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Ijaz Ahmad, King Abdulaziz University, Saudi Arabia
Mohammad Rehan, King Abdulaziz University, Saudi Arabia
Mansour Balkhyour, King Abdulaziz University, Saudi Arabia
Mohsin Abbas, King Abdulaziz University, Saudi Arabia
Jalal Basahi, King Abdulaziz University, Saudi Arabia, et al.
REVIEW OF ENVIRONMENTAL POLLUTION AND HEALTH RISKS AT MOTOR VEHICLE REPAIR WORKSHOPS: CHALLENGES AND PERSPECTIVES FOR SAUDI ARABIA

Ijaz Ahmad1,2, Mohammad Rehan2*, Mansour A. Balkhyour1, Mohsin Abbas1, Jalal M. Basahi2, Talal Almeelbi2, Iqbal M.I. Ismail2

1Department of Environmental Science, Faculty of Meteorology, King Abdulaziz University, Jeddah, Saudi Arabia
2Center of Excellence in Environmental Studies (CEES), King Abdulaziz University, Jeddah, Saudi Arabia

*Corresponding author: dr.mohammad_rehan@yahoo.co.uk; mrehan@kau.edu.sa

Abstract

The increasing population, urbanization and industrial growth are causing serious environmental challenges including air pollution worldwide. According to WHO, the indoor and outdoor air pollution exposure has caused around 7 million deaths globally only in 2012. The major air pollution sources include transportation and petrochemical based industry. Motor vehicle repair workshops (MVRW) pose many environmental as well as occupational health challenges. Workers safety and protection at workplace has been a great concern for employees, employers, governments and the entire society for years. This review article highlights the prominent air pollutants and health and safety challenges at MVRW. Many scientific articles studying pollutants that are detrimental to health e.g. benzene, PAHs, VOCs, heavy metals, PM, NOx, and SOx, are reviewed here. The national and international environmental legislations and health and safety standards by Occupational Safety and Health Administration (OSHA), US Environmental Protection Agency (USEPA) and Presidency of Meteorology and Environment (PME) Saudi Arabia have been mentioned and compared for air quality both outdoor and in occupational environment. Latest developments in ambient air pollution monitoring and occupational personal health risk assessment methods and strategies have also been reviewed coherently, including the prominent physical, chemical, biological, musculoskeletal and accidental safety hazards at MVRW. The current environmental challenges and perspectives for Saudi Arabia in terms of both ambient air pollution as well as in occupational settings are also discussed. The review ends with identifying gaps and limitations in monitoring and legislation in the subject area, and suggesting the way forward for Saudi Arabia including further research and development needed in the subject area.

Key Words: Environmental pollution, Health and Safety, Motor vehicle repair workshops (MVRW), Occupational health assessment, Air pollution, Particulate matter (PM)

1. Introduction

Due to increase in automobiles and urbanization in towns and cities in the world, there is an exponential increase in urban air pollution with traffic being the major pollution contributor (Patil et al., 2004). Among major air pollution sources are traffic related air pollutants, which pose a
serious challenge in the present era due to increasing number of automobiles in our cities throughout the globe (Rostogi et al., 1991). Vehicular exhaust is the worst type of exhaust as it is emitted at ground near the breathing level, and it gives maximum human exposure. Traffic exhaust contains different noxious oxides of sulphur (SO$_2$), nitrogen (NOx), carbon (CO), volatile organic compounds (VOCs) and suspended particulates (Evans et al., 1988; Chawla and Lavania, 2008). These traffic related pollutants may have direct or indirect health effects on public as well as on different occupational workers in urban areas. The most vulnerable are those who spend most of their time in traffic / vehicle congested environment and road sides like petrol stations, vehicle workshops, bus stops, and road wanderers.

The indoor and outdoor air pollution exposures have caused around 7 million deaths globally only in 2012 (WHO 2014). Around 4.3 million deaths were correlated to indoor air pollution whereas 3.7 million deaths were attributed to outdoor air pollution. The low and middle income countries in South-East Asia and Western Pacific Regions had most deaths linked to air pollution, with estimated 3.3 and 2.6 million deaths correlated to indoor and outdoor air pollution, respectively. As shown in Fig. 1, the estimated deaths caused by outdoor air pollution of 111,000 (3%), 222,000 (6%), 407,000 (11%), 1,480,000 (40%) and 1,480,000 (40%) were related to major diseases such as Acute Lower Respiratory Infection (ALRI), Lung Cancer, Chronic Obstructive Pulmonary Disease (COPD), Stroke and Ischemic Heart Disease (IHD), respectively. Similarly, the estimated deaths caused by indoor air pollution of 516,000 (12%), 258,000 (6%), 946,000 (22%), 1,462,000 (34%) and 1,118,000 (26%) were related to major diseases such as Acute Lower Respiratory Infection (ALRI), Lung Cancer, Chronic Obstructive Pulmonary Disease (COPD), Stroke and Ischemic Heart Disease (IHD), respectively.

![Fig.1. Graphs re-constructed based on the WHO data, representing the global deaths breakdown by diseases attributed to outdoor and indoor air pollution in 2012.](image-url)

Motor vehicle repair workshops (MVRW) and maintenance garages help to maintain the vehicles on the roads. Commercial and domestic customers also do repairing and maintenance of motor vehicle at road sides as well as in MVRW and maintenance garages. The demand for
MVRW is increasing due to significant increase in number of motor vehicles on roads worldwide, for example, increasing business of MVRW and maintenance garages employed about 170,000 workers in UK belongs to small and medium-sized establishments and majority of these workers are also self-employed. Common work related accidents in MVRW are slips, trips and falls and the resulting occupational injuries are serious often. Every year due to collapsing of under repaired vehicles trigger fatal accidents. Serious burns, fire eruption and some fatal accidents have been caused and reported at petrol fuel related workplaces. Occupational illness and diseases are also reported such as disabling dermatitis in MVRW workers due to the use of toxic substances like paints containing isocyanates. Such paints were considered as the main cause of occupational asthma in UK in the past. Use of power tools in MVRW industries causes white finger and physical vibration (HSE, 2009).

The environmental pollution exposure is more critical for workers, such as drivers of motor vehicles, fuel station workers, petrochemical based industry workers, petrol police personals, parking attendants, tunnel workers, road side vendors, and roadside workshop workers in trafficked areas, who are at higher risks of illness and diseases. Especially, the air pollution is severely harmful for fetus, children, old people, cardiovascular and angina pectoris patients (Balashanmugam et al., 2012). Functions of significant parts of body such as heart and brain are also disturbed due to air pollution and its effect can be fatal especially at higher concentrations.

MVRW operations such as welding, gas cutting and petrol-engine exhausts emit nitrogen dioxide, which can cause emphysema, lung irritation, pneumonia, pulmonary edema, asthma, bronchitis, and respiratory infections. Combustion of products emit sulfur dioxide, responsible for low atmospheric visibility, acid rain, smog and disturb human respiratory system and lungs function.

Motor vehicles have become essential part of today’s life. Vehicles repair and maintenance need has led to the emergence of a really large sector named repair and maintenance, which is also known as workshop. This is an informal sector also categorized as small and medium size enterprise. It’s a labor-intensive sector, and its size of enterprise, number of workers and job characterization vary considerably (Heer et al., 2011; Caldwell, 2000). Employes of all ages are routinely seen at these workshops. From health and safety point of view, this is the tough sector to tract and supervise. Hundreds and thousands of risks and hazards go unnoticed. Common occupational hazards such as physical, ergonomic, biological and chemical are found in MVRW activities, due to heavy machinery, petroleum fuels/ oils, high use of solvents, smoke, particulate matter and various other pollutants. These hazards become more critical when there is a lack of awareness, controls measures and implementation of health and safety rules and regulations (Caldwell, 2000).

Globally, workers safety and protection at workplace has been a great concern for employees, employers, governments and the entire society for years. Safe work place not only promote physical, mental and social wellbeing but also saves considerable amount of money that can be attributed to medical bills, insurance claims, loss of work, loss of experienced personals, corporate reputations and integrity of organization (Tadesse & Admassu, 2006). According to International Labour Organization (ILO) statistics annually 270 million work related accidents, and 2 million deaths are reported worldwide (Isaac et al., 2014). Also some severe accidents leave victims paralyzed, loss of body parts, muscoskeletal disorders, skin diseases, neurological, psychological, mental and respiratory diseases (Tadesse & Admassu, 2006; ILO, 2005; Punnett & Wegman, 2004). Many research studies proved that small scale industry workers are more prone to work place hazards, risks and ill health effects (Adei et al., 2011) which can be somehow attributed to
less resources, low technical capacity, lack of knowledge and awareness regarding occupational health safety guidelines.

MVRW workers are usually exposed to many chemical and physical hazards. Among chemical hazards, are volatile compounds from fuel, used gasoline oils, solvents and paints, isocyanates and chromium from paint operations, and dust and silica exposure from sanding and sand blasting. Among physical hazards noise, fire and explosion, flying objects, dust cutting tools oil and grease spills and lifts are important. These hazards cause adverse health effects like respiratory ailments, acute injuries, eyes injuries, hearing loss, backache, and musculoskeletal disorders (Brosseau, 2012). The vehicular air pollution, its types, sources, its assessment methodology and its detrimental health impact on human beings have been discussed in this review paper. The focus was more on the occupational settings of MVRW in their ambient environment. Many international studies on the subject are also included in the paper to compare different vehicular related pollutants, and standards for ambient air quality as well as in occupational environment. The current environmental challenges and perspectives for Saudi Arabia in terms of both ambient air pollution and in occupational settings are discussed. The review ends with identifying gaps and limitations in monitoring and legislation in the subject area, and suggesting the way forward for Saudi Arabia including further research and development needed in the subject area.

2. Environmental, Health and Safety Regulations

The Constitution of Saudi Arabia, under Article 32 sets forth the requirement for the country to preserve, protect, and improve the environment, although no requirements for how to make that happen is provided in the Basic Law. The main implementing regulations addressing environmental and occupational health and safety issues in Saudi Arabia are the Labor Law and the General Environmental Law. Most of the rules and regulations are adopted on an ad-hoc basis and often contained as part of other laws and regulations not seemingly related to the environment or health and safety (Box 1). Saudi Arabia has also used the signing of international agreements and treaties regarding environmental matter as an extension of its regulations. Islamic law is supreme in the Kingdom. The two main sources of Islamic law are the Qur'an and Hadith. Throughout the Qur'an and Hadith there are many general references for the protection of environment, humanity, animals, plants, mountains, seas etc.

There are some general occupational health and safety guidelines but formal regulations, standards, code of practices and proper occupational exposure limits are needed to be revised on regular basis. Motor vehicle repairing and maintenance workshops are posing enormous challenges to ambient environment as well as to the workers. All over the world, most developed countries have chalked out comprehensive rules and regulations to cope with this issue to protect environment as well as workforce. For example, many countries have replaced leaded gasoline with other less hazardous derivatives, and achieved reduced emissions of CO, O₃, and VOCs by enforcing strict regulations. Occupational safety and health act of 1970 of USA has paved way for creation of occupational safety and health administration (OSHA). The OSHA developed standards and guidelines for the protection of workers in every occupation including MVRW (Box 1).

OSHA Regulations cover everything from mechanics rights to know and having access to proper personal protective equipment’s. Noncompliance results in penalties. Occupational Safety and Health Act of 1970 of USA gives rights to workers to work at safe workplace. OSHA hazard
communication regulations are included in a state Employee Right-to-Know Act. Throughout the year emissions from motor vehicles and ozone making VOCs are strictly regulated under clean air act amendments of 1990. Health and safety at work act 1974 of UK covers all health and safety aspects of workforce. Health and Safety Executive (HSE) is in charge of enforcing all provisions of the act along with some other statutory instruments related to workplace environment. Some important safety and health regulations are also provided (HSE, 1991). Besides this there are British Standards to cope up with worksite workers safety challenges and to protect and preserve their health.

**Box 1. Environmental, Health and Safety Regulations**

<table>
<thead>
<tr>
<th>Saudi Arabia Regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Resolution No. 1/1/4/5/1/924 Implementing Requirements under the Public Environmental Law</td>
</tr>
<tr>
<td>• National Ambient Water Quality Standard of 2012</td>
</tr>
<tr>
<td>• Standard on Emissions from Mobile Sources 2012</td>
</tr>
<tr>
<td>• Royal Decree No. 21 (6/9/1389 H) on Safety in the Workplace</td>
</tr>
<tr>
<td>• Labor Inspection Order No. 435 (4/11/1404 H)</td>
</tr>
<tr>
<td>• Ministerial Decree No. 435 of 1983 to Establish Which Industries Potentially Have Workers Who Are Exposed to Poison by Lead and the Procedures to be Taken by Employers to Protect those Workers</td>
</tr>
<tr>
<td>• Cooperative Health Insurance Law (Issued by Royal Decree no. M/10 01/05/1420 H and the Council of Minister’s Resolution No. 71 27/04/1420)</td>
</tr>
<tr>
<td>• Social Insurance Law (Council of Minister’s Decision No. 199 17/08/1421/H)</td>
</tr>
<tr>
<td>• Ratification of the ILO Convention on the Elimination of Worst Forms of Child Labor</td>
</tr>
<tr>
<td>• Labor Law (Royal Decree No. M/51)</td>
</tr>
<tr>
<td>• Minister of Labour Decree No. 159 (7/3/1430 H), Establishing a Chart of Occupational Diseases in the Kingdom Saudi Arabia</td>
</tr>
<tr>
<td>• Minister of Labour Decree No. 160 (7/3/1430 H), Establishing a Table Directory for Determining Occupational Disabilities in the Kingdom of Saudi Arabia</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>International Regulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Management of Health and Safety at Work Regulations 1999</td>
</tr>
<tr>
<td>• Manual Handling Operations Regulations 1992 (as amended) (MHOR)</td>
</tr>
<tr>
<td>• Health and Safety (Display Screen Equipment) Regulations 1992</td>
</tr>
<tr>
<td>• Control of Vibration at Work Regulations 2005</td>
</tr>
<tr>
<td>• Workplace (Health, Safety and Welfare) Regulations 1992</td>
</tr>
<tr>
<td>• Provision and Use of Work Equipment Regulations 1998</td>
</tr>
<tr>
<td>• Lifting Operations and Lifting Equipment Regulations 1998</td>
</tr>
<tr>
<td>• Personal Protective Equipment at Work Regulations 1992</td>
</tr>
<tr>
<td>• Manual Handling Operations Regulations 1992</td>
</tr>
<tr>
<td>• The Control of Substances Hazardous to Health Regulations 2002 (COSHH)</td>
</tr>
<tr>
<td>• European Community (EC) Directive 89/656/EEC for PPES</td>
</tr>
</tbody>
</table>
3. Pollution Monitoring Methods

The type and quantity of pollutants in ambient air is measured by systematic methods known as ambient pollution monitoring. Whereas measurement of particulate and gases from a specific source is called emission measurement. The main reason to carry out monitoring is to ensure compliance with local, national and international legislation, to review the degree of pollution, to provide data for modeling and to evaluate controls. Many different methods are available, ranging from simple passive technique to highly delicate remote sensing devices that can measure any pollutant depending upon given data and reliability (Ashmore et al., 2000). An example of state of the art equipment from Horiba with their measurement principles and detection limits are given in table 1.

Table 1. List of instruments for ambient air quality monitoring with their specifications, calibration and working limits.

<table>
<thead>
<tr>
<th>Analyzer</th>
<th>NOx</th>
<th>SO₂</th>
<th>O₃</th>
<th>CO</th>
<th>THC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>APNA-370</td>
<td>APSA-370</td>
<td>APOA-370</td>
<td>APMA-370</td>
<td>APHA-370</td>
</tr>
<tr>
<td>Application</td>
<td>NO₂, NO, NOₓ</td>
<td>SO₂, H₂S</td>
<td>O₃</td>
<td>CO</td>
<td>THC, NMHC, CH₄</td>
</tr>
<tr>
<td>Principle</td>
<td>Cross flow modulation, Chemiluminescence</td>
<td>UV fluorescence</td>
<td>Cross flow modulation, UV absorption</td>
<td>Cross flow modulation, non-dispersive IR absorption</td>
<td>Flame ionization detection</td>
</tr>
<tr>
<td>Range (ppm)</td>
<td>0 – 10</td>
<td>0 – 10</td>
<td>0 – 10</td>
<td>0 – 100 ppmC</td>
<td>0 – 100 ppmC</td>
</tr>
<tr>
<td>Lower Detectable limit (LDL)</td>
<td>0.5 ppb (3 sigma)</td>
<td>0.5 ppb (3 sigma)</td>
<td>0.5 ppb (3 sigma)</td>
<td>0.02 ppm (3 sigma)</td>
<td>0.022 ppmC (3 sigma)</td>
</tr>
<tr>
<td>Repeatability</td>
<td>±1.0% of F. S.</td>
<td>±1.0% of F. S.</td>
<td>±1.0% of F. S.</td>
<td>±1.0% of F. S.</td>
<td>±1.0% of F. S.</td>
</tr>
<tr>
<td>Linearity</td>
<td>±1.0% of F. S.</td>
<td>±1.0% of F. S.</td>
<td>±1.0% of F. S.</td>
<td>±1.0% of F. S.</td>
<td>±1.0% of F. S.</td>
</tr>
<tr>
<td>Zero drift (at lowest range)</td>
<td>&lt;LDL/day</td>
<td>&lt;LDL/day</td>
<td>&lt;LDL/day</td>
<td>&lt;LDL/day</td>
<td>&lt;LDL/day</td>
</tr>
<tr>
<td></td>
<td>±1.0ppb/week</td>
<td>&lt;LDL/week</td>
<td>&lt;LDL/week</td>
<td>&lt;0.2ppm/wee k</td>
<td>&lt;LDL/day</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Span drift (at lowest range)</td>
<td>&lt;LDL/day</td>
<td>&lt;LDL/day</td>
<td>&lt;LDL/day</td>
<td>&lt;LDL/day</td>
<td>&lt;LDL/day</td>
</tr>
<tr>
<td></td>
<td>±1.0% of F. S./week</td>
<td>&lt;LDL/week</td>
<td>&lt;LDL/week</td>
<td>&lt;LDL/week</td>
<td>&lt;LDL/week</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Response time (T₉₀) (Sec) (at lowest range)</td>
<td>Within 90 sec</td>
<td>Within 120 sec</td>
<td>Within 75 sec</td>
<td>Within 50 sec</td>
<td>Within 60 sec</td>
</tr>
<tr>
<td>Sample gas flow rate (L/min)</td>
<td>0.8</td>
<td>0.7</td>
<td>0.7</td>
<td>1.5</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Many parameters like operational cost, ease of operation, initial investment costs, and method used for monitoring must be taken into account before any monitoring strategy (Arriaga-Colina et al., 2004). Monitoring stations are totally dependent on reason for monitoring. While designing monitoring networks, the main objective is to protect human health, this is the reason that monitoring stations are established in population centers (Afroz et al., 2003). Background sampling or environmental sampling is also needed along with personal sampling for occupational settings. For source apportionment purposes, background monitoring stations are established, which act as a "control" (USEPA). Studies on gaseous air pollutants and particulate matter by different epidemiologists have been compromised due to complexity in exposure assessment. Air
pollution concentrations in the ambient environment may be estimated, using fixed site monitoring equipment in the area or region of interest. Ambient air pollutant levels cannot be used as personal exposure predictors due to spatial variations (Liard et al., 1999; Kousa et al., 2002; Adgate et al., 2002). For example, according to a study in Paris (Liard et al., 1999) variance of personal NO\textsubscript{2} exposure was found in adults up to 41% whereas in children it was 17% on average. For ozone, stationary measuring data were proved to be a poor predictor of personal ozone exposure. In US personal PM\textsubscript{2.5} exposure variance were determined both indoor and outdoor. It was determined up to 26% and 4%, respectively for indoor and outdoor (Adgate et al., 2002). When traffic related exposure is main focus then traffic indicators and geographic information system can be adopted as an alternative option (Hoek et al., 2002; Brauer et al., 2003).

Portable measuring equipment’s, for personal exposure assessment are now commonly used all over the globe. These portable measuring equipments measure the direct exposure to various pollutants and are used to address exposure problems for highly dangerous and on high risk population, as well as important in rigorous epidemiological studies. Saarela et al. (2003) studied VOC exposure levels in many indoor, outdoor and other microenvironments. In this regard portable personal monitoring using personal samplers were carried out continuously for 48 hours for measurement of real personal exposure. Using this technique results found that VOC concentrations were found to be almost 30% more than the values calculated in the microenvironment. These findings prove that portable samplers can be used effectively for accurate assessment of personal exposure assessment even for less mobile persons.

4. Workers Health Risk Assessment Protocols

For real assessment of risks, accurate estimation of human exposure to pollutants is necessary. This will not only help in proper designing and implementation of the control strategies, but also limit the risks. Three aspects of exposure are important for shaping health related consequences i.e. magnitude, duration and frequency. General approaches referred in different studies for environmental and occupational exposure assessment at repairing workshops and at gasoline stations are air monitoring, biological monitoring and questionnaire based methods.

4.1 Risk Management: Managing the risk at workplace is the systematic process which should include all work characteristics, workers activities, machinery, materials, working procedures and working environment. It basically aims at what could possibly go wrong, which can pose injury or ill health effects to workers. Deciding on proper safety controls and their implementation to protect workers from accidents and exposures is also aim of risk management. Risk management consists of many parallel consecutive steps as shown in Fig. 2. It starts with identification of hazards, its type, nature, number and frequency of hazards at work place. The second step is the identification of population at risk i.e. “who is at risk”, followed by risk evaluation. After that existing and new control measures are looked for. Action plan is then chalked out by focusing on practicable most effective control measures. These controls are then implemented. Monitoring and reviewing of the process are of core importance for successful risk management.
4.2 Air Monitoring: It is the most traditional and principal method of exposure assessment. It can be done by using either direct approach or indirect approach.

Direct Approach to Exposure Assessment: Very sensitive and portable light weight device known as personal portable monitor is used to detect small quantities of pollution. Personal monitoring technique are used to measure large population exposures by selecting a small sample size (Underhill, 1984; Kring et al., 1984). According to different studies SO₂, CO, NOₓ, formaldehyde, organic vapors, and respirable particles can be measured easily by this method (Coleman, 1983; Sheldon et al., 1985; Akland et al., 1985; Ott et al., 1986).

Indirect approach to exposure assessment: It refers to fixed-site monitors combined with data on time activity patterns for exposure assessment. It estimates integrated exposure by adding pollutant concentrations taken at fixed sites along with workers time spent in different environment diaries and data log (Ott, 1986; Sexton et al., 1983). There are different air quality standards used worldwide that dictate the safe levels of various pollutants including gaseous and PM in terms of hourly, daily and annual safe limits. The air quality standards developed by USEPA, WHO and PME (Saudi Arabia) are given in table 2.

Table 2. Comparative air quality standards of EPA, WHO & PME

<table>
<thead>
<tr>
<th>Pollutants</th>
<th>Time</th>
<th>USEPA 1997</th>
<th>WHO 2001</th>
<th>PME (Saudi Arabia) 2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>1 hour</td>
<td>35 ppm</td>
<td>26 ppm</td>
<td>35 ppm</td>
</tr>
<tr>
<td></td>
<td>8 hour</td>
<td>9 ppm</td>
<td>8.7 ppm</td>
<td>9 ppm</td>
</tr>
<tr>
<td>NO₂</td>
<td>Annual</td>
<td>53 ppb</td>
<td>21 ppb</td>
<td>100 µg/m³</td>
</tr>
<tr>
<td></td>
<td>1 hour</td>
<td>----</td>
<td>106 ppb</td>
<td>660 µg/m³</td>
</tr>
<tr>
<td>PM₁₀</td>
<td>24 hour</td>
<td>150 µg/m³</td>
<td>----</td>
<td>340 µg/m³</td>
</tr>
<tr>
<td></td>
<td>Annual</td>
<td>50 µg/m³</td>
<td>----</td>
<td>80 µg/m³</td>
</tr>
<tr>
<td>PM₂.₅</td>
<td>24 hour</td>
<td>65 µg/m³</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td>Annual</td>
<td>15 µg/m³</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>O₃</td>
<td>1 hour</td>
<td>120 ppb</td>
<td>----</td>
<td>0.15 ppm</td>
</tr>
</tbody>
</table>
4.3 Biological Monitoring: It is the measurement of occupational or environmental contaminants and their biological consequences after the contamination has occurred to the body or some tissues of the body. Usually two methods are used for biological monitoring.

(1) Measurements of environmental metabolites, their contaminants and derivatives in excreta or body fluids (exposure markers).

(2) Biological responses measurement in tissues and cells (Miller, 1983).

Immunoassays, direct chemical analysis and bioassays specific for mutagenicity are used for measurement of first type of monitoring. Bioassays, chemical analysis and immunoassays are used for pollutants assessment in urine, blood, breast milk, semen and saliva (Ho and Dillion, 1986). Chemical and immunological methods are used for second category. They detect and quantify covalently bound derivatives formed between cellular macromolecules, such as proteins and nucleic acids, and activated chemicals and mutation observations, sister chromatid exchange, and chromosome aberrations (Wogan and Gorelick, 1985). A study by Angela and Natalia (2015) was conducted to assess the immunological and hematological alterations in the workers due to the exposure of benzene. The study revealed that biomarker approach can be successfully used for early diagnosis of human immune and hematological disruptions due to such exposures.

4.4 Questionnaires Techniques: Particularly in epidemiological studies questionnaires are also used besides biological monitoring and air monitoring. By this monitoring method respondents are categorized into two or more groups like low exposure or high exposure and exposed or unexposed. In general, this method is retrospective qualitative method for estimating occupational and environmental exposures (Akpakpavi, 2014). Apart from questionnaires being the main research instrument used, observations and discussions are also used to some extent in gathering respondent’s response and information via structured questionnaires and face-to-face interviews. According to a study at vehicle workshops by Monney et al. (2014) on attendants, for assessment of illness and injuries, use of personal protective equipment (PPE), their access to first aid and on provision of welfare facilities, 78% attendants have lack of knowledge and first aid training. Ignorance to first aid was much high and recorded as 92%, whereas self-medication was up to 55%. Due to physical exertion of their body 57% attendants reported musculoskeletal disorders. The use of PPEs and hand hygiene practices were 27 and 28%, respectively among workshop workers (Monney et al., 2014).

To find the prevalence of respiratory illness a cross-sectional study was conducted in petrol pump workers in Kerala. Peak flow meter was used to measure expiratory volume from 75 workers, among which majority were male members (78.67%). Age groups were between 20-29 (32%) and 30-39 (36%) and their service was less than 10 years. Out of 75 workers, 21 got respiratory ailment symptoms. Workers who got ailment symptom up to 41.67% were those who were having their service more than 10 years, whereas workers having service less than 5 years had respiratory symptoms up to 20.69% (PSBH, 2009). To study the potential risk of exposure to premium motor spirit fumes (PMS) among automobile mechanics and petrol pumps workers a
research was carried out in Calabar. Among 150 workers, taken as a sample, packed cell volume (PCV) and Methahemoglobin (MetHb) were studied. It was found that after comparison these values were higher than the general pollution. This study revealed that PCV was inversely whereas MetHB was directly proportional to the exposure duration. Also MetHb was found as a useful biomarker for determining level of exposure to C6H6 in gasoline vapors (Udonwa et al., 2009).

Hematological changes have been reported for many years due to exposure to pollutants and are being commonly used to assess human’s health and well-being (Khuder et al., 1999; Shaham et al., 2000). Poly Aromatic Hydrocarbons (PAHs) presence in workers’ blood causes disturbance to homeostasis of human body. It also negatively affects hematological parameters of workers as anemia was reported in workers of petrochemical industry (Tsai et al., 2001). Even a low level of occupational exposure has been reported in many studies to cause severe changes in hematological parameters like cell count, cell volume, hemoglobin in peripheral venous blood in car repair and car paint works. Blood is a sensitive medium and any hematological change may lead to develop the immunological function disturbances among all ages (Baak et al., 1999).

At motor vehicle workshops exposures to fumes of gasoline, diesel, used gasoline oil and mobil oil in the form of PAHs can be assessed using human body fluids like blood and urine (Strickland et al., 1996). Many biomarkers in blood and urine have been reported to measure PAHs exposure (Castano et al., 2004; Rahman et al., 2003; Wu et al., 2002). Urinary 1-hydroxypyrene (1-OHP) is the commonly used biomarker in urine as it is used in many epidemiological studies for PAHs exposure determination to traffic pollutants, tobacco smoke and many occupational sources (Tsai et al., 2003).

5. Health Effects, Major Exposures and Safety Hazards at Workshops

According to statistics, announced by Bureau of Labor Statistics USA, almost 1.5 million servicemen were recruited in automobile repairing and gas service stations industry in 1985. Such statistics is not patently available for employments in Saudi Arabia. This industry covers various dimensions of services including muffler, brake, ignition, glass, body and paint shops. The most catered services are lubricating oils and greases. Workers face chemical exposures from gasoline vapor, epoxies, fiberglass, solvents, asbestos, and fumes from welding, vehicles exhaust, paints, adhesives and benzene (Schwartz, 1987).

<table>
<thead>
<tr>
<th>Study settings/subjects</th>
<th>Pollutant</th>
<th>Study Year</th>
<th>Exposure type</th>
<th>Country</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>In front of automotive workshop</td>
<td>Black carbon, various other elements, PM</td>
<td>2009</td>
<td>Ambient</td>
<td>Pakistan</td>
<td>Siddique et al., 2013</td>
</tr>
<tr>
<td>Inside motor industry</td>
<td>SO2, NO2, CO, PM</td>
<td>2014</td>
<td>Ambient, indoor</td>
<td>India</td>
<td>Arunkumar et al., 2014</td>
</tr>
<tr>
<td>Urban canyon</td>
<td>PM2.5</td>
<td>2002</td>
<td>Ambient</td>
<td>Budapest, Hungary</td>
<td>Salma et al., 2004</td>
</tr>
<tr>
<td>Fixed</td>
<td>PM10</td>
<td>1999</td>
<td>Ambient</td>
<td>Argentina</td>
<td>Bogo et al., 2003</td>
</tr>
<tr>
<td>Mini bus</td>
<td>PM2.5, CO</td>
<td>2002</td>
<td>In vehicle</td>
<td>Mexico</td>
<td>Gomez Parelaz et al., 2004</td>
</tr>
</tbody>
</table>
A normal trend, as observed, is that automobile mechanics and gas station workers have similar experience of workmanship. This is because they often work together in the same workplaces and they have similar kind of duties. The population-based proportionate mortality ratio (PMR) studies and case reports about these workers have helped in collecting findings about their death rates (Schwartz, 1987). These case studies show aplastic anemia, excesses of leukemia multiple sclerosis, nonmalignant respiratory disease, cancers of the buccal cavity, testicular and kidneys, esophagus, duodenal ulcers, suicide and injuries among automobile mechanics and gasoline service station workers (Schwartz, 1987). Exposure to benzene at workplaces is considered as one of the main reasons behind blood disorders such as acute lymphoid leukemia, chronic myeloid and non-Hodgkin’s lymphomas (Carletti and Romano, 2002).

The vehicle technicians are also exposed to many health hazards. According to WHO out of 2.8 billion workers around the globe, 160 million encounter work related diseases due to exposure to hazardous and dangerous workplace conditions each year (IARC, 2012; Browne, 2007). Table 3 presents some studies on various pollutants at different occupational settings and their implications on health and safety.

### 5.1 Major Exposures:

Workers while working at MVRW are exposed to many solvents, adhesives, resins, poly aromatic hydrocarbons and heavy metals. The hazards and risks depend upon the exposure type, time, root of exposure, magnitude and personal susceptibility. The major exposures are listed below.

**Benzene:** Benzene is a constituent of gasoline and a proved cancer causing agent (IARC, 2012). Due to its carcinogenic nature its exposure is strictly regulated and monitored throughout world. Different studies cited that its exposure damages biomolecules, micronuclei, breaks of DNA strands, and chromosomal abbrevations (Ruchirawat et al., 2010; Roma-Torres, 2006). Exposure assessment of benzene can be performed using t,t- muconic acid a urinary metabolite, and is regarded as an effective biological monitoring instrument (Carrieri, 2012). The other such techniques used to evaluate DNA damage and genotoxicity are comet assays and micronucleus assays (Wang et al., 2012; Sun et al., 2009).

**Lead:** Lead exposure is common among vehicle repairers. This constitutes 0.9% of global health burden and most affected population is among developing countries. Health hazards due to lead are globally recognized for many decades (ATSDR, 2007). There was an epidemic of lead poisoning in an automobile industry in the USA as far back as 1924 (ILO, 2012). In adults, occupational exposure is the main cause of lead poisoning. These occupational exposures have
adverse effects on workers as well as on their family’s health. Workers may also transfer lead contents through their clothes to families and indoor environment. The automobile technicians exposed to lead including battery manufacturers and repairers, panel beaters, spray painters and radiator repairers. There have been reported cases of lead poisoning and deaths from ingestion and inhalation of gasoline among mechanics. Automobile mechanics were also reported to suck petrol and use it to wash hands with, which leads to absorption of tetraethyl lead through mucosa, and this, with inorganic lead from exhaust fumes, may lead to elevated blood levels (ILO, 2012, Oluwagbemi, 2007).

**PAHs:** International agency for research on cancer (IARC) has categorized some PAHs as carcinogens to humans, particularly to the workers continually inhaling fumes, vapors and mist of used gasoline engine oil (UGEo) like auto repair workers. Different studies proved that both virgin oils and UGEo contain carcinogenic contents. Also, the PAHs having three or more than three rings are responsible for 70% carcinogenicity of UGEo (Kamal et al., 2015). Other reported health effects according to Kamal et al., (2011, 2015) associated with long and short term exposure to crude or petroleum oil are tumors, blood disorders, reproductive problems, reduction in growth, morphological problems and nephrotoxicity.

**5.2 Occupational Health Hazards:** During work at MVRW, workers come across a number of occupational health hazards which depend upon the type of job they perform. Some routine hazards are accidental, physical, chemical, biological and ergonomic, the details of which are as follows.

**Accident Hazards:** These include fall hazards, injury hazards, crushed toes, eye injury, electrocution, musculoskeletal disorders, burns (ILO, 1998; HSE, 1991), acute musculoskeletal injuries, burns, soldering, brazing and welding operations. Other accidental hazards include carbon monoxide poisoning, fires and explosions, cuts, abrasions, punctures, tires bursting, and accidents to steam water pressure cleaners (Vyas et al., 2011).

**Physical Hazards:** Different examples of physical hazards at MVRW include IR, UV, microwave, and radio frequency radiation exposures. Power driven hand tools continuous can cause hand arm vibration and if continues white finger syndrome can result. Exposure to excessive noise, and exposure to excessive heat or cold are also examples of physical hazards (HSE, 1991).

**Chemical Hazards:** Exposure to lubricants, brake fluids, used gasoline oils, degreasers, adhesives, asbestos, detergents, paints, solvents, antifreeze and epoxy resins can pose serious health hazards to workers (ILO, 1998; HSE, 1991). During break drum cleaning and body spraying asbestos exposure causes asbestosis and mesothelioma. Exposures to benzene, toluene, ethylene and xylene (BTEX) have reportedly caused hematological changes. Inhalation of diesel exhaust fumes, NOx and respirable particulates, and ingestion of adhesives causes increased risk of brain damage, acute eye and mucous membrane irritation, headaches, breathing difficulties and chest tightness (ILO, 1998; HSE, 1991).

**Biological Hazards:** These are also called biohazards. The biological materials which pose threat to humans refer to biological substances that pose a threat to the health of living organisms, primarily that of humans. These are the hazards caused by living organisms while performing jobs
at workshops. The commonly used adhesives may promote growth and contamination of microbes and these microbes may cause infections among workers, exposed to adhesives.

**Ergonomic:** Ergonomic hazard is a physical factor which can harm workers while at work. The main factors with working environment are repetitive movement, lifting and handling heavy loads, unsuitable body postures, workstation height, task design and manual handling. The outcomes are acute musculoskeletal injuries i.e. hernia, back bone stress, strain and pain, intervertebral disk rupture, tendon rupture. etc. (Vyas et al., 2011; ILO, 1998).

5.3 Psychosocial and Organizational Factors: MVRW workers face psychosocial hazards such as stress due to long working hours under time pressure, carpal tunnel and trauma damages due to repetitive work schedules (HSE, 1991). At vehicle repairing workshops, workers perform variety of jobs. While performing repairing and maintenance tasks their main role is to investigate the problem immediately and quickly using their senses, experience as well as electronic gauges. Their job might be to fix or repair a single part or more parts interconnected (Anslem et al., 2014). The auto mechanics use to suck oils using a tube through mouth can easily expose the worker. They are also exposed to fuel oils while washing different parts of vehicles. Exposure to automotive gasoline most likely occur from breathing in its vapors at workshops by sniffing, washing, degreasing mechanical engine repair works while fixing of atomizer and diesel oil pump, pistons rings etc. (Anslem et al., 2014).

5.4 Hazard Control Hierarchy: In hierarchy of controls, elimination or removing of hazards from work place is most effective tool and is preferred, if practicable (Fig. 3). One or sometimes combination of the different hazard control strategies are employed, wherever practicable. Replacement or substitution of more hazardous tool or equipment with less hazardous is also effective control. Technological or engineering controls are also viable options wherever changes have to be made in the machinery, equipment or system design. Isolation, barrication, ventilation are some examples of engineering controls. Administrative controls are used to change working practices, policies and rules. Examples include training, behavior changes, awareness, work shifts changes and capacity building programs. The last defense line is the use of PPEs alone or in combination with other options to reduce the exposure. This is the least effective tool in hazard control hierarchy.
6. Challenges and Perspectives for Saudi Arabia

Saudi Arabia is one of the most devout and wealthiest country in the world. It is largest country in Arab Region, containing bulk of Arabian Peninsula. Geographically it lies in Western Asia and is the fifth largest country of Asia. Most area of Saudi Arabia is made of deserts (Habeebullah et al., 2015) as shown in Fig. 4. It covers an area of 2149,000 Km². It’s the only country having both red sea and Persian Gulf. It contains the world largest contiguous sand desert. The country has the largest oil reserves in the world, therefore the economy is heavily dependent on oil production and its exports (Ouda et al., 2015). The huge oil-revenues in the last few decades have brought significant socio-economic development in the country. As a result, the population (annual growth rate of 3.4%), urbanization (annual rate of 1.5%) and living standard have increased many folds (Nizami et al., 2015a). The current energy demands (peak electricity demand of 55 GW) will be doubled in 2032 and currently most of the electricity is produced from fossil fuels. The significant increasing population, urbanization, transportation, especially motor vehicle, energy consumption and high dependency on fossil fuels are causing serious environmental challenges and issues (Nizami et al., 2016; Nizami et al., 2015b; Rehan et al., 2016). Furthermore, the harsh meteorological conditions such as high solar radiation, high temperature, high humidity, low wind speed, and low rain fall are further aggravating the environmental problems (Munir et al., 2015).

United States has almost 236,000 employees working in 37,600 motor vehicle repair businesses (NAICS code 811121). A majority of these enterprises (55%) have four or fewer employees, and 23% have 10 or more employees. These workers encounter a wide variety of physical and chemical hazards during repairing, painting and assembling. In motor vehicle repair industry isocyanate exposure occurs commonly while spraying and painting and the use of engineering controls and personal protective equipment (PPE) have been of keen importance and reported by many studies (Sparer et al., 2004; Liu et al., 2006; Vel´azquez et al., 2008; NIOSH 1996). Nevertheless, during work at workshops include many hazards including fire, explosion, electrical and machine-related hazards, and the programs required to manage these hazards, have not been examined in detail. In particular, air-powered tools are likely to produce noise levels
exceeding 90 dBA. Such highly detailed and accurate occupational data has not been published much and not easily available to general public in Saudi Arabia.

Saudi Arabia has witnessed highest urban, economic and infrastructure development in recent decades. At present there are around 18 million registered vehicles in the Saudi Arabia (IBI, 2007; Arab news, Al Eqtisadiah daily). There are about 70,000 fuel stations and thousands of workshops for repair and maintenance of motor vehicles (Saudi gazette), employing hundreds of thousand foreign workers (Vyas et al., 2011). People use their personal vehicles for 93% of their travel (IBI, 2007). To meet the needs of population growth, transportation infrastructure and vehicles are increasing day by day along with their related businesses like repair, maintenance workshops and facilities, service stations and fuel filling station (Chawla & Lavania, 2008).

In developing countries, especially in informal, small size and self-employed establishments like MVRW, workers lack awareness regarding routine chemicals and other hazards. They work in unhygienic conditions, daily exposed to UGEO and don’t normally use PPEs and other protective measures that can minimize many risks, especially skin cancer risk and respiratory ailments (Kamal et al., 2015). There is a lack of proper monitoring and awareness programmes regarding safety measures, standards and practices at MVRW. The rules and regulations are not uniform throughout the world. At the workshops, workers work amid hot weather, wearing no PPEs, exposed to a number of occupational hazards and risks, it makes them a vulnerable occupational group (Kesavachandran, 2006). On vehicle workshops some dangerous practices like smoking, bad housekeeping, unhygienic clothes, working beneath vehicles, manual handling, lifting heavy loads, naked welding, unhealthy eating and drinking are a matter of daily life.

All over the globe, air pollution from vehicles is an inescapable part of the urban life. Chronic exposure to traffic air pollutants leads to harmful effects on the lung functions and causes various other serious illnesses. Ambient air pollutants and other workplace chemicals like benzene, lead and carbon monoxide can cause serious health effects. The uncontrolled increase in number of vehicles in most cities are causing an equivalent increase in air pollution. Also the failure to use personal protective measures causes a greater health risks for employees of gasoline

Fig. 4. Saudi Arabia map showing large desert areas
stations. (Salvi et al., 1999). The vapors and fumes in such work places are a complex combination of hydrocarbons. Among these 95% are aliphatic and acyclic compounds and less than 2% are aromatics. Benzene, the proved carcinogen, have been reported in the range of 1–5%. This job can cause 1 ppm exposure for routine 8 hour working and it may reach 2-3 ppm for shorter periods in between (Onat and Stakeeva, 2013).

Most of the vehicle workshops and gasoline stations in Jeddah City are open and through way, their workers are exposed to petroleum vapors, used diesel oil, vehicular exhaust etc. In Saudi Arabia, at gasoline stations and motor vehicle workshops petrol fumes exposure is normal. The combined effects of these all exposures may result in accelerated decline in lung functions (Ahmed, 2001). Shorter life expectancy due to long term exposure to traffic related exhaust have been reported by Hoek et al. (2002). Traffic is a major emission source of particles, especially in urban areas (Weijers et al., 2004; Gertler, 2005; Ede et al., 2014). Long term exposure to petrol fumes and vapor has proved to alter physiological functions in the human body. Different case control studies has shown that exposure to ambient airborne pollutants causes respiratory, lungs and cardiovascular damages in humans (Dockery et al., 1993; Pope et al., 1995; WHO, 2000). WHO (Sehgal et al., 2011) stated that prolonged exposure through inhalation and handling might, therefore constitute a significant occupational hazard at such distribution centers. Consequently, it is important to screen air in the work environment for the presence of aromatic hydrocarbons as well as other pollutants such as CO, NO3 and PM (Begum and Rathna, 2012).

Alharbi et al., (2014) conducted a study in Riyadh, Saudi Arabia and measured PM10 concentrations and five other air pollutants i.e. O3, CO, NO2, SO2, H2S over a 6 year period using 5 air quality monitoring stations. The study focused on ambient air quality assessment and its possible health effects in urban area. The study used USEPA air quality index and five criteria pollutants. The selected pollutants concentrations were found to have positive trends over time except for H2S. In Basahi et al., (2015) study, variations in concentrations of CO, NO2, benzene, toluene, xylene, PM10, PM2.5 were studied and monitored in Jeddah City at different gasoline stations. The concentrations of xylene, toluene, benzene, CO, NO2, PM2.5 and PM10 concentrations were 4326, 2143, 3114, 2152, 36, 344 and 710 μg m−3, respectively. Results showed higher concentrations as compared to Saudi Arabia National Standards, which indicates substandard air quality at local gasoline stations. Pulmonary functions as well as benzene, toluene and xylene exposure were determined during the course of study. Pulmonary functions were significantly decreased among subjects as compared to controls. It shows impairment of pulmonary functions, and this impairment was associated with dose response to petrol fumes, diesel exhaust and VOCs exposure at work stations. The study also found a strong correlation between exposure to chemicals and PM and lung functions. Also a significant correlation was observed among benzene exposure and tt-MA in study group.

Some latest important studies on air pollution in the Holy City Makkah are reported i.e. quantifying temporal trends of atmospheric pollutants in Makkah from 1997-2012 (Munir et al. 2013a), modeling particulate matter concentrations in Makkah, applying a statistical modeling approach (Munir et al., 2013b), comparing the performance of statistical models for predicting PM10 concentrations (Sayegh et al., 2014). Al-Jeelani et al (2008) conducted a study on assessment of air quality due to traffic emission. Meteorological as well as some important traffic related pollutants e.g., CO, NO2, SO2, O3, CH4 and total hydrocarbons were measured. The study was conducted from November 2002 to October 2003. According to study NO2 and CO levels were found to be higher in the opening hours of day. SO2 concentrations were relatively higher and constant. The O3 values indicated the photochemical reactions rate changes. The results of
the study can be used for modelling and air quality parameters estimation in the urban settings having the similar settings. Another study conducted by the same group (Al-Jeelani et al., 2013) assessed the impact of traffic emissions on air quality. Existing air quality and pollutants concentrations were measured using mobile air quality monitoring system around the Harram Mosque at three different locations. Air movements and pollutant dispersion was also modeled using an ISC-AERMOD dispersion model. Time lag of pollutants, correlation coefficients, and auto correlations were calculated using statistics. Among measured and analyzed pollutants were \( \text{SO}_2 \), \( \text{CO} \), \( \text{NO}_2 \), \( \text{O}_3 \) and \( \text{PM}_{10} \). The study results revealed that modelled values were in agreement with observed values. Moreover, high concentrations of PM were found, probably due to huge construction work and high building restricting good air flow and inhibiting air pollutants dispersion.

### 7. Conclusions

Globally increasing urbanization, industrialization and automobiles has caused exponential increase in urban air pollution with road traffic being the major pollution contributor. In recent times motor vehicles have become essential part of today’s life, MVRW sector is a SMEs and categorized as informal sector. The workers at MVRW face many physical, accidental, chemical, biological and ergonomic hazards along with toxic pollutant exposure from benzene, PAHs, VOCs, heavy metals, PM, \( \text{NO}_x \) and \( \text{SO}_x \). Safe work conditions promote physical, mental and social wellbeing along with enormous monetary benefits attributed to medical bills, insurance claims, and loss of work, experienced personals and corporate reputations and integrity of organization. Annually 270 million accidents and 2 million deaths are reported worldwide. Also some severe accidents leave victims paralyzed, loss of body parts, reproductive problems, musculoskeletal disorders, skin diseases, neurological, psychological, mental and respiratory diseases.

In developed countries, a lot of emphasis has been put on controlling workplace challenges to workers but it has been compromised in developing countries. In Saudi Arabia, this sector employs diverse international labour force which are more prone to risks due to local harsh climatic, geographical and legislative conditions. Exposure research studies are instrumental in health status evaluation of workers but its importance becomes many fold in informal, small and self-employed MVRW sector. However, this area has been neglected by the scientific community in Saudi Arabia. It is, therefore, strongly recommended to carry out comprehensive exposure assessment studies of workers from various occupational settings, especially petrochemical based industry and MVRW (Box 2). The findings of such studies can be used to update the health and safety conditions in different occupational settings, achieving multiple socio-economic benefits for Saudi Arabia.

**Box 2. Further Research**

- Study the concentrations of various pollutants such as \( \text{PM}_{10} \), \( \text{PM}_{2.5} \), heavy metals, PAH and other petrochemical based pollutants using state of the art tools in occupational settings such as MVRW.
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9. References


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