tualeka, A. R., & Widajati, N. (2021). *Correlation Between Individual Characteristics And Work Position With Work Fatigue On Workers Hubungan Karakteristik Individu Dan Posisi Kerja Dengan Kelelahan Kerja Pada Pekerja*. [Crossref], [Publisher]