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Cardiovascular Risk Assessment Among Workers in the West Attica Landfill

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Abstract

Introduction: Landfill workers are frequently exposed to a multitude of deleterious factors that can adversely affect their health. These include environmental contaminants such as dioxins, furans, biogas, and heavy metals,

as well as occupational hazards like noise, vibration, and extreme temperatures. **Aims and Scope:** This pilot study, conducted at the Integrated Solid Waste Management Facility of Fili (OEDA Filis), aimed to measure environmental risk parameters and assess their effects on the cardiovascular health of workers. **Method:** Data collection involved questionnaires to record personal history, work stress and job positions, clinical examinations, and blood lipid tests. Cardiovascular risk (Heart Score) was evaluated based on standards set by the Hellenic Heart Association, which incorporated the Heart Score using Greek data. **Results:** The majority of employees at OEDA Filis were married men from lower socioeconomic backgrounds, with 77% reporting no chronic health issues and self-assessing their health status as good. Most subjects had body mass indices categorized as either normal or overweight. Environmental assessments identified elevated concentrations of PM10 and phenanthrene in the workplace, though levels of benzo(a)pyrene and naphthalene were within safety thresholds. About 21% of the workforce was identified as being at considerable risk for cardiovascular disease. No statistically significant relation was found between the Heart Score and job positions ($p = 0.3$), indicating that occupational role alone does not predict cardiovascular risk. However, elevated Heart Scores were more frequently observed among positions with greater exposure to environmental and occupational hazards. Conversely, office workers, who had reduced exposure to exhaust, noise, and air pollutants, exhibited lower Heart Scores. Univariate analysis showed a significant association between occupational stress and Heart Score ($p = 0.037$); workers under high stress had significantly lower levels of high-density lipoprotein (HDL) ($p = 0.006$). Additionally, a significant association existed between the use of personal protective equipment (PPE) and lower Heart Score risk index values ($p = 0.012$), highlighting the protective impact of PPE in mitigating cardiovascular risk among exposed workers. **Conclusion:** This study enhances understanding of the associations between cardiovascular risk and exposure to environmental and occupational hazards at landfill sites. It underscores the critical need to establish a specialized observatory for continuous monitoring of occupational health and safety at these locations. Such an observatory should include regular health assessments for workers and systematic monitoring of environmental pollutants. Furthermore, the study advocates for initiatives aimed at improving the cardiovascular health of landfill workers, underscoring their necessity in this high-risk occupational environment.

Keywords: Cardiovascular risk, Landfill workers, Occupational Health, Heart Score

Introduction

All urban solid waste from the city of Athens is meticulously processed at the Integrated Solid Waste Management Facility of Fili (OEDA Filis), where cutting-edge management techniques are deployed to meet stringent standards aimed at minimizing environmental impacts. Despite the comprehensive legislative and regulatory framework designed to mitigate potential pollution and contamination, concerns remain regarding the environmental and health impacts associated with waste management practices.

Effective primary prevention is crucial for workers aged 40-65 years employed at landfill facilities. This study analyzes the relationship between exposure to various workplace variables—such as heavy metals, particulate matter (PM_{2.5} and PM₁₀), work stress, and others—and cardiovascular risk (measured with HeartScore) among these workers.

To estimate the likelihood of a fatal cardiovascular event within the ensuing decade, healthcare professionals employ the Hellenic HeartScore, an adaptation of the European Society of Cardiology's assessment tool. This instrument is pivotal in evaluating cardiovascular risk and guiding preventive strategies in clinical settings (Elisaf, Pitsavos, Liberopoulos, & Athyros, 2011). However, for patients already diagnosed with clinical atherosclerotic cardiovascular disease, diabetes mellitus, or chronic kidney disease, the standard SCORE system is inadequate. These conditions indicate an inherently high risk, rendering conventional risk estimation methods insufficient (Conroy, 2003). Alternative risk assessment models are thus necessary to ensure precise risk stratification and appropriate management (Price, 2004).

Environmental monitoring studies have consistently highlighted the significant relationship between air pollution and increased cardiovascular risk. Both long-term and short-term exposures to particulate matter, specifically PM₁₀ and PM_{2.5}, have been strongly correlated with the development of arterial hypertension and accelerated atherosclerosis. Remarkably, exposure to PM_{2.5} has been linked to an elevated risk of myocardial infarction occurring as soon as one day after exposure, underlining the acute effects of particulate pollutants (Yang et al., 2018; Newell et al., 2018; Neophytou et al., 2019).

Moreover, the introduction of the Environmental Risk Score (ERS) has facilitated deeper investigations into the cardiovascular implications of heavy metal exposure. Significant correlations have been established between heavy metals such as barium, cadmium, and arsenic and increases in blood pressure and overall cardiovascular risk. These findings highlight the urgent need for

integrating environmental health considerations into broader public health strategies (Park, Zhao, & Mukherjee, 2017).

Further systematic reviews have clarified the associations between various environmental contaminants and cardiovascular health. Specifically, exposure to heavy metals like chromium, barium, and nickel has been linked to a higher incidence of atherosclerotic cardiovascular diseases. Additionally, there is compelling evidence of the detrimental effects of polycyclic aromatic hydrocarbons (PAHs), which elevate homocysteine and cholesterol levels, further exacerbating cardiovascular risks. Such exposures, often occurring within occupational settings, underscore the importance of stringent environmental controls and proactive health monitoring to mitigate their impacts (Nigra et al., 2016; Alhamdow et al., 2017; Dutta & Ray, 2013; Banerjee et al., 2012).

In conclusion, while the management practices at the Integrated Solid Waste Management Facility of Fili are robust and designed to minimize environmental and public health risks, the persistent threats posed by environmental contaminants and occupational exposures necessitate ongoing vigilance. This calls for enhanced regulatory measures, rigorous environmental monitoring, and comprehensive health surveillance to protect the cardiovascular health of exposed populations. Such multidimensional approaches are essential to effectively manage and mitigate the complex interactions between environmental contaminants and public health.

Methods

In this epidemiological study conducted at the Integrated Solid Waste Management Facility of Fili and involving external contractors, the focus centers on assessing the cardiovascular impacts of occupational exposure. The active workforce subjected to the survey totals 470 individuals, with the study sample comprising 102 workers. This represents a sampling fraction of approximately $1/4.6$, assuming full participation in the sampling effort. In the study, the Heart Score—a measure of cardiovascular risk—was calculated for 64 of the participants, while all 102 participants underwent biochemical assessments of their lipid profiles and clinical examinations (see *Heart Score data collection*).

The primary research question investigates the potential cardiovascular effects of occupational exposure among workers. Occupational epidemiology typically categorizes workers into "exposed" and "unexposed" groups or stratifies them according to exposure levels. The main goal of such studies is not necessarily to ensure the representativeness of the entire workforce but to focus on those exposed. This approach aims to capture any health effects more accurately by including those most at risk due to their exposure levels. To address potential bias—such as the exclusion of workers

who may have left the job due to exposure-related health effects—the study includes individuals who have departed from the workplace (through retirement, resignation, or death) within the last five years.

For the purposes of this study, the 102 landfill workers were categorized into eight distinct posts. Each post potentially represents different levels of exposure to hazardous substances, thereby allowing the study to differentiate the degree of risk associated with specific job functions within the landfill operation. This methodological approach is crucial for identifying and understanding the nuances of occupational exposure and its impact on cardiovascular health among workers.

Table 1: Job Positions

- Post 1	Supervisors/ Facility Operators
- Post 2	Weighing/Macroscopic inspections/Radioactive material control (main tasks at the gate)
- Post 3	Electrical and plumbing work
- Post 4	General worker
- Post 5	Drivers of service vehicles on and off site
- Post 6	Special machinery operators (thrusters/compressors/presses)
- Post 7	Vehicle/machinery workshop workers
- Post 8	Office workers (secretarial, clerical, etc.) secretarial support/informatics/accounting/cleaning)

For the cardiovascular assessment within the study, specific procedures were meticulously followed to ensure the accuracy and reliability of the data collected from the landfill workers. Workers with a 5-year history of presence in the landfill were selected. Initially, the workers convened in a designated area of the landfill where they were briefed about the study's objectives through an information leaflet. They then signed consent forms, indicating their voluntary participation in the study.

Before measuring blood pressure, workers were given specific instructions to ensure the accuracy of the results. They were advised to refrain from smoking for at least 30 minutes prior to the test. Additionally, a minimum fasting period of 14 hours was required to standardize conditions across all participants. For those on morning medication, it was essential to take their medication as usual to prevent any fluctuations in blood pressure that could arise from missed doses. These precautions were carefully communicated to optimize the reliability of the blood pressure measurements. Blood pressure measurement was conducted using a certified automatic sphygmomanometer equipped with a cuff appropriately sized for the worker's arm circumference. To ensure comfort and reduce variability in measurements, workers were seated in chairs with back support, feet flat on the ground, following a rest period of approximately 15 minutes. This resting period helps in stabilizing their physiological state, reducing the potential for transient increases in blood

pressure due to physical activity or stress. To further enhance measurement reliability, three separate blood pressure readings were taken from each worker. The mean of these three readings was calculated and used as the final measure to mitigate any potential errors from individual readings. The blood pressure limits were set according to the latest guidelines, with systolic pressure not exceeding 130 mmHg and diastolic pressure capped at 80 mmHg. These structured protocols are critical in minimizing measurement errors and ensuring that the blood pressure data reflects the true cardiovascular status of the workers, thus providing valid inputs for the study's analysis on the impact of occupational exposure on cardiovascular health.

The sampling strategy was carefully designed to focus on workers with prolonged exposure durations to better understand the potential health effects of occupational exposure. Recognizing that the magnitude of health effects often correlates with exposure duration, the study specifically excluded workers with less than five years of exposure. This approach enhances the effectiveness of detecting potential health impacts by concentrating on a population with significant exposure histories.

Sampling and Data Collection Techniques:

Workers with over five years of exposure were included, and stratified sampling was applied to ensure a representative analysis of each workplace. The workforce at the landfill primarily consists of employees on fixed-term contracts, with only a limited number of permanent workers possessing more than five years of experience. Furthermore, a significant portion of the workforce is employed through subcontractors, and therefore, they are not directly affiliated with the Integrated Solid Waste Management Facility of Fili. This employment structure presents unique challenges for this study. The sampling fraction was set at $1 / 3.0$, utilizing random number selection within each stratum to ensure unbiased sample selection.

Employees were asked to self-assess their health status and report any chronic health issues through a questionnaire designed to capture comprehensive health and lifestyle data. This questionnaire was tailored to the demographic and health specifics of the general population of Greece, ensuring its relevance and effectiveness, it included a special section for mental health with questions according to PHQ-9.

Extensive data was collected, including demographic information, personal and family health history, employment history, lifestyle habits (such as smoking, alcohol consumption, diet, and physical activity), reasons for recent doctor visits, known health issues, mental health and occupational exposure to hazardous agents. The use of personal protective equipment was also recorded.

Clinical and Laboratory Procedures:

All workers underwent comprehensive physical measurements, including height, weight, and body mass index (BMI), which were categorized according to standard formulas. In addition to these physical assessments, each worker participated in a thorough cardiovascular evaluation. Clinical examinations included checking the arterial pulse in both the upper and lower limbs, assessing the jugular pulse, and auscultation of the heart by trained medical personnel.

Laboratory testing was an integral part of the health assessment, with blood samples drawn by trained nursing staff. These samples were analyzed for lipid profiles, including LDL, HDL, triglycerides, and total cholesterol, at a biopathology laboratory accredited to ISO 15189 and ISO 9001:2008 standards.

Furthermore, a subset of 30 workers underwent biochemical testing for heavy metals. This testing included screening for lead (Pb), arsenic (As), chromium (Cr), and cadmium (Cd), providing valuable data on the potential exposure to these hazardous substances.

Environmental monitoring was also a critical component of the study. Noise levels at various workplaces were measured using specialized sensors, with data collected by a dedicated team. Additionally, biogas and particulate matter levels were monitored by an accredited laboratory, ensuring a comprehensive understanding of the environmental conditions faced by the workers.

This multifaceted approach provided a detailed overview of the physical health and environmental exposures experienced by workers at the landfill site, highlighting the various risks and underscoring the need for targeted health and safety interventions.

Study Design Considerations:

This strategic focus on a specific subset of the workforce aims to generate more precise and meaningful insights into the health impacts associated with occupational exposure. The careful design of the questionnaire, combined with the comprehensive nature of the data collection process, ensures that the study can reliably inform the formulation of workplace safety policies and health interventions specifically tailored to the needs of workers with significant exposure histories. This methodical approach not only enhances the study's ability to accurately identify health effects but also supports the development of targeted preventive measures to mitigate these risks.

Environmental measurements procedure:

This comprehensive occupational health study at a landfill integrates meticulous environmental and medical data collection, adhering to established standards and ethical guidelines. The sampling of Total Suspended Particles (TSP) follows the EN12884:2000 standard, with a 24-hour collection period using high flow samplers equipped with quartz and polyurethane filters. For PM10 particulate matter, the methodology aligns with the EN12341:2014 standard, which specifies the gravimetric measurement method for assessing particulate concentrations.

The study strategically selected three points (#1 Landfill Entry, #2 Mechanical Processing, #3 Landfill Cell) within the landfill, considering the topography to assess environmental factors that could impact workers. Environmental measurements were conducted in three phases (Phase A 19/04/2018 until 10/05/2018, Phase B 17/09/2018 until 08/10/2018, Phase C 21/01/2019 until 07/02/2019) corresponding to spring, autumn, and winter, allowing for the analysis of seasonal variations in particulate exposure. In Phase A, the winds at points #1, #2, and #3 were north-east, north-north-east, and south-east, respectively. In Phase B, point #1 was affected by east winds, while points #2 and #3 were affected by east-north-east and north-west winds, respectively. Phase C: Points #1 and #2 were subject to east-northeast winds, while at #3 the winds were east-south-southwest.



Picture 1: Three sampling points at the landfill #1,#2,#3

Heart Score data collection :

In terms of health assessments, the Heart Score analysis was conducted for 64 out of the 102 workers who met the study's eligibility criteria. This analysis excluded individuals with pre-existing cardiovascular conditions or diabetes, ensuring a more accurate assessment of cardiovascular risk within the studied population. The broader health assessment included testing for cholesterol, glucose, triglycerides, and HDL cholesterol among all 102 participants, complemented by clinical examinations.

Data collection was meticulously organized, with demographic and occupational history gathered separately from examination data to ensure clarity and confidentiality. Mental health and occupational stress were examined through the questionnaire with a section using the PHQ-9 questionnaire model. Each worker was assigned a unique code, and the collected information was consolidated into a single Excel database, which contains data for 102 workers across more than 750 variables.

Statistical analysis:

The statistical analysis for the study was conducted using the R programming language, version 3.6, facilitated by RStudio. This powerful environment allowed for efficient and thorough data analysis using a suite of specialized statistical packages. To handle various statistical functions, several packages were employed. The "brglm" package was particularly useful for performing penalized logistic regression, which is beneficial when dealing with data that has separation or near separation issues. This advanced method ensures more reliable results in such complex data scenarios. For managing the input and output of data in Excel format, the "xlsx" package was utilized. This package streamlined the workflow, making it easy to import and export data, thus enhancing the efficiency of the analysis process. Data manipulation tasks, such as formatting and grouping, were accomplished using the "reshape2" package. This package facilitated the transformation and organization of data into formats suitable for analysis, making the data handling process more manageable. Visualizing the data was an important aspect of the analysis, and several packages were used to create various types of plots. The "lattice" package was employed to create point plots, providing a clear representation of individual data points. The "vcd" package was used for creating correlation plots, helping to visualize relationships between variables. Additionally, the "ggplot2" package was utilized for creating box plots, offering a detailed view of data distributions and highlighting any potential outliers.

By combining these tools and packages, the analysis was robust and comprehensive. This approach provided clear insights through both rigorous statistical testing and detailed graphical presentations, enabling a thorough

understanding of the data and its implications. The Heart score is calculated based on systolic blood pressure, age, sex, smoking and total cholesterol. Therefore, it was thought not meaningful to test its association with these variables univariately, as they are related by definition. Instead, these four variables were considered at multivariate model using penalized logistic regression. Univariate linear regression data analysis was used for the relationship between HEART SCORE and the other variables of interest "Cholesterol", "Glucose", "Triglycerides" and "HDLc".

Results

The gender distribution among the workers involved in the landfill study showed a significantly higher proportion of men, with 49 men (77%) compared to 15 women (23%). This disparity is largely attributed to the physical nature of the work typically found at landfill sites. The ages of the participants were evenly distributed across all groups, which helps in making age-related analysis more reliable.

Regarding marital status, a majority of the workers were married (78), followed by those who were unmarried (17), with smaller numbers being divorced (4), separated (1), and widowed (2). The educational level among the workers predominantly reached secondary education, with only a minimal percentage having attained higher education. This educational distribution is a factor in understanding the workers' socio-economic status, which was predominantly categorized as middle or low based on annual family income. When it came to health status, slightly less than half of the employees (43) reported not having any chronic health problems requiring medication. In terms of self-assessed health status, 24% of the workers considered their health to be very good, 50% good, 23% moderate, 2% bad, and 1% very bad. Among the 38 workers who reported chronic health issues, cardiovascular diseases were the most prevalent, primarily resulting from arterial hypertension and hyperlipidemia. Musculoskeletal disorders and thyroid diseases were also commonly reported, indicating significant health concerns within this workforce.

From the clinical examinations conducted, workers' health was further quantified through the calculation of their Body Mass Index (BMI), categorized into standard grades. This BMI data is essential for assessing the prevalence of obesity or underweight conditions within the workforce, which are critical factors in the overall health profile and risk factors for various diseases, including those related to cardiovascular conditions.

Table 2: Body Mass Index -employees distribution

BMI	<19 Underweight	19-25 Normal weight	26-29 Overweight	30-34 Obese	35-39 Severe obesity	40-50 Morbid obesity	>50 Malignant obesity
Employees distribution	0	33	48	11	7	3	0

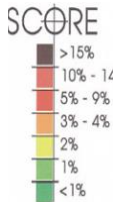
In relation to the health impacts, dyslipidemia was identified as a major risk factor for cardiovascular diseases. Early diagnosis and effective management of dyslipidemia are crucial for reducing cardiovascular morbidity and mortality. As part of the health assessment, workers underwent blood tests to evaluate their lipid profiles, including measurements of cholesterol, triglycerides, LDL, and HDL. This biochemical assessment is essential for identifying workers at elevated risk of cardiovascular conditions, thereby facilitating timely intervention and management strategies to mitigate these risks in a population exposed to environmental contaminants at the landfill site.

Table 3: Biochemical Lipid profile of landfill workers

Biochemical test	Values (mg/dl)	Employees percentage
HDL	> 40	77%
	<40	23%
Total cholesterol	<200	57%
	>200	43%
Triglycerides	>200	14%
	150-200	13%
	<150	73%

The HeartScore was calculated by incorporating various cardiovascular risk factors, including gender, age, smoking habits, and key lipid metrics such as total cholesterol, HDL cholesterol, LDL cholesterol, triglycerides, and systolic blood pressure. This approach allows for a detailed evaluation of the cardiovascular risk profile across different demographics within the workforce. Importantly, the assessment excluded workers with pre-existing cardiovascular conditions such as arterial hypertension, coronary heart disease, or diabetes mellitus since these individuals already possess an elevated risk. By focusing on those without diagnosed cardiovascular disease, the analysis aims to identify subtle trends in cardiovascular risk across the sample, providing a clearer picture of the potential impacts of occupational exposure on heart health. This methodical application of the HeartScore facilitates targeted health interventions by pinpointing workers at higher risk due to modifiable factors.

Table 4: Distribution of employees according to HeartScore

Heart Score	0-2,5%	2,5-5%	5-10%	10-15%	>15%	non calculate	
Number of employees	44	10	6	2	2	38	

To facilitate a more granular understanding of cardiovascular risk among landfill workers, the initial risk group (0-5% HeartScore) was subdivided. This decision was motivated by the recognition that clustering a majority of employees in this broad category would obscure subtle variations in their cardiovascular risk profiles. It was determined that HeartScores exceeding 2.5% indicate a notable cardiovascular risk, necessitating intervention. Notably, about 21% of the sampled population falls into this higher risk category, underscoring the need for targeted health strategies within this group.

Further analysis revealed no statistically significant connection between HeartScore and specific job roles (p -value = 0.3), suggesting that cardiovascular risk does not vary markedly across different positions within the landfill site. However, descriptive data indicates some variation, with certain job roles associated with higher or lower risk indices. Interestingly, a significant portion of workers are within a normal weight range, while a small number are categorized as obese or morbidly obese. This finding contrasts with common assumptions about occupational health risks and highlights the diverse health profiles within this workforce. Regarding lifestyle factors, smoking habits and alcohol consumption were also analyzed. The survey found that 27% of workers had never smoked, 12% were ex-smokers, and 61% were current smokers. In terms of alcohol consumption, 66% of workers reported consuming alcohol, typically wine, on a weekly or monthly basis, while 34% abstained. This consumption pattern is relevant as it has the potential to influence lipid and cholesterol levels, indirectly affecting the HeartScore and overall cardiovascular risk. These insights collectively inform the development of health interventions aimed at mitigating cardiovascular risk, emphasizing the importance of personalized health strategies that account for individual behaviors and job-specific factors.

Table 5: Relation of job position and HeartScore

<i>HeartScore</i>	0-2,5%	2,5-5%	5-10%	10-15%	>15%
Workplace job position - People					
1. Supervisors/Facility Operators	2	1	1	1	0
2. Weighing	8	1	2	0	0
3. Electrical and plumbing work	2	1	0	0	0
4. General worker	8	3	0	1	1
5. Drivers of service vehicles	3	0	1	0	0
6. Special machinery operators	6	2	2	0	1
7. Vehicle/machinery workshop workers	5	2	0	0	0
8. Office workers	10	0	0	0	0

It is significant to observe that job positions associated with higher HeartScore (HS) are those involving substantial exposure to various environmental and occupational hazards. Conversely, workers stationed in office settings experience less exposure to exhaust, noise, or air pollutants compared to their counterparts in more exposed, outdoor environments (Table 5). A univariate linear regression analysis reveals a statistically significant relationship between occupational stress and HS, as evidenced by a p-value of $0.037 < 0,05$, indicating that greater occupational stress affects HeartScore with higher values. This finding highlights the impact of job-related environmental factors on cardiovascular risk, underscoring the importance of considering occupational exposure in health risk assessments.

From the multivariate analysis, a notable observation emerges regarding the relationship between HDL cholesterol, commonly referred to as "good" cholesterol, and occupational stress. The analysis, which included controlling for potential confounding factors (age, gender, smoking, exposure to exhaust gas, etc), identified a significant univariate association between job stress and HDL levels. (Table 6) Specifically, workers reporting stress at their jobs exhibited HDL levels that were, on average, 7.6 times lower than those of workers who reported no stress. This finding is statistically significant, with a p-value of $0.006 < 0.05$, highlighting the substantial impact that occupational stress can have on an individual's cholesterol levels, potentially increasing their risk for cardiovascular diseases. This underscores the critical need for workplace interventions that address stress management to help mitigate its adverse effects on health.

Graph 1: Relation of duration of work- work related or not stress and HDL-c

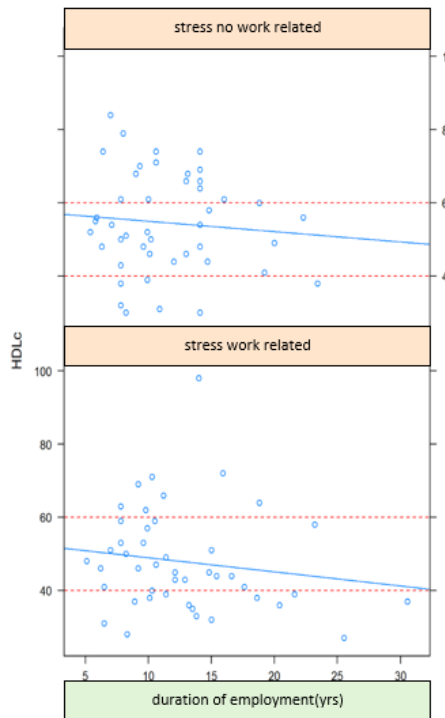


Table 6: Regression of the derivative HDL-c

Variables	Effect size	p-value
Fixed	79,849	
occupation years	-0,313	0,252
Age	-0,198	0,246
Gender (female)	16,889	<0,001
Smoking	-3,659	0,269
ex smoker	-2,371	0,565
BMI	-0,681	0,004
internal job position	-1,068	0,794
PPE	0,052	0,991
Sleep Apnea	22,331	0,077
no PPE	-3,324	0,333
no exhaust gas	-0,816	0,782
no stress	7,6	0,006

The analysis also demonstrates a connection between gender, the Body Mass Index (BMI) and sleep apnea. However, the interpretation of the gender connection is complicated by the uneven distribution across different job roles and, consequently, the degree of exposure to hazardous agents, making it difficult to draw definitive conclusions from this aspect of the data. Regarding BMI, the findings suggest that workers with a higher BMI tend to have proportionately higher levels of HDL cholesterol, with an average increase of

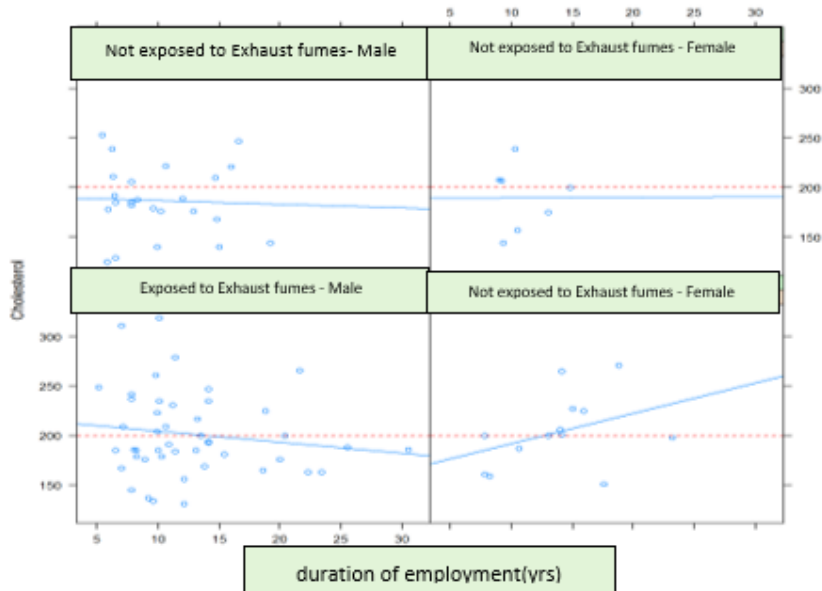
0.681 times. This result may reflect the complex interactions between body fat, metabolic health, and cholesterol levels. The prevalence of sleep apnea, as reported in the study under the category of respiratory health, was relatively low, which could potentially bias the representation of its impact within the overall dataset. The small number of cases makes it challenging to assess the condition's true prevalence and its potential correlation with other health issues within the workforce accurately.

Additionally, the study explored the relationship between exposure to exhaust and cardiovascular risk. The findings indicate a potential trend towards a connection between these two factors, with a p-value of 0.08 (table7) While this result does not meet the conventional threshold for statistical significance ($p < 0.05$), it does suggest a possible association that may warrant further investigation, especially given the p-value is less than 0.10, hinting at emerging patterns that could become significant with a larger sample size or additional data.

The relationship between cholesterol levels and exposure to exhaust gases has been thoroughly investigated as a potential factor influencing the HeartScore, especially in the context of various other variables. A univariate analysis assessing the relation between cholesterol levels and exposure to exhaust gases revealed no significant association; the p-value of 0.51 indicates statistical non-significance, with similar proportions of physiological test outcomes among those exposed to exhaust gases compared to those not exposed.

Despite these findings, graphical representations of the data demonstrate noteworthy patterns. Specifically, among the individuals not exposed to exhaust gases, the initial two observations boxes(not exposed to exhaust fumes-male and not exposed to exhaust fumes-female-graph2) fall below the 200 mg/dL cholesterol threshold, which is considered normal. Conversely, for those exposed to exhaust gases, the linear regression analysis intersects the diagnostic upper limit of cholesterol, showing a notably steeper slope of increase, particularly among women.

Further regression analyses, which accounted for confounding factors such as age and gender, indicated that workers exposed to exhaust fumes exhibit an average increase of 20.4 units in cholesterol levels compared to their non-exposed counterparts. These findings underscore the necessity of considering multiple confounding variables when exploring the health impacts of environmental exposures on cholesterol levels and subsequent cardiovascular risk.

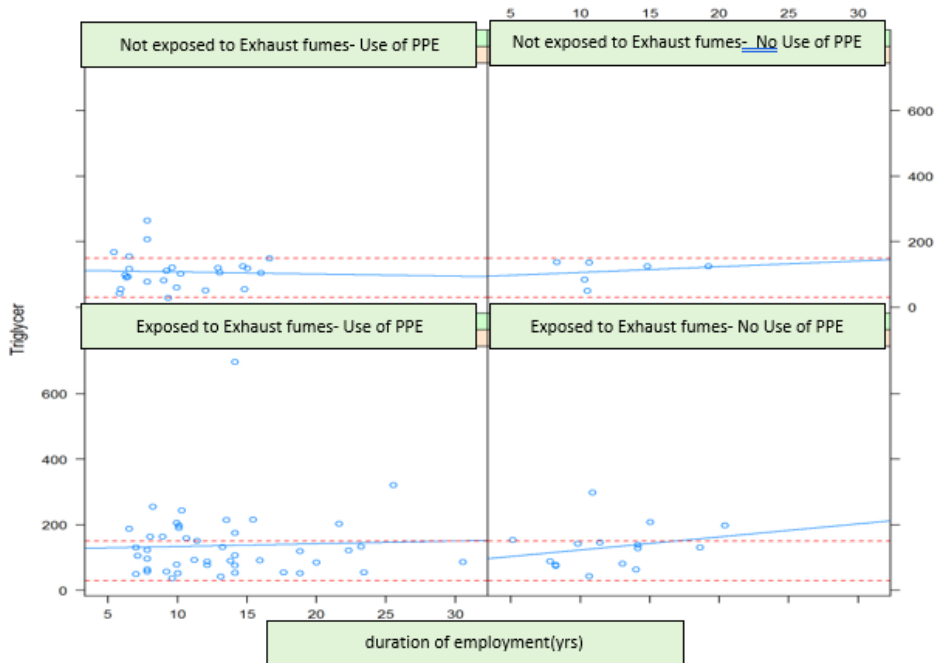


Graph 2: Association of years of work with cholesterol exposure to exhaust fumes and gender

Table 7: Regression of CHOLESTEROL

Variables	Effect size	p-value
Fixed	115,379	
occupation years	-1,07	0,232
Age	1,326	0,019
Gender (female)	22,028	0,08
Smoking	25,84	0,019
ex smoker	0,781	0,954
BMI	0,563	0,457
internal job position	-7,973	0,553
PPE	-22,501	0,14
Sleep Apnea	22,331	0,127
no PPE	5,876	0,6
no exhaust gas	-20,388	0,038
no stress	8,174	0,352

In a detailed examination of the relationship between exposure to exhaust fumes and abnormal triglyceride levels, a univariate linear analysis revealed a marginally significant association ($p\text{-value} = 0.09 < 0.10$). Notably, a higher proportion of abnormal triglyceride measurements was observed in those exposed to exhaust fumes (33.33%) compared to those not exposed (16.13%). Graphical analysis further illustrates that regression lines intersect the upper diagnostic limits of triglycerides more frequently among workers exposed to exhaust fumes. Additionally, it was observed that the lack of personal protective equipment (PPE) usage tends to be associated with increasing triglyceride levels over time among those exposed to exhaust fumes.



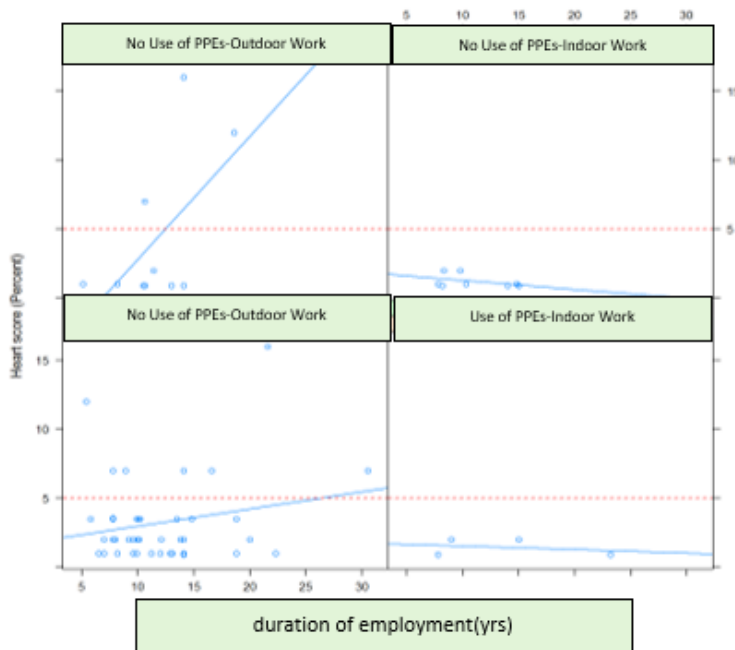
Graph 3: Association of years of work with Triglycerides exposure to exhaust fumes and the use of PPEs

Conversely, univariate analyses of the association between heart score (HS) and various other environmental factors, such as dust, noise, vibration, and exposure to extreme temperatures, did not demonstrate statistically significant relationships. The respective p-values (dust exposure p-value = 0.7, noise exposure p-value = 0.56, vibration exposure p-value = 0.67, and extreme temperatures p-value = 0.57) all exceeded the conventional threshold of 0.05, suggesting no significant impact on cardiovascular risk. This outcome suggests that with a larger sample size, a significant relation might emerge for one of these factors.

Furthermore, a multivariate analysis with penalized logistic regression confirmed that age, smoking habits, and systolic blood pressure significantly influence cardiovascular risk, as evidenced by p-values less than 0.05. These findings underscore the complex interplay of various risk factors in determining cardiovascular health and highlight the critical need for comprehensive protective measures, particularly for workers in environments with potential hazardous exposures.

In evaluating the composite factors contributing to the HeartScore and considering workplace environment variables (indoor/outdoor), a statistically significant connection was observed between the use of personal protective equipment (PPE) and the HeartScore risk index (p-value = 0.012 < 0.05). Specifically, the data indicates that the use of PPE results in an average

reduction of 1.75 points in the HeartScore risk index, demonstrating its protective benefit in mitigating cardiovascular risk.



Graph 4: Association of years of work with HeartScore, the use of PPEs and place of work

Table 9: Regression of diastolic pressure factor

Variables	Effect size	p-value
Fixed	63,573	
occupation years	0,472	0,091
Age	0,168	0,332
Gender (female)	-9,905	0,012
Smoking	-4,718	0,162
ex smoker	-4,026	0,337
BMI	0,547	0,022
internal job position	-0,928	0,329
NSAID	11,553	0,016
Sleep Apnea	-8,248	0,516
no PPE	4,498	0,198
no exhaust gas	3,085	0,306
no stress	-0,136	0,96

Further analysis through regression models, which included confounding factors such as age, gender, body mass index, and the use of nonsteroidal anti-inflammatory drugs (NSAIDs), revealed a trend in diastolic blood pressure changes relative to years of employment. For workers engaged for 10 years at a landfill, there is an average increase in diastolic blood pressure of 4.72 units. Additionally, the use of NSAIDs is associated with a more substantial increase in diastolic blood pressure, about 11.5 units on average.

These findings emphasize the significant health implications of long-term employment in high-risk environments and the protective role of PPE in

reducing cardiovascular risk factors. It also highlights the impact of NSAID use on diastolic blood pressure, which could be of particular concern in occupational health settings (Table 9).

The study of particulate matter at the landfill site revealed varying concentrations of PM₁₀ and PM_{2.5} across different areas and phases, influenced by wind directions and other environmental factors. In Phase A, notably high levels of particulate matter were recorded at area #3 for both PM₁₀ and PM_{2.5}. During Phase B, an increase in PM₁₀ was observed at point #2, while PM_{2.5} levels rose at point #3. In contrast, Phase C showed a rise in PM₁₀ at point #1, with no significant change in PM_{2.5} levels. The chemical analysis of PM₁₀ and PM_{2.5} included assessments of their heavy metal content, with results aggregated for all three points. Additionally, the presence of polyaromatic hydrocarbons (PAHs) was evaluated, revealing that phenanthrene, a known skin irritant and photosensitivity inducer, was predominantly found during Phase A at all sites. Conversely, benzo(a)pyrene levels remained below the EU concentration limit of 1 ng/m³ at all points and throughout all phases. Phase B showed very high PAHs concentrations at site #1 and very low levels at site #2, with naphthalene being the predominant PAH at points #1 and #3. In Phase C, the highest PAH concentrations were again noted at point #3, this time with benzo(b)fluoranthene as the predominant compound, whereas naphthalene was most significant at point #2.

Discussion

Occupational hazards at landfill sites significantly impact workers' cardiovascular health, as evidenced by our analysis utilizing the HeartScore index. Approximately 21% of the sample population exhibited a tangible risk of cardiovascular disease. This finding is consistent with the study by Brook et al. (2010), which discusses the adverse effects of particulate matter and gaseous pollutants on cardiovascular health (Robert D Brook, Sanjay Rajagopalan, C Arden Pope 3rd, Jeffrey R Brook, 2010). The exposure to exhaust gases from diesel-engine machinery, which is rich in harmful chemicals such as carbon monoxide, carbon dioxide, and sulfur dioxide, is particularly concerning.

In our study, general duty workers and those operating specialized machinery showed elevated levels of abnormal triglyceride measurements. This observation aligns with the findings of Lee et al. , who reviewed the clinical impact of air pollution on cardiovascular disease and highlighted the role of pollutants in increasing cardiovascular risks (Byeong-Jae Lee, Bumseok Kim, Kyuhong Lee, 2014).

Furthermore, the objective of incorporating the HeartScore in our study was to utilize it as a preventive tool, potentially initiating follow-up actions to mitigate these risks. Bhatnagar (2017) emphasized the importance

of understanding environmental determinants of cardiovascular disease, which supports our approach of using HeartScore for preventive measures (Bhatnagar, 2017).

Our findings underscore the significant cardiovascular dangers landfill workers face, compounded by factors such as increased diastolic pressure, poor dietary choices, lack of physical activity, and additional environmental exposures. This comprehensive view is supported by Simon J. Wilson, who discussed the toxic effects of diesel exhaust particles on the cardiovascular system (Simon J. Wilson, Mark R. Miller, and David E. Newby, 2018). These combined factors present a formidable challenge to maintaining cardiovascular health among this population, necessitating targeted interventions and continuous monitoring to alleviate these risks and promote long-term well-being.

Conclusion

To safeguard the health of landfill workers, establishing a Monitoring and Reporting Centre at the landfill site is recommended. This center would significantly enhance the surveillance of environmental pollutants and the exposure levels of workers to various occupational hazards such as noise and particulate matter.

One of the primary measures is the regular assessment of noise levels within the facility to ensure they remain within safe limits, thereby preventing hearing loss and other health effects. Equally important is the monitoring of odour dispersion around the plant's perimeter, which can impact worker comfort and community relations.

Continuous tracking of airborne emissions at the landfill's boundaries is essential to assess and manage air quality impacts effectively. In addition, regular checks at designated sites to evaluate the release of biogas, a byproduct of waste decomposition, are crucial due to its hazardous nature. Compost quality control is another vital aspect, involving the analysis of compost composition, especially for heavy metal content, to ensure the safe and quality use of the compost produced.

Examining the composition of liquid waste from the Mechanical Recycling Plant processes before it is sent to treatment facilities is necessary to ensure compliance with environmental standards. Similarly, controlling the composition of treated liquids resulting from wastewater processes is imperative to prevent environmental contamination. Recording local weather conditions, including temperature, wind, rain, and humidity, is also essential to better understand and manage environmental and operational challenges.

Furthermore, the Reference-Monitoring Centre should facilitate periodic health examinations for staff, conducted by occupational health specialists. These health checks, coupled with comprehensive monitoring of

workplace conditions, will provide a robust framework for protecting worker health in a thorough and multidimensional manner. This approach ensures that both environmental and occupational health risks are systematically addressed, promoting a safer work environment and supporting the overall well-being of the workforce.

In conclusion, the establishment of a Monitoring and Reporting Centre at the landfill site is a critical advancement in ensuring the health and safety of workers. This initiative represents a comprehensive approach to occupational health management, integrating extensive environmental monitoring with systematic health assessments. Such measures are not merely regulatory compliance; they exemplify a commitment to safeguarding human health and promoting sustainable environmental practices. It is essential for stakeholders—including regulatory bodies, corporate management, and the workforce—to engage collaboratively in sustaining and enhancing these practices. The health of landfill workers mirrors broader societal values and a dedication to sustainable development. Through meticulous monitoring, ongoing refinement of practices, and dedicated healthcare provision, this initiative will cultivate a safer and healthier workplace environment. The creation of this center underscores a collective commitment to not only maintaining but improving the quality of life for workers and exemplifying sound environmental stewardship. As such, it contributes significantly to the overarching objectives of public health and environmental sustainability, reinforcing the imperative for a harmonized approach to occupational and ecological well-being.

Declaration for Human Participants: The study adhered to medical ethics and a code prepared by the Bioethics Committee of the Department of Public Health Policies at the University of West Attica, ensuring that all procedures and analyses maintained high ethical standards. This rigorous approach underscores the study's commitment to generating reliable and valuable insights into the occupational health impacts faced by landfill workers. (Code of Practice UNIWA. 2019).

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