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GENERAL AND RESPIRATORY HEALTH OF WORKERS EXPOSED TO LIQUIFIED PETROLEUM GASES IN BOTTLE-GAS TUBES FACTORY

BY

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Abstract

Introduction: Liquefied petroleum gas consists of commercial mixture as butane, propane, ethane, pentane and sulphur based odorizing agent. Acute, subacute or chronic diseases especially respiratory and skin diseases may occur due to the exposure to the toxic gases during the industrial processes. **Aim of Work:** To asses respiratory and some other health hazards associated with chronic direct exposure to liquefied petroleum gas. **Materials and Methods:** A descriptive cross-sectional study was conducted including 137 gas attendant workers comprising about 83 workers,11 technicians, 7 drivers and 36 supervisors. All the studied workers completed the questionnaire and pulmonary function tests were performed for 115 of them **Results:** About (71.5%) of the sample aged ≥40 years, with mean working duration of 19.27 ± 6.41, 44.5 % were smokers and 83.9% reported regular use of

the PPE. Prevalence of respiratory symptoms were: cough (20.4%), breathlessness (19%), phlegm (21.2%) and wheezes (4.4%). Restricted pattern in pulmonary function was found in 26.9% and 17.3% of them had obstructed pattern. Statistically significant relationships ($p<0.05$) were detected between using masks and history of periodic medical examination with workers with normal pulmonary function tests. **Conclusion and Recommendations:** Gas filling attendance were at high risk for respiratory health effects, so more concern should be given from factories and government for the periodic examination and more trainings for safe operations and proper use of personal protective equipment.

Keywords: Liquefied petroleum gas (LPG), Gas filling attendance, Pulmonary function test, Smoking and Personal Protective Equipment.

Introduction

Liquefied petroleum gas (LPG) is considered as clean cooking fuel, which contains commercial mix as butane and propane and tiny quantities as ethane and pentane that is highly flammable, colorless and readily evaporates into gas. For safety reasons, sulphur based odorizing distinguished agent as Ethyl Mercaptan (EM) with a distinctive, unpleasant odour which allow easily recognizing any leakage (Seven et al., 2017).

While LPG is generally considered safe when handled and used properly, it does pose health hazards when mishandled or when there are leaks or accidents. Gas cylinder refilling is a tough job, as it needs dynamic effort as the gas refill attendants are involved in manual handling tasks (Weibrecht and Rhyee, 2011). Therefore, this leaves vulnerable workers susceptible to numerous occupational hazards, including chemical, physical, mental, and other risks. Fire and explosion are the most dangerous hazards with LPG (Joshua et al., 2020).

According to the length, quantity, its solubility and inhalation duration; acute, subacute, or chronic disease may occur. Toxic gases exposure may arise as single unintentional industrial exposure or numerous extended exposure occurring during maual packing, testing, leaking a faulty valve or pump in a gas tank as well as in gas transport (Patocka and Kuca ,2014; Seven et al.,2017).

Explosive mixtures can be formed by Methane and Ethane with air. Thus, bottle gases which comprises gas under pressure; may explode especially if heated. Also, they are asphyxiant gases that displace oxygen producing suffocation, drowsiness and dizziness rapidly (Airgas,2023).

Similarly, Propane is usually known as liquified petroleum gas. It is colorless and almost odorless gas that is normally compressed and stored as a liquid. In addition it is an extremely flammable gas. It is stored under pressure as a gas and can explode if heated. Propane is an asphyxiant and accumulates in low lying areas. LPG can displace air and reduce the concentration of oxygen in an area, which can create a potentially hazardous situation for workers who need sufficient oxygen for safety. Exposure to high concentrations may lead to cardiac arrest, seizures or unconsciousness. Frostbite may occur due to continuous skin contact (CCOHS 2020).

Accidental inhalation of liquefied petroleum gas (LPG) in a large amount may lead to respiratory symptoms as wheeze, cough, chest tightness, nasal irritation, dizziness and for some individuals, persistent airway hyper-responsiveness and asthma may develop. While on chronic long term exposure, bronchitis may develop (Akpan et al., 2021).

Few previous studies investigated low levels of liquified petroleum gases exposure and its respiratory health affection (Sirdah et al., 2013; Moitra et al., 2014; Torky et al., 2016), but there were no previous studies on manual fillling gas bottle workers who had direct and long term exposure to the studied gases.

Aim of Work

To asses respiratory and some other health hazards associated with chronic direct exposure to liquefied petroleum gas.

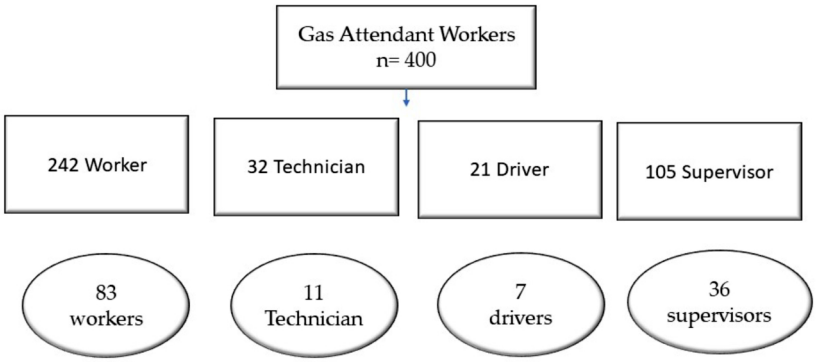
Materials and Methods

Study design: A descriptive cross-sectional study was conducted.

Place and duration of study: the study was conducted in a single bottle-gas tube factory during the period between September to December 2021. The factory is responsible for production of bottle gas cylinders which is necessary for cooking, it is located in Mankabad area north to Assiut city, holding nearly 400 workers. The work process includes receiving and unloading the gases after testing according to the guidelines,

conveyance of the empty gas cylinders to the point where it would be refilled, filling in packing area and weighing the gas cylinders, testing for any valve leaks and reorganizing the filled cylinders (AIGA, 2020).

Study Sample: Sample size was calculated using EPI info 2000 statistical package based on an expected prevalence of chronic respiratory symptoms among Natural Gas Processing workers of 15.8 % (Torky et al., 2016) with 5% difference and confidence interval 95%. The minimum calculated sample was 136 workers. Sample included active personnel (137) working in packing tents of bottle-gas tubes factory comprising about 83 workers, 11 technicians, 7 drivers and 36 supervisors. Only 115 accepted to perform spirometer. Propionate random sampling technique was applied for data collection of this study.



Flow chart of recruitted Gas Attendant Workers

Study methods:

- **Questionnaire:** Data was collected through pre-tested, structured questionnaires.

Several literatures were reviewed, the questionnaire was revised from all authors and pilot study was done by authors to test questionnaire (5 questionnaires) and procedure arrangements, the pilot study results were not entered in the analysis.

The questionnaire was done through personal interview, comprising sociodemographic and detailed occupational history (nature of exposure, duration, working shifts, previous periodic examinations, previous working accidents and personal protective equipment's used), respiratory symptoms evaluation was adopted from the British Medical Research Council (BMRC) adult respiratory assessment questions (Cotes,1987). Workers were asked about one or more of their chronic respiratory symptoms, as chronic cough, chronic phlegm, chronic wheezing and chronic shortness of breath, which last at least three months in one year (Feng et al., 2018). Also history of chronic diseases, neurological, dermatological, cardiac and auditory symptoms were taken.

Smoking status was as follow: non-smokers stated that they had never smoked or smoked <100 cigarettes (lifetime), current smokers at the time of data collection or smoked ≥100 cigarettes during the past year and former smokers are smokers ≥100 cigarettes but did not smoke during the past year were considered. The smoking index was calculated by using the following formula: Cigarette per day (CPD) × years of tobacco use. Smoking index categories were <400, 400–799, and ≥800. The CPD was estimated for current and former smokers (Feng et al,. 2018).

- Spirometry tests were performed according to American Thoracic Society (ATS) specifications (Graham et al., 2019), by using the portable spirometer (Spirolab III) supplied by Medical International Research MIR, Rome, Italy. All lung function tests were performed by the same professional technicians, within 30 minutes during the worker shift. Before the test height and weight of workers were measured. The tests were performed with the subject seated and three acceptable maneuvers were performed and the best result according to ATS/ERS criteria was taken in the analysis (Ponce et al,. 2022).

Consent

Informed consent was obtained from each participant before filling the questionnaire and after clarification of the study objectives.

Ethical Approval

The study protocol was reviewed by Institutional Research Board (IRB) in faculty of Medicine, Assiut University

No: 17300874. Confidentiality and anonymity were assured. The study was abided with the Declaration of Helsinki guidelines.

Data Management

Data was analyzed using computer software program SPSS software package version 21 (IBM-SPSS inc. Chicago, Illinois, USA). Descriptive statistics (in the form of frequencies, mean and SE, median and interquartille range) to describe the workers characteristics and to find the percentages of different symptoms. Then Bivariate analysis in the form of Chi-square (X2) test as the test of significance to compare the variations in the characteristics' proportions. Significant p-value was set at 0.05 cutoff.

Results

Table (1): Sociodemographic characteristics of bottle-gas factory workers.

Characteristics	No. (137)	%
Age: (years)		
< 40	39	28.5
≥ 40	98	71.5
Residence:		
Urban	49	35.8
Rural	88	64.2
Educational level:		
School	127	92.7
University	10	7.3
Smoking history:		
Non-smokers	76	55.5
Current Smokers	61	39.4
Former smokers	10	5.1
Smoking index categories: (No= 71) #		
Mild smokers (<400)	55	77.5
Moderate smokers (400–799)	14	19.7
Heavy smokers (>800)	2	2.8

#: More than one answer were selected

Table (1) showed that 71.5% of the sample aged ≥40 years and 64.2% of them lived in rural areas; 92.7% had school education, 39.4% were current smokers and 77.5% were mild smokers.

Table (2): Occupational history of bottle-gas factory workers.

Characteristics	No. (137)	%
Job title:		
Worker	83	60.6
Supervisor	36	26.3
Technician	11	8.0
Driver	7	5.1
Duration of work: (Mean± SD)	6.41 ± 19.27	
Work shift:		
Alternating	118	86.1
Morning	19	13.9
Exposure to hazards other than gas exposure: #		
Noise	95	69.3
Heat	11	8.0
Chemicals	9	6.6
Regular use of personal protective equipment (PPE):	115	83.9
Types of used personal protective equipment: # (No=115)		
Gloves	84	73.0
Safety shoes	82	71.3
Masks	54	47.0
Eye goggles	9	7.8
Reported accidents:	23	16.8
History of regular periodic medical examination:	75	54.7

#: More than one answer were selected ǂ: fire, fall of heavy objects, sliding

Table (2) showed that (60.6%) of the studied sample were workers and (86.1%) had alternatig shifts system. The mean work duration in years was 19.27 ± 6.41. Noise (69.3%) was the most reported occupational hazards. The majority of the

workers (83.9%) mentioned that they use PPE and the most widely used were gloves (73%) followed by safety shoes (71.3%). Accidents rate among them was 16.8% and more than one half (54.7%) reported that they had history of regular periodic medical examination.

Table (3): General, respiratory and auditory symptoms of bottle-gas factory workers.

Characteristics	No. (137)	%
Chronic respiratory complaints: #	45	32.8
- Cough	28	20.4
- Sputum	29	21.2
- Shortness of breath	26	19
- Wheezes	6	4.4
History of chronic bronchitis:	9	6.6
History of asthma:	12	7.3
Improving of respiratory symptoms at the weekend:	16	11.7
History of auditory complaints: #	49	35.8
- Hearing loss	32	23.4
- Otitis media	12	8.8
- Tinnitus	3	2.2
History of neurological complaints: ##	19	13.9
History of cardiac complaints: •	4	2.9
History of dermatological complaints: ǂ	7	5.1
History of chronic diseases:	46	33.6
- Diabetes Mellitus	21	15.3
- Hypertension	11	8
- Others^	6	4.5

#: More than one answer were selected. ##:Neurological complaints include: headache, numbness, pins and needles, weakness, unsteadiness, stiffness or clumsiness, altered consciousness. •Cardiac complaints include: chest pain, chest tightness, chest pressure and chest discomfort (angina),irregular heartbeats that feel rapid, fluttering, swelling of the legs, ankles and feet, ǂ Dermatological complaints include: rash, skin lesion, itch and blistering. ^Others include: autoimmune diseases, hepatitis and cancer

Table (3) illustrated that chronic respiratory symptoms among the studied group were as follows: chronic cough (32.8%), breathlessness (21.2%), phlegm (20.4%) and wheezes (19%). Improving of respiratory symptoms at weekend was reported by 11.7% of them. Chronic bronchitis and asthma were announced by 6.6% and 7.3%, respectively. More than one third (35.8%) of the workers had history of auditory complaints; and hearing loss was the most reported complaint (23.4%). History of neurological, dermatological and cardiac complaints among the studied sample were 13.9%, 5.1% and 2.9%, respectively. One third (33.6%) of the studied workers had history of chronic diseases.

Table (4): Pulmonary function tests of bottle-gas factory workers

Characteristics (No=115)	**Mean ± SE**	**Median (IQR)**
FVC (Liter)	4.7 ± 0.2	3.9 (2.2)
FVC (%)	111.3 ± 7.3	91 (48)
FEV1 (liter)	3.7 ± 0.1	3.4 (1.3)
FEV1 (%)	104.8 ± 4.9	92 (25)
FEV1 / FVC	82.4 ± 1.6	88.2 (17.4)
PEFR (liter)	5.3 ± 0.2	5.1 (2.4)
PEFR (%)	61.2 ± 1.7	59 (27)
FEF 25-75 (liter)	6.4 ± 2.1	59 (27)
FEF 25-75 (%)	71.4 ± 3.8	78 (74)
Interpretation of Pulmonary Function	**No. (115)**	**%**
Normal	64	55.6
Restriction	31	27.0
Obstruction	20	17.4

FEV1 = forced expiratory volume in one second, FVC = forced vital capacity, FEF 25-75 = forced expiratory flow at 25% to 75% of FVC, PPFR = Peak expiratory flow rate.

Table (4) showed pulmonary function test results of the studied group which revealed that the mean values ± SE of spirometric measurements regarding FVC%, FEV1%, FEV1/FVC, PEFR (%) and FEF25-75% of the workers who accepted (No=115) to do lung function tests were : 111.3 ± 7.3, 104.8 ± 4.9, 82.4 ± 1.6, 61.2 ± 1.7 and 71.4 ± 3.8, respectively. As regard the interpretation of spirometer results, 27% of the workers had restricted pattern and 17.4% had obstructed pattern.

Table (5): Demographic and occupational factors in relation to pulmonary function interpretations of bottle-gas factory workers.

Characteristics (No=115)	**Normal (No =64)**	**Obstructed (No =20)**	**Restricted (No =31)**	**p-value#**
Age group				
<40 (No =32)	18(56.3%)	5(15.6%)	9(28.1%)	0.94
≥40 (No = 83)	46(55.4%)	15(18.1%)	22(26.5%)	
Residence				
Urban (No =38)	21 (55.3%)	6(15.8%)	11(28.9%)	0.92
Rural (No =77)	43(55.8%)	14 (18.2%)	20(26.0%)	
Smokers (No =61)	34(55.7%)	12(19.7%)	15(24.6%)	0.71
BMI				
Normal (No =23)	10(43.5%)	4(17.4%)	9(39.1%)	0.32
Overweight or obese (No =91)	53(58.2%)	16(17.6%)	22(24.2%)	
Job title				
Workers	35(49.3%)	14(19.7%)	22(31.0%)	0.08
Supervisors	20(71.4%)	2(7.1%)	6(21.4%)	
Technicians	5(55.6%)	2(22.2%)	2(22.2%)	
Drivers	4 (57.1%)	2(28.6%)	1(14.3%)	
Using masks (No=44)	25(56.8%)	13(29.5%)	6(13.6%)	**0.01***
History of regular periodic examination (No =69)	42(60.9%)	14(20.3%)	13(18.8%)	**0.05***

BMI: Body Mass Index. *:Statistically significant #:Chi-square test was used.

Table (5) showed statistically significant difference ($p<0.05$) between using masks and history of periodic medical examination among workers with normal pulmonary function tests. No statistically significant difference was detected between the results of pulmonary function tests and age, residence, smokers, job title and BMI.

Regarding job title, higher occurrence of normal PFTs results was among supervisors, while lower percent were among workers.

Discussion

The present study assessed the health profiles of liquefied petroleum gas workers in a bottle-gas factory located in Upper Egypt with special concerns to their respiratory conditions and lung function status. The study included 137 male participants, 71.5% of them aged ≥40 years. Manual workers represented 60.6% while the others were supervisors, technicians, and drivers. The most common occupational hazards reported by all participants were noise (69.3%) (Table 1 and 2)

During the production of bottle gas cylinders, LPG is infused by workers into cylinders. Tasks of workers in this industry include moving, checking appearance of rustiness, weighting, and infusing gas for recycled cylinders. During this processes, high-level impulsive sounds generated from the collisions between cylinders or cylinders to the ground. At the moment of connecting tube removal, when infusion is completed, a blast with sudden noise is also obvious (Chang and Chang, 2009)estimated prevalence, and identify risk factors of noise-induced hearing loss (NIHL.

Respiratory symptoms including chough, sputum production and chest tightness were the common reported complaints among the studied participants. Impaired lung functions were objectively assessed by spirometer and 26.96% of the studied sample had restricted pattern in pulmonary function while 17.39% of them had obstructed pattern (Table 3 and 4).

LPG is a mixture of short-chain hydrocarbon fuels (propane or butane) and tiny quantities of lighter and heavier portions as ethane and pentane (Seven et al. ,2017) along with odorants (such as methanethiol or ethyl mercaptan, which may containing sulphur at a level of 52%).The supplied LPG may also contain sulphur containing compounds, in various types and proportions, according to the source of production. Previous studies had reported the negative impact of these gases on respiratory system and may be associated with respiratory impairment (Emrah Isbilen et al., 2014).

Sulfur dioxide (SO2) reacts with water in the upper airway and bisulfite ion is produced which is the main initiator of sulphur dioxide inducing bronchoconstriction. Exposure to very low concentrations of sulfur dioxide can aggravate chronic pulmonary diseases

(such as asthma and emphysema). Asthmatics may develop bronchospasm when exposed to sulfur dioxide (ATSDR , 2014).

Andersson et al. 2006, reported that repeated exposure to SO2 causes a three fold increased risk of asthma.

The results of this research were consistent with Akpan et al., 2021,in their study on respiratory symptoms and pulmonary impairments due to exposure to non-combusted liquefied petroleum gas among workers in Calabar, Nigeria; and concluded that cough (53.3%), wheeze (40%) and chest tightness (26.7%) with a significant decrease in the pulmonary function indices (FEV1%, FVC% and PEF) were common among those workers. Also, Sirdah et al., 2013 in their study on possible health effects of liquefied petroleum gas on workers at filling and distribution stations of Gaza governorates reported that 76.7% were complaining of cough and 80% of shortness of breath among LPG workers. The results of the current study were also comparable with Raju et al., 2016 who detected decrease in FVC, PEFR, FEV25% and FEV1% in senior LPG gas workers in India.

Most of the participants in the current study (83.9%) were committed to wear personal protective equipment. Moreover, using masks and history of periodic medical examination among workers were significantly higher among those with normal pulmonary function tests (Table 2 and 5).

This demonstrates the importance of adhering to personal protective equipment and regular periodic medical examinations to reduce the respiratory effects of hazards, especially the gases to which these workers are exposed.

The rate of PPE use in the current study was higher (83.9%) compared to a study done in Nigeria (76%) by (Joshua et al., 2020), in Pakistan (69.3%) by (Zeb et al., 2017) and in Iran in which only 29 -31% of them used PPE (Nasab et al., 2009).

Auditory symptoms including hearing loss, otitis media and tinnitus were also common health problems among the studied population (Table 3). This matched with the results of a cross-sectional study in a liquefied petroleum gas cylinder infusion factory in Taipei City, Taiwan; which reported that Noise Induced Hearing Loss (NIHL) is a common problem among workers in this industry (Chang and Chang, 2009) estimated prevalence, and identify risk factors of noise-induced hearing loss (NIHL).

History of neurological, dermatological and cardiac complaints among the studied sample were 13.9%, 5.1% and 2.9%, respectively (Table 3).

It was established from previous studies that butane sensitizes the myocardium to the effects of catecholamines. In addition to this, butane may cause direct toxicity to the brain and the myocardium and may predisposes the patient to life-threatening tachyarrhythmias while propane may cause an anesthetic effect on the central nervous system (Sen and Erdivanli, 2015).

Inhalation of LPG may cause drowsiness or dizziness and long-term exposure may lead to central nervous system damage (Michanowicz et al., 2023).

Regarding cardiac effects, the results of the current study were matched with Ismail et al. ,2023, who reported that exposure to non-combusted LPG is associated with increased systolic blood pressure and mean arterial pressure.

About 5% of the studied group had a history of dermatological complaints (Table 3); which was in accordance with what concluded by a study conducted among workers at filling and distribution stations of Gaza governorates that LPG workers had significantly higher rates of skin itches, redness and rash. This may be explained by skin irritation that may occur due to direct contact with LPG (Sirdah et al., 2013).

Limitations of the study: One of the most important strength points in our study that no previous studies were done on gas filling attentance workers in gas bottle factory to assess their chronic long term direct exposure especially with manual filling technique. On the other hand, this study encountered several limitations: the cross-sectional nature of the current study jeopardized its external validity and lacks causal effect.

Conclusion: Bottle-gas industry and refill exposing workers to liquified petroleum gases such as to Ethane, Methane and Butane still carry a hazardous effect on workers health specially their lung functions. Impaired lung functions in the form of both obstructive and restrictive patterns were reported on long term chronic exposure.

Recommendations: Safety measures should be kept closely and regular check for gas leakage and prompt repair. Proper arranging of cylinders and tanks in upright position

and in well-ventilated areas should be done. Regular periodic examination should be maintained to catch early occupational respiratory effects. It is important to address the problem of noise at the working place and advice the administration to mitigate the sources of noise, periodic audiogram for exposed personnel. All managers, health organizations and government should encourage and regulate the use of PPE. LPG refill workers' safety practice is crucial to prevent accidents and protect workers.

Conflict of interest

The authors declared that they have no competing interests.

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References

1. AIGA (2020) : Asia Industrial Gases Association. Filling Liquified Gases in Cylinders - Hazards & Safeguards Filling Liquified gases in Cylinders-Hazards & Safeguards. Available at: https://www.asiaiga.org/uploaded_docs/en_AIGA_TP_26_20_Liquified_Gases_Filling_Hazard_and_Safeguard_Final_Ver_16_June_2020.pdf
2. Airgas (2023) : Air liquid company. Safety Data Sheet .Flammable Gas Mixture: 1-Butene / Ethane / Ethylene / Hydrogen / Methane / N-Butane / Propane / Propylene: An air liquid company. In: Mater. Saf. Data Sheet. Available at: https://www.airgas.com/msds/008593.pdf
3. Akpan E, Moffat I, and Abara U (2021) : Analytical data on respiratory symptoms and pulmonary impairments due to exposure to non-combusted liquefied petroleum gas. Data Br; 36107106.
4. Andersson E, Knutsson A, Hagberg S, Nilsson T, Karlsson B, et al. (2006) : Incidence of asthma among workers exposed to sulphur dioxide and other irritant gases. Eur Respir J; 27(4):720–5. https://doi.org/10.1183/09031936.06.00034305
5. ATSDR (2014) : Agency for Toxic Substances and Disease Registry. Medical Management Guidelines for Sulfur Dioxide. Available at: https://wwwn.cdc.gov/TSP/MMG/MMGDetails.aspx?mmgid=249&toxid=46
6. CCOHS (2020) : Canadian Centre for Occupational Health and Safety. Propane. Chemical Profiles. Available at: https://www.ccohs.ca/oshanswers/chemicals/chem_profiles/propane.html
7. Chang S-J, and Chang C-K (2009) : Prevalence and risk factors of noise-induced hearing loss among liquefied petroleum gas (LPG) cylinder infusion workers in Taiwan. Ind Health; 47(6):603–10. .https://doi.org/10.2486/indhealth.47.603
8. Cotes JE (1987) : Medical research council questionnaire on respiratory symptoms (1986). Lancet; 330(8566):1028.
9. Emrah Isbilen K, Kadayificioglu M, and Yasar UD (2014) : Sulpher-Free Gas Odorant United States Patent. In: United States Pat.

Available at: https://patents.google.com/patent/US9587191B2/en

10. Feng X, Qian Z, Zhang B, Guo E, Wang L, et al. (2018) : Number of cigarettes smoked per day, smoking index, and intracranial aneurysm rupture: A case-control study. Front Neurol; 9(MAY): Available at : https://www.frontiersin.org/articles/10.3389/fneur.2018.00380/full. https://doi.org/10.3389/fneur.2018.00380
11. Graham BL, Steenbruggen I, Barjaktarevic IZ, Cooper BG, Hall GL, et al. (2019) : Standardization of spirometry 2019 update an official American Thoracic Society and European Respiratory Society technical statement. Am J Respir Crit Care Med; 200(8):E70–E88.https://doi.org/10.1164/rccm.201908-1590ST
12. Ismail AU, Ibrahim SA, Gambo MD, Muhammad RF, Badamasi MM, et al. (2023) : Impact of differential occupational LPG exposure on cardiopulmonary indices, liver function, and oxidative stress in Northwestern city of Nigeria. Sci Total Environ; 862160881.
13. Joshua IA, Muhammed U, Sufiyan MB, Olaniyan AF, Sabitu K, et al. (2020) : Knowledge, attitude and practice of safety measures among cooking gas refill attendants in Zaria metropolis, Kaduna state, Nigeria. Sci World J; 15(3):106–10.
14. Raju K, Pradesh A, Kiran S and Kumar P (2016): Pulmonary Function Studies in Liquified Petroleum Gas (LPG) Workers. Indian J Appl Res; 6(10):210–2.
15. Michanowicz DR, Leventhal OM, Domen JK, Williams SR, Lebel ED, et al (2023) : Natural gas odorants: A scoping review of health effects. Curr Environ Heal reports; 10(3):337–52.
16. Moitra S, Blanc PD, and Brashier BB (2014) : Airflow obstruction among street vendors who refill cigarette lighters with liquefied petroleum gas. Int J Tuberc Lung Dis; 18(9):1126–31.
17. Nasab HS, Tavakoli R, Ghofranipour F, Kazemnejad A, and Khavanin A (2009) : Evaluation of knowledge, attitude and behavior of workers towards occupational health and safety. Iran J Public Health; 38(2):125–9.
18. Patocka J, and Kuca K (2014) : Irritant compounds: respiratory irritant gases. Milit Med Sci Lett; 83(2):73–82.
19. Ponce MC, Sankari A, and Sharma S (2022) : Pulmonary Function Tests - StatPearls - NCBI Bookshelf. https://www.ncbi.nlm.nih.gov/books/NBK482339/#_article-28030_s4_. Accessed 19 Dec 2021.
20. Sen A, and Erdivanli B (2015) : Cardiac arrest following butane inhalation. Anesth Essays Res; 9(2):273.
21. Seven E, Horoz U, Sari E, Ozakpinar HR, Sandikci MM, et al. (2017) : A rare type of burn injury due to butane gas inhalation. Turkish J Trauma Emerg Surg; 23(3):212–16.
22. Sirdah M, Al Laham NA, and Al Madhoun R (2013) : Possible health effects of liquefied petroleum gas on workers at filling and distribution stations of Gaza governorates. East Mediterr Heal J; 19(3):289–94.
23. Torky A, El-Gamal FM, Foda NM, Meleis D, and Zaky G (2016) : Respiratory symptoms, spirometric values and chest radiological findings in natural gas processing workers. Alexandria Med J; 58(4):766–76.
24. Weibrecht KW, and Rhyee SH (2011) : Acute respiratory distress associated with inhaled hydrocarbon. Am J Ind Med; 54(12):911–14.
25. Zeb A, Riaz H, Tahir Q, Anwar I, and Altaf A (2017) : Assessment of knowledge, attitude and practices regarding occupational safety among Onshore Oil Rig workers in District Karak, KPK, Pakistan. Int J Heal Policy Manag; 2(3):134.