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ORIGINAL ARTICLE

Oxidative Stress Associated with Chronic Occupational Exposure to Petroleum Hydrocarbons among Gas Station Attendants in Gampaha District, Sri Lanka

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Abstract

***Background*:** Gas station attendants (GSA) are at risk of adverse health outcomes due to chronic occupational exposure to petroleum hydrocarbons and poor occupational safety practices. In Sri Lanka, extended working hours, minimal use of personal protective equipment (PPE), and limited health surveillance exacerbate these risks. This study aimed to evaluate oxidative stress biomarkers and associated health risks among GSA in the Gampaha District.
***Methods*:** A cross-sectional study was conducted among 25 exposed workers and 25 age-matched unexposed controls. Data on sociodemographic characteristics, occupational exposure history, lifestyle factors, and self-reported health symptoms were collected using a structured questionnaire. Blood samples were analyzed for oxidative stress biomarkers, including glutathione (GSH), 8-hydroxydeoxyguanosine (8-OHdG), and total antioxidant capacity (TAC), using enzyme-linked immunosorbent assay (ELISA).
***Results*:** GSH levels were significantly higher among GSA ($p = 0.043$), indicating a potential early-phase compensatory antioxidant response to chronic petroleum vapor exposure. However, no statistically significant differences were found in TAC ($p = 0.101$) or 8-OHdG ($p = 0.770$) between exposed and control groups. Self-reported symptoms such as headaches, fatigue, memory disturbances, and respiratory complaints were more prevalent among the GSA. Alarmingly, PPE usage was extremely limited, with only 4% reporting access to masks and none to gloves, indicating a critical gap in occupational health protection.
***Conclusion*:** The findings indicate early biochemical signs of oxidative stress among gas station attendees, alongside poor adherence to occupational safety practices. Immediate implementation of regulatory interventions, including mandatory PPE provision and health education, is essential to reduce long-term health risks in this vulnerable workforce.

Keywords: 8-Hydroxy-2-deoxyguanosine (8-OHdG); Gas station workers; Occupational exposure; Oxidative stress; Personal protective equipment

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INTRODUCTION

Occupational exposure to petroleum hydrocarbons (PH) poses a significant public health concern, particularly in developing countries where occupational health and safety regulations are often inadequately enforced. Gas station attendants (GSA) are consistently exposed to volatile organic compounds (VOCs), including benzene, toluene, ethylbenzene, and xylene (BTEX), as well as heavy metals and combustion byproducts, primarily via inhalation of fuel vapors and vehicular exhaust [1,2]. This chronic exposure is linked to a range of adverse health effects, from respiratory and cardiovascular disorders to genotoxicity and carcinogenic outcomes [3,4].

Benzene, a major component of petroleum fuel, has been extensively studied for its hematotoxic, neurotoxic, and carcinogenic properties. Classified as a Group 1 carcinogen by the International Agency for Research on Cancer (IARC), benzene is implicated in the pathogenesis of hematologic malignancies and other systemic conditions [5,6].

The tropical climate in Sri Lanka, characterized by high

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ambient temperatures, exacerbates fuel vaporization and consequently increases BTX concentrations in the breathing zone of GSA. Additionally, local fueling practices, where vehicles are often left running during refueling, further elevate occupational exposure risks [7]. Compounding these risks is the limited use of personal protective equipment (PPE), inadequate worker training, and minimal awareness of occupational hazards, factors which collectively amplify susceptibility to toxic exposure [8].

Oxidative stress plays a central role in mediating the biological effects of PH exposure. It arises from an imbalance between reactive oxygen species (ROS) production and antioxidant defenses, leading to oxidative damage to cellular macromolecules, including DNA, lipids, and proteins [9,10]. Biomarkers such as 8-OHdG, GSH, and TAC are widely used to assess oxidative damage and antioxidant defense status in occupational health studies [11,12]. Elevated 8-OHdG levels reflect oxidative DNA damage, while decreased GSH and TAC suggest compromised antioxidant defense mechanisms [13,14].

Recent investigations have provided strong evidence supporting the link between occupational hydrocarbon exposure and oxidative imbalance in gasoline-station workers. Yasin and Salih (2025) observed significantly increased malondialdehyde (MDA) and decreased glutathione peroxidase-1 (GPX1) activity among gas station workers compared with unexposed controls. The oxidative imbalance correlated positively with exposure duration and heavy-metal accumulation, indicating that concurrent exposure to metals aggravates oxidative stress [15]. Similarly, Elkama et al. (2025) reported elevated serum 8-OHdG concentrations and increased buccal-micronucleus frequencies among Turkish gas-station attendants, particularly those with over ten years of employment, suggesting cumulative benzene-induced oxidative DNA damage independent of smoking status [16].

Previous studies have shown that workers with prolonged exposure to petroleum hydrocarbons exhibit significantly higher levels of oxidative stress markers compared to unexposed individuals [17,18]. Consequently, decreased GSH levels and increased 8-OHdG have been observed in GSA, indicating systemic oxidative stress. Moreover, studies from India and other regions in South Asia highlight that GSA often report symptoms such as headaches, fatigue, dizziness, and respiratory discomfort symptoms linked to oxidative damage and toxic exposure [19,20].

Although global research on this topic is expanding, comprehensive studies examining oxidative stress biomarkers among GSA in Sri Lanka remain limited. Most existing Sri Lankan research has centered on air quality and pollutant exposure levels rather than direct biological effects [7]. Therefore, it is critical to investigate whether occupational exposure to BTX compounds results in measurable oxidative stress and potential long-term health implications for these workers.

This study addresses the existing knowledge gap by evaluating BTX exposure-associated oxidative stress biomarkers among GSA in the Gampaha District of Sri Lanka. It specifically assesses the concentrations of 8-OHdG, GSH, and TAC in exposed individuals compared to age- and gender-matched controls.

METHODS

Study population and person characteristics

A cross-sectional analytical study was conducted to assess oxidative stress biomarkers among GSA in the Gampaha District, Western Province, Sri Lanka. Gampaha District is known for its high population density and rapid industrialization, making it a relevant setting.

A total of 50 male participants were recruited and categorized into two groups: 25 GSA with direct occupational exposure to PHs and 25 age- and gender-matched office workers without occupational exposure (control group). The control participants were selected from administrative and technical staff employed at the Faculty of Medicine, University of Kelaniya, and the North Colombo Teaching Hospital, Ragama.

GSA were recruited from four gas stations (P1 to P4). These stations were situated along major roadways (Figure1, reproduced with permission). At these stations, workers operated in rotating shifts to provide continuous 24/7 service, resulting in extended working hours ranging from 8 to 16 hours per day. Rest periods varied by station, with some attendants receiving only one or two days off per month, while others followed a two-week alternating shift schedule.

All participants provided informed written consent before enrollment. A structured questionnaire was administered to obtain detailed information on demographic characteristics, educational background, occupational history, and lifestyle behaviors such as smoking, alcohol consumption, betel chewing, and use of personal protective equipment (PPE). Additional questions explored potential chemical exposures both at the workplace and in domestic environments, including off-duty exposure sources. GSA was also asked to maintain a diary reporting incidents of fuel spills that could result in dermal or inhalation exposure.

Anthropometric measurements

Height and weight were measured using standard anthropometric techniques. Standing height was recorded using a wall-mounted stadiometer (Seca, Germany), with participants positioned upright, barefoot, and aligned to the Frankfort horizontal plane. Body weight was measured to the nearest 0.01 kg using a calibrated digital scale (Seca 813, Germany), with participants in light clothing and without footwear. Body mass index (BMI) was subsequently calculated using the formula: BMI = weight (kg) / height^2 (m^2), and expressed in kg/m^2, as per the method described by Peterson et al. [21].

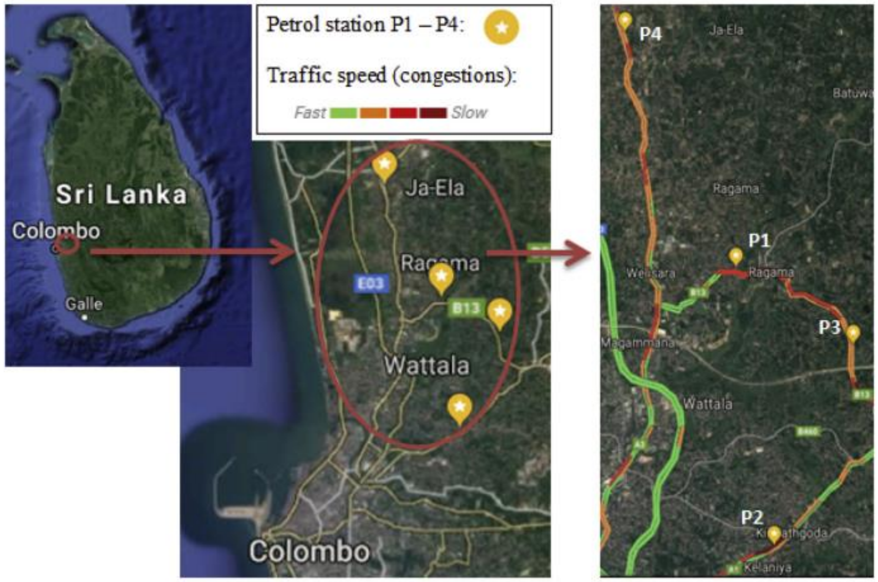

Figure 1. Map of the selected fuel station locations within the Gampaha district, Sri Lanka. Gas station P1 is located at Ragama–Mahabage Rd, P2 at Colombo–Kandy Rd, P3 at Kadawatha–Ragama Rd, and P4 at Negombo–Colombo Rd. Source: Scheepers et al[7], Environmental Research, 178, 108670, p. 3. Copyright © 2019 Elsevier Inc.

Blood sample collection and processing

Blood samples were collected under the supervision of a trained phlebotomist at the Faculty of Medicine, University of Kelaniya, during the same data collection window. A venous blood sample (10.0 mL) was collected into two EDTA-coated tubes, and one tube coated with sodium citrate. Plasma was separated by centrifugation (at 1000g for 10 minutes) and stored at −40 °C until further analysis. Serum levels of GSH, 8-OHdG, and TAC were quantified at the Department of Biochemistry and Clinical Chemistry, Faculty of Medicine, University of Kelaniya.

Biochemical analysis

Estimation of oxidative stress biomarkers

Serum levels of GSH and 8-OHdG were measured using ELISA kits (Elabscience®, USA), according to the manufacturer's instructions, and absorbance was read at 450 nm using a microplate reader (Thermo Scientific™). Concentrations were calculated based on a standard calibration curve. GSH and 8-OHdG levels were expressed as µg/mL and ng/mL, respectively.

Total antioxidant capacity (TAC) assay

Total antioxidant capacity (T-AOC) in serum was determined using a colorimetric assay kit (Elabscience®, USA), and absorbance was measured at 520 nm using a spectrophotometer. T-AOC activity was expressed in units per milliliter (U/mL), with one unit defined as an increase of 0.01 in optical density per minute per milliliter of reaction mixture.

Workplace exposure characteristics

Data on working hours, weekly workdays, duration of employment, self-reported health issues (SRHI) of chronic exposure to petroleum hydrocarbons, and the availability of personal protective equipment (PPE) were collected via a questionnaire. Details on PPE (uniforms, gloves, masks, and boots) usage rates were collected.

Statistical analysis

Data was analyzed using IBM SPSS Statistics software (version 26). Independent sample t-tests were used to compare continuous variables such as anthropometric parameters and oxidative stress biomarkers between the two groups. Categorical variables, including lifestyle behaviors and PPE use, were analyzed using chi-square tests. The significance level of $p < 0.05$ was considered statistically significant.

RESULTS

Population characteristics

The study cohort comprised 50 male participants, including 25 GSA (attendees) and 25 age- and sex-matched controls. The mean age of the GSA was 34.36 ± 1.98 years, while that of the control group was 34.96 ± 1.97 years, with no statistically significant difference between the groups ($p = 0.830$) (table 1). Similarly, no significant differences were observed in anthropometric parameters, including height (166.28 ± 7.26 cm vs. 167.40 ± 5.05 cm; $p = 0.529$), weight (67.35 ± 15.70 kg vs. 65.29 ± 9.15 kg; $p = 0.574$), and body mass index (BMI) (23.26 ± 0.57 kg/m² vs. 24.27 ± 0.93 kg/m²; $p = 0.363$), between the attendees and controls, respectively.

Working pattern and duration of exposure

Table 2 summarizes the working patterns and duration of occupational exposure among GSA. Most workers (36%)

reported working 8 hours per day, while 12% worked 10 hours, 24% worked 12 hours, and 28% exceeded 12 working hours daily. Regarding the number of working days per week, 48% of participants reported working six days, 20% worked five days, 12% worked three days, 8% worked four days, and 12% worked continuously throughout the week without a day off. In terms of occupational history, over half of the attendees (52%) had between 1 to 5 years of exposure, while 8% had worked for 5 to 10 years. Additionally, 20% of the participants reported working for 10 to 15 years, and another 20% had over 15 years of cumulative exposure in petrol dispensing environments.

Table 1. Study population characteristics

Parameter	Study Group	Mean ± SE*	P < 0.05
Age (Years)	GSA**	34.36 ± 1.98	0.830
	Controls	34.96 ± 1.97	
Height (cm)	GSA	166.28 ± 7.26	0.529
	Controls	167.40 ± 5.05	
Weight (kg)	GSA	67.35 ± 15.70	0.574
	Controls	65.29 ± 9.15	
BMI(Kg/m^2)	GSA	23.26 ± 0.57	0.363
	Controls	24.27 ± 0.93	

*SE- Standard Error, **Gas station attendants

Table 2. Percentage frequency of working pattern and duration of exposure in the study group

Characteristic	GSA* (n = 25)	Percentage (%)
Working hours per day		
8 hours	9	36
10 hours	3	12
12 hours	6	24
More than 12 hours	7	28
Working days per week		
Three days	3	12
Four days	2	8
Five days	5	20
Six days	12	48
Seven days	3	12
Years of exposure		
1-5 years	13	52
5-10 years	2	8
10-15 years	5	20
More than 15 years	5	20

*Gas station attendants

Use of personal protective equipment

Data on the availability of personal protective equipment (PPE) among GSA showed that 76% were provided with uniforms by their employers. Only 4% of the workers had access to masks and shoes or boots. Notably, none of the workers reported being provided with gloves (figure 2a).

Oxidative stress biomarkers

Serum levels of oxidative stress biomarkers, total antioxidant capacity, reduced glutathione, and 8-hydroxydeoxyguanosine were measured for both groups. TAC levels were marginally low in the GSA (71.28 ± 0.68 U/mL) compared to the control group (73.17 ± 0.90 U/mL), but this difference was not statistically significant ($p = 0.101$). GSH levels were significantly higher among GSA (65.89 ± 1.22 µg/mL) than controls (62.16 ± 1.30 µg/mL), with a p-value of 0.043. The mean 8-OHdG concentration was 7.44 ± 0.48 ng/mL in the GSA and 7.28 ± 0.33 ng/mL in the control group, showing no significant difference ($p = 0.770$) (table 3).

Table 3. Comparisons of oxidative stress markers (TAC, GSH, and 8-OHdG) among the GSA and the control group

Parameter	Study Group	Mean ± SE*	P < 0.05
TAC(U/mL)	GSA**	71.28 ± 0.68	0.101
	Controls	73.17 ± 0.9	
GSH(µg/mL)	GSA	65.89 ± 1.22	0.043*
	Controls	62.16 ± 1.30	
8-OHdG(ng/mL)	GSA	7.44 ± 0.48	0.77
	Controls	7.28 ± 0.33	

*SE- Standard Error, ** Gas station attendants

Risk factors for oxidative stress

The prevalence of selected behavioral and environmental risk factors was compared between the two groups (table 4). A significantly higher proportion of GSA reported smoking (56% vs. 20%, $p = 0.009$), betel chewing (68% vs. 20%, $p = 0.001$), and exposure to exhaust fumes or smoke (60% vs. 16%, $p = 0.001$) compared to controls. No statistically significant differences were observed between the groups in terms of alcohol consumption (76% in both groups, $p = 1.000$), working with organic solvents or paints (8% vs. 20%, $p = 0.221$), or pesticide use (20% vs. 16%, $p = 0.713$).

Self-reported health issues (SRHI)

A comparison of self-reported health conditions revealed a notably higher prevalence of both chronic non-communicable diseases and occupational symptoms among GSA relative to control participants (figure 2b).

Among the GSA, 20% (n = 5) reported having diabetes mellitus, 12% (n = 3) reported hypertension, 8% (n = 2) reported bronchial asthma, and 4% (n = 1) reported anaemia. In contrast, only 8% (n = 2) of controls reported bronchial asthma and diabetes mellitus, while no cases of hypertension or anaemia were reported in this group.

Table 4. Prevalence of risk factors among GSA* and controls

Risk Factor (Yes)	GSA (%)	Controls (%)	χ²	p value
Alcohol consumption	76	76	0.000	1.000
Betel chewing	68	20	11.688	0.001*
Exposure to exhaust fumes or smoke	60	16	10.272	0.001*
Smoking	56	20	6.876	0.009*
Using pesticides	20	16	0.136	0.713
Working with organic solvents/paints	8	20	1.495	0.221

*Gas station attendants

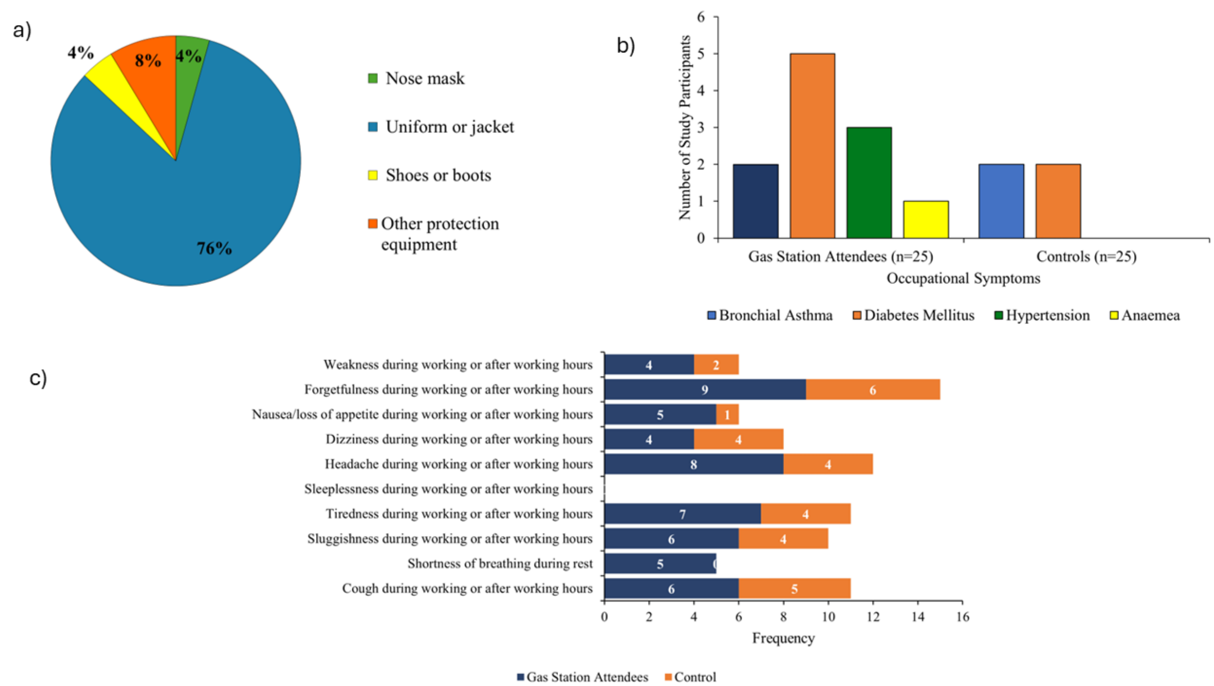

Figure 2. a) Distribution of personal protective equipment use among GSA. The majority reported using uniforms or jackets, while nose masks and other PPEs were less commonly used. b) Frequency of self-reported chronic health conditions among GSA and controls (n = 25 per group). GSA exhibited a higher prevalence of diabetes mellitus, hypertension, bronchial asthma, and anaemia compared to the unexposed control group. c) Frequency of self-reported occupational symptoms among GSA and controls (n = 25 per group).

With respect to acute and chronic occupational symptoms (Figure 2c), GSA consistently reported a higher frequency of complaints compared to the control group. Prominent symptoms included forgetfulness (n = 9), headache (n = 8), tiredness (n = 7), sluggishness (n = 6), cough (n = 6), and shortness of breath during rest (n = 5). Additional complaints, such as dizziness, nausea/loss of appetite, and weakness, were also more frequent in the GSA. In contrast, controls reported considerably fewer symptoms, such as forgetfulness (n = 6), tiredness (n = 4), and headache (n = 4). None of the participants reported sleeplessness during working or after working hours.

DISCUSSION

In this study, we provide novel findings on oxidative stress among GSA in Sri Lanka. It was found that GSH levels were significantly higher among GSA. However, no statistically significant differences were found in TAC or 8-OHdG between the GSA and control groups. Self-reported symptoms such as headaches, fatigue, memory disturbances, and respiratory complaints were more prevalent among the GSA. The findings of elevated BTX exposure, early biochemical indicators of oxidative stress, high prevalence of SRHI, and near total absence of PPE use are particularly relevant in the context of developing countries such as Sri Lanka, where occupational health regulations are often poorly enforced and protective measures are largely inadequate.

Occupational exposure to benzene, toluene, and xylene among GSA continues to raise public health concerns, particularly in low- and middle-income countries (LMICs) like Sri Lanka. These workers are routinely exposed to BTX through inhalation of fuel vapors, dermal contact during fuel dispensing, and through additional exposures from vehicle exhaust. Previously published data by Scheepers et al.7 based on measurements conducted at the same locations and during the same study period, demonstrated that GSA were exposed to significantly higher levels ($p < 0.05$) of benzene, toluene, and m/p-xylene compared to controls. Notably, 28% of the exposed individuals had benzene concentrations exceeding 50% of the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) of 1.6 mg/m^3 (1600 $\mu g/m^3$) for an 8-hour time-weighted average, highlighting a significant occupational health risk [22].

Currently, Sri Lanka lacks enforceable national occupational exposure standards for BTX, and compliance with international thresholds such as those set by ACGIH or OSHA (Occupational Safety and Health Administration) remains limited. In comparison, the ACGIH TLV for benzene (1.6 mg/m^3) and for toluene (75 mg/m^3) provide a reference point for evaluating occupational safety, but in our study, nearly a third of the sample exceeded 50% of the TLV for benzene.7 Given that cumulative and low-dose chronic exposure to benzene is linked with hematotoxicity and carcinogenicity, especially acute myeloid leukemia, such exposures raise red flags for regulatory and public health authorities [23].

BTX compounds, particularly benzene, are well-known to generate reactive oxygen species, leading to oxidative stress and various cellular dysfunctions [14, 24]. Chronic exposure to these compounds may overwhelm the body's antioxidant defenses, resulting in cellular and DNA damage [24, 25]. In this study, however, while TAC was significantly lower among exposed workers, GSH levels were unexpectedly higher than in the control group. This paradoxical rise may suggest a compensatory response to oxidative insult, a phenomenon reported in early-phase oxidative stress where endogenous antioxidant mechanisms, including upregulation of GSH synthesis, attempt to neutralize ROS [26].

Despite the observed upregulation of serum GSH levels among GSA, the non-significant difference in 8-OHdG levels suggests that the duration of BTX exposure may not have yet resulted in measurable oxidative DNA damage, or that endogenous antioxidant systems, particularly GSH, were temporarily effective in buffering oxidative burden. This phenomenon aligns with prior findings where increased GSH levels reflected a compensatory antioxidant response to early-phase oxidative stress. Mahmood et al., similarly observed that cadmium-exposed power plant workers exhibited altered antioxidant responses without statistically significant changes in GSH levels during short-term exposures [27]. Moreover, studies by Hall et al., and Khan et al., have demonstrated that the oxidative response to environmental pollutants is modulated by a range of variables, including individual genetic susceptibility, nutritional status, co-exposure to other toxicants, and overall exposure history [28, 29].

In the context of the present study, occupational exposure patterns support this interpretation. Results indicated that the majority of GSA worked 8-hour shifts (38%) and six days per week (48%). Notably, 52% of participants had less than five years of cumulative exposure, suggesting limited long-term oxidative accumulation in over half the cohort. However, a significant portion (20%) reported over 15 years of continuous exposure, and another 28% had between 5 to 15 years, reflecting a clear subgroup with substantial cumulative BTX burden. Considering that workers are typically exposed to elevated BTX levels for approximately 8 hours a day, five days a week on average, the risk of long-term oxidative and systemic damage is considerable, particularly in the absence of mitigating measures. Alarmingly, most workers reported minimal or no use of PPE, further compounding their vulnerability to chronic exposure and its associated health effects.

The findings highlight that lifestyle factors also act as confounders in oxidative stress biomarker levels. Smoking and betel chewing were significantly more prevalent among the GSA, with 56% and 68% prevalence, respectively. These habits are independently known to contribute to increased oxidative stress [30]. Tobacco smoke introduces a variety of free radicals and carcinogenic agents that damage cellular lipids, proteins, and DNA. This dual exposure, occupational and behavioral, further complicates the oxidative burden borne by these workers and may obscure the true extent of BTX-induced oxidative damage.

In addition to biomarker analysis, the self-reported symptomatology among GSA in this study offers valuable insight into the potential systemic effects of chronic BTX exposure. Workers commonly reported respiratory complaints such as coughing and shortness of breath, as well as neurological symptoms including dizziness, fatigue, memory loss, and occasional sleep disturbances. Gastrointestinal symptoms, particularly nausea and appetite loss, were also prevalent. These findings are consistent with those of Malakootian et al., who reported increased incidences of fatigue, respiratory difficulties, and cognitive impairments among Iranian petrol station workers occupationally exposed to BTX compounds [31]. Similarly, Laffon et al., documented an increased incidence of neurobehavioral symptoms in individuals exposed to hydrocarbons following oil spills [32]. Although causality cannot be definitively established from self-reported symptoms alone, their frequency and pattern, along with biomarker evidence, raise substantial concern. However, the absence of further clinical evaluations in this study prevented further exploration.

Contributing to this occupational risk is the widespread lack of personal protective equipment use among GSA employees. With only 4% of workers reporting access to masks and none having gloves, our findings align with the trend in Sri Lanka, specifically in the informal labor sector, where occupational safety standards are inadequate and overlooked [7]. The tropical climate, extended shift durations, and lack of enforcement mechanisms contribute to further exacerbating the exposure risks. Such negligence is significant considering that inhalation and dermal absorption are primary routes of BTX entry into the human body. Previous research by Laffon et al., has shown that even transient exposure to oil spills and petroleum vapors without adequate protection leads to measurable genotoxic and immunotoxic effects in exposed individuals, emphasizing the importance of PPE use and occupational health education as mitigatory measures [33].

Unfortunately, from a regulatory standpoint, Sri Lanka lacks fuel station-specific occupational exposure limits or mandatory PPE provisions, despite the adoption of general TLVs from international bodies such as ACGIH (Sri Lanka Ministry of Labour, 2014). Unlike high-income countries, where periodic medical screening, vapor recovery systems, and air monitoring are standard practice [34], the Sri Lankan regulatory framework remains outdated and poorly enforced. Most GSAs are informally employed and excluded from structured occupational health services or biological monitoring programs [35]. By introducing enforceable regulations to mandate employers to provide basic occupational health education and essential personal protective equipment (footwear, gloves, and masks) and introducing exposure limits, adherence to safe workplace practices can be easily promoted. Given the growing evidence that even low-level BTX exposure and resulting oxidative stress may lead to endocrine disruption, hematotoxicity, and genotoxicity, these proposed reforms can be beneficial in reducing long-term health burdens among GSA in Sri Lanka [23, 34].

While the present study provides valuable insights into occupational BTX exposure and associated oxidative stress responses among GSA, several limitations need consideration. The cross-sectional design restricts causal inference, and the relatively small sample size, coupled with geographic confinement to a single district, may limit generalizability. These concerns align with previous research emphasizing the need for larger, multicenter, and longitudinal studies to elucidate chronic health effects of BTX exposure [16, 19, 36]. Additionally, reliance on self-reported health symptoms and lifestyle data introduces potential recall bias, while unmeasured confounding factors such as dietary intake, nutritional status, physical activity, and genetic predisposition may have influenced biomarker variability [28, 29]. Furthermore, present analyses were based on unadjusted comparisons between exposed and control groups. Although the groups were age- and BMI-matched, lifestyle variables such as smoking and betel chewing could have residual confounding effects. Moreover, multiple biomarkers were tested simultaneously without correction for multiple comparisons; therefore, the observed p-values should be interpreted cautiously. Future studies with larger samples will employ multivariable regression models and false-discovery-rate adjustments to control these potential sources of bias.

Despite these limitations, this study makes a significant contribution by documenting exposure-related oxidative changes in a population largely overlooked in occupational health literature and highlighting the mitigatory measures to occupational BTX exposure.

CONCLUSION

This study highlights the association of oxidative stress biomarker profile with occupational exposure to BTX among GSA in Gampaha district, Sri Lanka. The elevated levels of BTX in end-exhaled air samples suggest routine inhalational exposure in this workforce, exacerbated by long working hours, inadequate personal protective equipment, and environmental factors such as high ambient temperatures. The unexpected elevation of serum glutathione levels among exposed workers suggests a compensatory antioxidant response to ongoing oxidative stress, while non-significant changes in 8-OHdG and TAC may reflect the early or transient nature of oxidative insults. The widespread lack of PPE usage, high prevalence of lifestyle-related risk factors like smoking and betel chewing, and lack of occupational health oversight compound the risks faced by this workforce. Immediate interventions such as regulatory enforcement of exposure limits, provision of PPE, and educational programs are essential to mitigate these risks associated. Furthermore, the study emphasizes the need for future longitudinal research with comprehensive biomarker panels and larger, more diverse populations. Further, integrating occupational health within national labor and public health policies will be vital for protecting workers in the petroleum retail sector. This research not only provides baseline data for future investigations but also reinforces the urgent need for multidisciplinary efforts to safeguard occupational health in Sri Lanka.

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Conflict of interest: The authors declare that they have no competing interests.

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