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Measurement of Background Radiation Levels in Some Selected Automobile Mechanic Workshops in Freetown

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ABSTRACT
Radiation is a natural and unavoidable part of the environment, emanating from both natural and artificial sources. Among the various forms of radiation, gamma radiation holds particular significance due to its high energy and deep penetration capability, which can have profound effects on human health and the environment. This research investigates the background gamma radiation levels in selected automobile mechanic workshops in Freetown, Sierra Leone, to address concerns about unintentional exposure to high quantities of ionizing radiation, particularly gamma rays. A handy automess 6150 AD 6/H survey metre was deployed to determine the exposure level of the workers and people around these automobile mechanic workshops to gamma radiation. The research showed that the highest annual equivalent dose rate is 2.081 mSv/yr and the lowest annual equivalent dose rate is 1.834 mSv/yr. These values exceed the annual dose limit of 1.0 mSv/yr as recommended by major international organizations like the ICRP, IAEA, and UNSCEAR. However, the outside background radiation exposure in the selected areas varies between 0.0124 and 0.0189 mR/hr, making an average of 0.0154 mR/hr in the surroundings, which also marginally exceeds the benchmark outside background radiation value of 0.011 mR/hr established by the U.S. NRC. The research suggests that the placement of these automobile mechanic workshops may have been influenced by nearness to radiation sources, which could pose serious health risks over time. Therefore, the workers, residents and the surrounding area are at the risk of chronic radiological effects due to long-term exposure.

Keywords:
Gamma radiation,
Equivalent dose,
Automobile workshops,
Radiation exposure.

INTRODUCTION

Radiation is an ever-present component of the environment, originating from both natural and artificial sources. Among its various forms, gamma radiation is particularly significant due to its high energy and deep penetration capability, which pose serious risks to human health and environmental safety (ICRP, 2007). Gamma radiation majorly originates from natural radionuclides like uranium-238, thorium-232, and potassium-40. Continued exposure to this form of radiation may cause serious health implications such as cancer, DNA alterations, and damage to internal organs, as documented by (UNSCEAR, 2000). While industrialized nations have well-established radiation safety measures, developing countries, including Sierra Leone, often lack comprehensive regulatory frameworks, leading to potential unmonitored exposure, especially in occupational settings.

One such occupational setting of growing concern is automobile mechanic workshops. These workshops are essential for vehicle repair and maintenance, yet they may unknowingly expose workers and surrounding communities to radiation hazards. The materials used in these environments, such as scrap metals, lubricants, and industrial tools, can contain naturally occurring radioactive materials (NORMs), which contribute to environmental gamma radiation (IAEA, 2014). Studies conducted in other parts of Africa, such as Nigeria and Ghana, have revealed that scrap metals sourced from unregulated supply chains may contain residual radiation, increasing occupational exposure risks (Nworgu et al., 2011). Additionally, diagnostic equipment and industrial tools used in repair operations may emit gamma radiation, further amplifying potential hazards in these workplaces.

Freetown, the capital of Sierra Leone, is home to numerous automobile mechanic workshops, many of which operate without radiation monitoring or adequate safety protocols. Unlike in developed countries where occupational radiation exposure is regularly assessed, Sierra Leone lacks empirical data on gamma radiation levels in mechanic workshops. This absence of data makes it difficult to determine the extent of potential radiation risks faced by workers and nearby residents. The increasing urbanization and industrial activities in Freetown further underscore the need for systematic monitoring of gamma radiation levels in these environments.

Research on occupational radiation exposure has traditionally focused on industries such as mining, healthcare, and nuclear energy production (ICRP, 2007). However, limited attention has been given to mechanic workshops, where unregulated recycling of automotive components and exposure to contaminated materials could pose long-term health risks. Previous studies from other African countries have measured gamma radiation levels in automobile repair zones, with some findings indicating elevated background radiation levels beyond global safety standards (James et al., 2014). However, no such studies have been conducted in Sierra Leone, leaving a critical gap in understanding the potential radiation hazards in this sector.

This research aims to establish the level of radiation and the associated risks around automobile workshops in Freetown. By employing scientific measurement techniques, including Geiger-Müller counters, scintillation detectors, and dosimetry assessments, this study will provide an accurate evaluation of radiation levels and their potential health implications. Furthermore, the findings will contribute to the development of occupational safety guidelines and policy recommendations for radiation monitoring in Sierra Leone's industrial sector.

Understanding the extent of gamma radiation exposure in mechanic workshops is crucial for ensuring workplace safety and protecting public health. By identifying potential sources of radiation and assessing exposure levels, this research will contribute to strengthening regulatory frameworks, raising awareness among workers, and guiding future studies on environmental radiation in urban settings. As Freetown continues to expand industrially, addressing radiation hazards in occupational environments will be fundamental to sustainable urban development and public health protection.

MATERIALS AND METHODS

Based on a number of factors, including their size, activity level, geographic dispersion around Freetown, and closeness to recognised industrial zones, scrap metal yards, or suspected radiation sources, eight automobile workshops were specifically chosen for the research. In an attempt to provide a realistic picture of occupational exposure throughout the city, workshops with different levels of operation, ranging from big commercial garages to tiny, roadside mechanics were included.

The main tool for measuring radiation was the Automess 6150 AD 6/H digital survey meter, a small and multipurpose gamma radiation dosimeter. The photon energy response range of this device is between 50 keV and 1.3 MeV, and its detection range is between 0.01 μSv/hr and 10 mSv/hr.

It meets IEC 60846 requirements and has energy-dependent efficiency that is especially optimised for environmental monitoring. A 137-Cs gamma source at the National Radiation Safety Laboratory in Freetown was used to calibrate the device before deployment, with a measurement uncertainty of ±5%. Every day, routine inspections were carried out to guarantee uniformity throughout sessions.

The measurements were taken from ten spatial points, adjusting for equipment layout, material concentration, and activity intensity. Data collection was conducted during three distinct sessions each day, over five consecutive days, and held 1.0 meters above ground level to simulate human exposure. The primary measurement unit was μSv/hr, which was converted into exposure rates in milliroentgen per hour (mR/hr) using radiological conversion formulas (Bushberg et al., 2001). The annual equivalent dose was estimated on yearly basis in millisieverts per year (mSv/yr) based on standardized exposure assumptions. The results were benchmarked against international exposure limits to assess compliance and potential risk.

$$Exposure\ Rate(mR/hr) = Ambient\ Equivalent\ dose \times 0.1 \quad (1)$$

$$Annual\ Ambient\ Equivalent\ Dose = Ambient\ Dose\ (mSv/hr) \times Hours/yr \quad (2)$$

RESULTS AND DISCUSSION

Table 1 shows the mean equivalent dose rates per session, measured from ten spatial points from each of the workshops

Table 1: **Ambient Equivalent Dose Rate in Selected Workshops (µsv/Hr*)***

Days	Session	Mayemi allen town	Old warf wellington	Temgbeh town	Wilkinson road	Sky street	Benz garage	Ross road	West street
Day 1	$M_{1,1}$	0.217±0.023	0.247±0.042	0.195±0.013	0.261±0.051	0.160±0.002	0.234±0.004	0.183±0.014	0.236±0.031
	$A_{1,1}$	0.248±0.014	0.224±0.015	0.215±0.032	0.236±0.045	0.180±0.012	0.196±0.015	0.207±0.021	0.250±0.015
	$E_{1,1}$	0.192±0.003	0.203±0.002	0.245±0.016	0.265±016	0.213±0.017	0.193±0.011	0.190±0.011	0.234±0.004
Day 2	$M_{2,2}$	0.207±0.021	0.238±0.031	0.229±0.051	0.237±0.003	0.167±0.016	0.217±0.023	0.225±0.033	0.247±0.014
	$A_{2,2}$	0.260±0.032	0.215±006	0.223±0.024	0.232±0.042	0.210±0.002	0.320±0.018	0.229±0.006	0.214±0.024
	$E_{2,2}$	0.238±0.031	0.192±0.012	0.205±0.011	0.269±0.035	0.238±0.031	0.224±0.005	0.276±0.042	0.206±0.022
Day 3	$M_{3,3}$	0.207±0.021	0.270±0.043	0.215±0.032	0.242±0.033	0.219±0.023	0.253±0.016	0.207±0.021	0.208±0.021
	$A_{3,3}$	0.232±0.030	0.252±0.034	0.258±0.006	0.310±0.007	0.229±0.018	0.212±0.023	0.248±0.005	0.167±0.013
	$E_{3,3}$	0.211±0.022	0.226±0.033	0.240±0.014	0.271±0.053	0.287±0.018	0.200±0.014	0.237±0.031	0.191±0.012
Day 4	$M_{4,4}$	0.235±0.004	0.190±0.011	0.211±0.022	0.181±0.011	0.214±0.031	0.203±0.015	0.210±0.002	0.253±0.016
	$A_{4,4}$	0.266±0.024	0.247±0.042	0.195±0.013	0.205±0.012	0.197±0.015	0.299±0.018	0.207±0.021	0.144±0.012
	$E_{4,4}$	0.235±0.004	0.226±0.033	0.244±0.005	0.222±0.004	0.208±0.021	0.228±0.006	0.213±0.031	0.276±0.042
Day 5	$M_{5,5}$	0.200±0.002	0.193±0.012	0.197±0.015	0.187±0.014	0.213±0.023	0.117±0.001	0.249±0.015	0.239±0.032
	$A_{5,5}$	0.235±0.004	0.292±0.044	0.227±0.018	0.206±0.015	0.198±0.015	0.262±0.017	0.177±0.011	0.118±0.011
	$E_{5,5}$	0.23±0.003	0.19±0.043	0.228±0.034	0.239±0.032	0.227±0.033	0.188±0.014	0.225±0.005	0.160±0.014

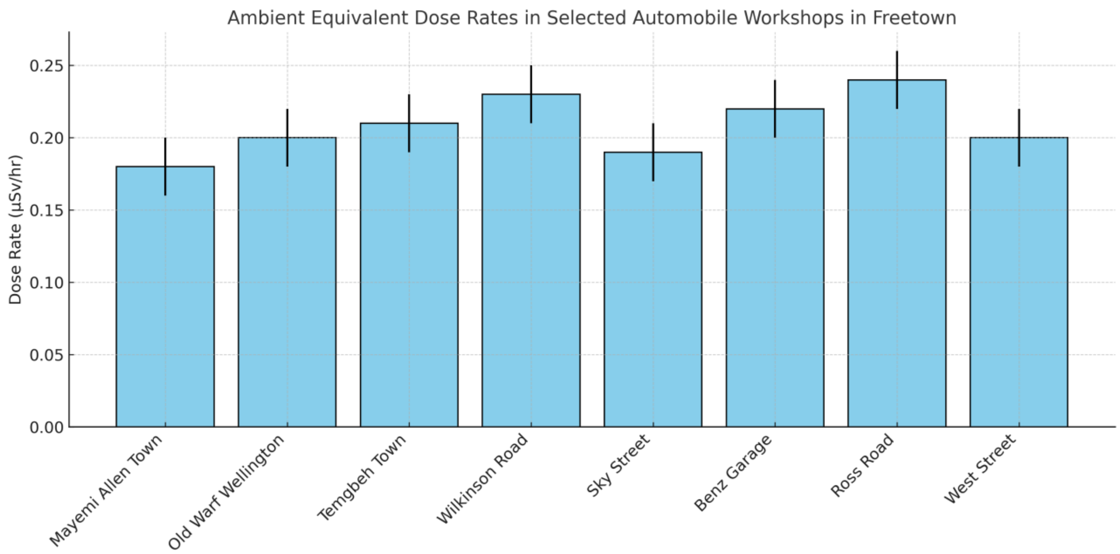

Figure 1**:** The Ambient equivalent dose rates by workshop

Figure 1 is a representation of the data in table 1 and it reveals that the workshop at Wilkinson Road as the highest detected form of background radiation while the sky street and West street had the least.

The results in table 1 were changed to exposure rates and annual equivalent dose rates in milliroentgen per hour and millisieverts per year respectively. Table 2a shows the mean for five consecutive days recorded in each of the eight selected automobile mechanic workshops.

Table 2a: Maximum Permissible Duration Using Exposure Rates

Location	**Exposure (µSv/hr)**	**Permissible Duration (hrs/yr)**
Mayemi Allen Town	0.023	4393.6
Old Warf Wellington	0.023	4393.6
Temgbeh Town	0.022	4509.5
Wilkinson Road	0.024	4209.6
Sky Street	0.021	4749.3
Benz Garage	0.022	4480.6
Ross Road	0.022	4570.1
West Street	0.021	4775.5

The maximum permissible durations are calculated using the public exposure limit of 1.0 mSv/yr divided by each exposure rate (µSv/hr).

Table 2b: Summary of Radiation Measurements in Selected Workshops

Location	**Ambient Eqv. Dose (µSv/hr)**	**Exposure (mR/hr)**	**Annual Eqv. Dose (mSv/yr)**
Mayemi Allen Town	0.2276 ± 0.016	0.0228	1.994
Old Warf Wellington	0.2276 ± 0.027	0.0228	1.994
Temgbeh Town	0.2218 ± 0.020	0.0222	1.943
Wilkinson Road	0.2376 ± 0.025	0.0238	2.081
Sky Street	0.2106 ± 0.018	0.0211	1.845
Benz Garage	0.2232 ± 0.013	0.0223	1.955
Ross Road	0.2188 ± 0.017	0.0219	1.917
West Street	0.2094 ± 0.019	0.0209	1.834
Average	$\mathbf{0.2221 \pm 0.019}$	**0.0222**	**1.945**

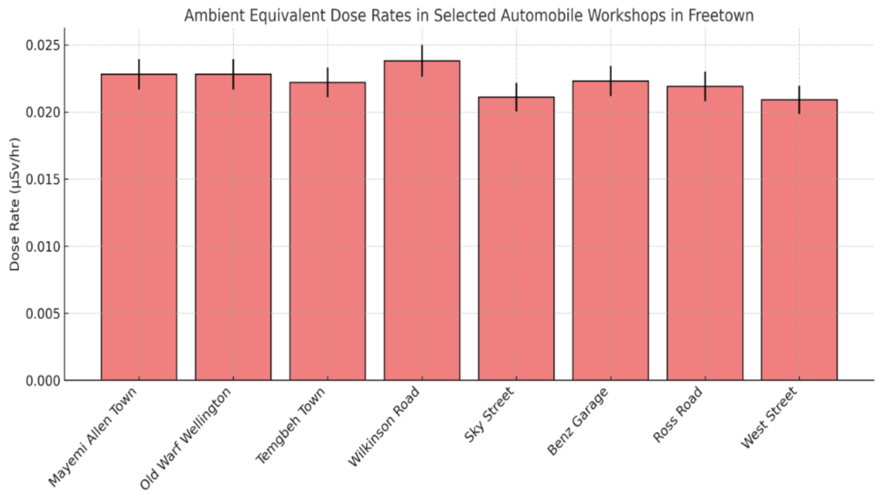

Figure 2: The Annual Equivalent dose rates by workshop

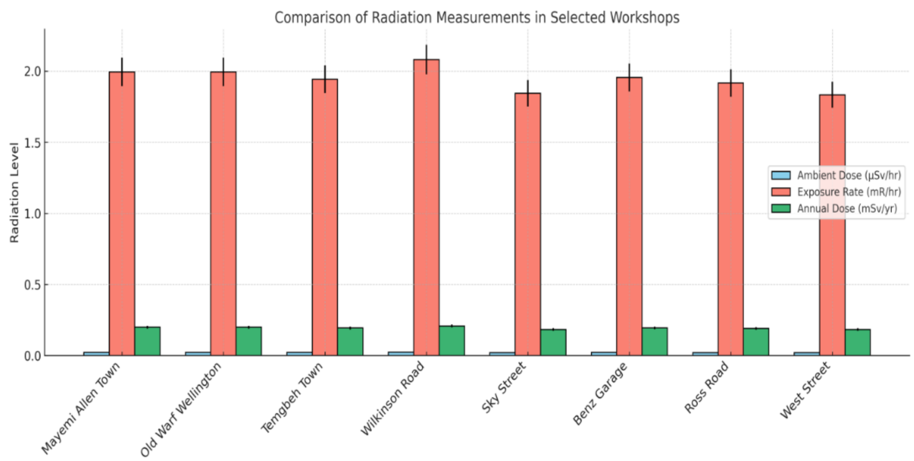

Figure 3: Comparison of Ambient equivalent dose, Exposure rate and Annual Equivalent Dose

Significant variances in gamma radiation exposure between the eight workshops were found by spatial analysis, which was correlated with geographic position and closeness to possible radiation sources. The highest annual ambient equivalent dose rate (2.081 mSv/yr) was found on Wilkinson Road as shown in Figure 2b, which is close to industrial areas and metal scrap yards. The lowest ambient equivalent dose rate (1.834 mSv/yr) was recorded on West Street, which maybe as a result of less workshop activity or less interaction with potentially contaminated components. According to (ICRP….1991), the set limit for occupational exposure is 20 mSv/yr (averaged over 5 years) and public exposure is 1.0 mSv/yr. This falls above the ICRP's threshold for public radiation exposure, since 2.081 mSv/yr and 1.834 mSv/yr exceed the public limit. However, these values are yet well below the occupational limit of 20 mSv/yr.
Figure 3 depicts a comparison of the Ambient equivalent dose, Exposure rate and Annual Equivalent Dose which reveals that the exposure rate is low for all the automobile workshops in Freetown, Sierra Leone.
Given the consistently high annual equivalent dose levels in all workshops and the marginally higher background radiation, this research offers compelling evidence that gamma radiation exposure in the workplace and environment in Freetown's automobile industry needs to be addressed. It is advised that further research be conducted to expand the research to additional industrial sectors and incorporate personal dosimetry for employees.
Table 3 represents values of the outside background radiation in each of the selected areas. These values vary from 0.0124 mR/hr (West Street) to 0.0189 mR/hr (Wilkinson Road) making an average value of 0.0154 mR/hr. Each of the measurements from the various locations slightly exceeds the standard outside background radiation limit, suggesting that site-specific factors may be contributing to elevated background levels. Based on the set standards, the recommended limit

is 0.011mR/hr (U.S. NRC…1979). The acquired mean result for outside background radiation in this research is in line with the results obtained in the monitoring of external background radiation level (Nwankwo et al., 2005).

Table 3: Outside Background Radiation (mR/hr) across the selected workshops

Location	Outside Background Radiation
Mayemi allen town	0.0173 ± 0.002
Oldwarf wellington	0.0184 ± 0.007
Temgbeh town	0.0142 ± 0.003
Wilkinson road	0.0189 ± 0.006
Sky street	0.0127 ± 0.004
Benz garage	0.0153 ± 0.002
Ross road	0.0141 ± 0.003
West street	0.0124 ± 0.005

CONCLUSION

The results showed that the ambient equivalent dose rates and exposure rates of all selected automobile mechanic workshops across Freetown are less than the required public limit. However, the annual equivalent doses of all the selected workshops exceed the public limit. This raises concern for continuous and long-term exposure. There is potential for cumulative, long-term exposure among individuals who work regularly in these environments, more so those in close contact with scrap materials and high activity zones. Without regular monitoring and protective measures, chronic exposure could lead to increase health effects over time, mostly for sensitive populations or those working in poorly ventilated areas.

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REFERENCES

Bushberg, J. T., Seibert, J. A., Leidholdt, E. M., & Boone, J. M. (2001). The essential physics of medical imaging (2nd ed., pp. 56–57). *Lippincott Williams & Wilkins.* https://shop.lww.com/The-Essential-Physics-of-Medical-Imaging/p/9780781721343

International Atomic Energy Agency. (2014). *Radiation protection and safety of radiation sources: International basic safety standards* (No. GSR Part 3). https://www.iaea.org/publications/8930/radiation-protection-and-safety-of-radiation-sources-international-basic-safety-standards

International Commission on Radiological Protection. (1991). *ICRP Publication 60: 1990 Recommendations of the International Commission on Radiological Protection*. *Annals of the ICRP, 21*(1–3). https://doi.org/10.1016/0146-6453(91)90005-2

International Commission on Radiological Protection. (2007). *ICRP Publication 103: The 2007 recommendations of the International Commission on Radiological Protection*. *Annals of the ICRP, 37*(2–4). https://doi.org/10.1016/j.icrp.2007.10.003

James, I. U., Moses, I. F., & Vandi, J. N. (2014). Measurement of gamma radiation in an automobile mechanic village in Abuja, North Central, Nigeria. *Journal of Applied Sciences and Environmental Management, 18*(2), 293–296. https://doi.org/10.4314/jasem.v18i2.11

Nwankwo, L. I., & Akoshile, C. O. (2005). Monitoring of external background radiation level in Asa Dam industrial area of Ilorin, Kwara State, Nigeria. *Journal of Applied Sciences and Environmental Management, 9*(3), 91–94. https://doi.org/10.4314/jasem.v9i3.17359

Nworgu, O. D., Osahon, O. D., & Obinyan, F. E. (2011). Measurement of gamma radiation in automobile mechanic workshops in an area of Benin City, Nigeria. *Advanced Materials Research, 367*, 801–805. https://doi.org/10.4028/www.scientific.net/AMR.367.801

United Nations Scientific Committee on the Effects of Atomic Radiation. (2000). *Sources and effects of ionizing radiation: UNSCEAR 2000 report to the General Assembly, with scientific annexes*. https://www.unscear.org/docs/publications/2000/UNSCEAR_2000_Report_Vol.I.pdf

U.S. Nuclear Regulatory Commission. (1979). *Standards for protection against radiation* (Title 10, Part 20,20.1003). https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/index.html