



Journal of Applied Sciences

ISSN 1812-5654

science
alert

ANSI*net*
an open access publisher
<http://ansinet.com>

An Environmental Impact Assessment of the Open Burning of Scrap Tires

¹Anf H. Ziadat and ²Emad Sood

¹Department of Civil Engineering, Abu Dhabi Men's College, Higher Colleges of Technology,
P.O. Box 25035, Abu Dhabi, United Arab Emirates

²Faculty of Engineering, Tafila Technical University, P.O. Box 179, Tafila, 66110, Jordan

Abstract: This study aimed to evaluate the environmental impact assessment of actual field measurements of the open burning of scrap tires and the level of health risk associated with such activities. The quality and quantity of polluted ambient air including smoke, gases, heavy metals, Volatile Organic Compounds (VOC) and Polycyclic Aromatic Hydrocarbons (PAH's) on the surrounding environment and its potential impact on human health were evaluated. The results showed that the mean concentrations of Particulate Matter (PM₁₀) for a full day burning (24 h) period was 280 µg m⁻³, which is seven times higher than the blank samples concentration obtained from the ambient air at the same location prior to the open burning of scrap tires. The results greatly exceeded the Environmental Protection Agency (EPA) maximum allowable limits standards for PM₁₀ concentration. The summation of the total means all PAH's compounds reached a concentration of 2918 µg m⁻³, indicating high levels of PAH's concentration in the surrounding environment. Sulfur dioxide emission from the open burning of scrap tires exceeded the EPA standards by three fold which causes major concerns for human health and air pollution in the study area.

Key words: Environment, scrap tires, open burning, pollution, polycyclic aromatic hydrocarbon, toxic gases, smoke

INTRODUCTION

The vast urbanization and industrialization of modern society has increased the dependence on different kinds of motor vehicles for various purposes. Consequently, the number of scrap tires has increased and poses serious health and environmental problems due to mismanagement in the disposal processes. Since, the early days of tire usage and the disposal of scrap tires has been a major environmental problem worldwide. Piles of thousands of tires at junkyards, landfills and other places are common in many countries of the world today (Haines *et al.*, 2010; Hassanien, 2007; Pehlken and Essadiqi, 2005; Lemieux, 2002). Tire stockpiles are a burden on the landscape causing environmental, public safety and health threats.

Scrap tires are land filled, stockpiled in tire dumps, burned for energy and re-used in whole tire applications, processed into useable other products or illegally dumped. The major environmental problems associated with scrap tires are attributed to the disposal process and pollution emissions especially from the open burning of scrap tires. Scrap tires take a very long time to degrade and are extremely difficult to compact in landfills as eventually scrap tires will rise over time to the surface of

the landfill causing consequent problems during the rehabilitation of landfill sites. Finding suitable space for the appropriate disposal of scrap tires represents a major problem regarding the disposal process (Haines *et al.*, 2010; Lemieux, 2002). Waste tires in landfills are a significant fuel source for accidental fires and there is not an easy solution to address the problems associated with illegal tire stockpiling. Stockpiles of tires are highly combustible and represent a major risk and potential threat of uncontrollable fires. This is due to the large quantities of petroleum and other hazardous chemicals in tires.

Open fires of uncontrolled burning of scrap tires create thick black toxic smoke and generate large quantities of toxic solid and hazardous gaseous emissions. The thick black smoke and toxic residues emitted from burning tires may cause environmental harm, nuisance and pose direct threats to public health and safety (Hassanien, 2007; Nova Scotia Environment, 2008; Asthana and Patil, 2006; Reisman, 1997). Furthermore, run-off exposed to scrap tires fire can contaminate groundwater and surface water. Opened and stored-waste tires may collect rainwater, providing a suitable breeding ground for mosquitoes and other insects.

The 3 R's (Reduce, Reuse and Recycle) of solid waste management for scrap tires are the main and the best management strategies to deal with the global scrap tire challenge.

The major chemical composition of tires are: Natural and synthetic rubber polymers, oil fillers, sulfur and sulfur compounds, phenolic resin, clay, aromatic, naphthenic and paraffinic oil, fabric, petroleum waxes, pigments such as zinc oxide and titanium dioxide, carbon black, fatty acids, inert materials and fiber made from steel, nylon, polyester or rayon (Haines *et al.*, 2010; Hassanien, 2007; Asthana and Patil, 2006; Luch, 2005; Air Resources Board, 2005; Kirk, 2000).

Due to the lack of knowledge, facilities and resources, airborne emissions from the open burning of scrap tires are a common occurrence in third world countries. Many researchers indicated the hazardous impact of such activities on the environment and health (EPA, 2010; Anderson *et al.*, 2006; Chien *et al.*, 2003; Lemieux, 2002). The present study focuses on examining airborne emissions related to open fires of burning scrap tires and their potential impact on the environment and human health. Considerable quantity of liquids and solids containing hazardous chemicals can be generated by melting along with the release of toxic gasses to the surrounding environment (Haines *et al.*, 2010; Mattima *et al.*, 2007).

The byproducts of burning tires are smoke, pyrolytic oil, ash, black carbon and many other harmful chemicals. Under open burning conditions, such chemicals possess a serious threat to the surrounding environment. Due to the massive amount of heat generated by the burning of scrap tires, pyrolytic reactions take place producing pyrolytic oil and releasing various chemical compounds such as: Polycyclic aromatic hydrocarbon, benzenes, naphthalenes, toluene, ethyl benzene, anthracene, thiazoles, dioxins, furans, amines and other different forms of petroleum hydrocarbons (EPA, 2010; Karagiannidis and Kasampalis, 2010; Blumenthal, 2005). On the other hand, a group of major byproducts and heavy metals from burning tires are cadmium, chromium, nickel and zinc, Volatile Organic Compounds (VOCs), Semi-volatile Organic Compounds (SVOCs), Polynuclear Aromatic Hydrocarbons (PAHs), particulate matter, carbon monoxide, sulfur, nitrogen oxides, acid gasses, sulfates and many others.

The concentration of different pollutants in the atmosphere varies significantly depending on how the fires were suppressed. On the other hand, meteorological conditions such as thermal inversions speed and wind direction play a significant role in the concentration levels of pollutants in the surroundings.

As a result, the length and the degree of exposure to the open burning of scrap tires could have direct effects on human health such as: Asthma and respiratory complications, aggravation of existing cardiovascular illnesses, eyes irritation, cough and chest pain, nervous system depression, high blood pressure and subsequent heart disease, adverse effects on kidneys, liver, nervous system, cancer and inflammation of mucous membranes (Haines *et al.*, 2010; Nova Scotia Environment, 2008; Chien *et al.*, 2003). Blackman and Palma (2002) conducted a study to assess the risks from the burning of scrap tire piles on the U.S Mexico border. The results reported that air pollution from tire pile fires poses the greatest threat to the surrounding environment. Meanwhile, the effects of burning scrap tires at industrial facilities are minimal and might not have significant adverse or environmental impact if conducted properly (EPA, 2000).

Tire Derived Fuel (TDF) is the first market for scrap tires on the global scale and remains the most important end use in Europe and the United States. Many industrial and utility companies have started to combust scrap tires as a supplementary fuel due to the higher energy content and lower price of Tire Derived Fuel (TDF) relative to coal and other petroleum products. However, the co-combustion of tire with coal may significantly alter the emissions of the combustion facility (Karagiannidis and Kasampalis, 2010; Carrasco *et al.*, 2002). Tire-derived fuel is mostly used in cement kilns, electric utilities and paper mills as an energy source in the production lines. Based on 15 years of experience with more than 80 individual facilities in the United States, the Environmental Protection Agency (EPA) recognized that the use of tire-derived fuels is a viable alternative to conventional energy sources provided specific standards and regulations are implemented (Karagiannidis and Kasampalis, 2010; Anderson *et al.*, 2006; Blumenthal, 2005; Blackman and Palma, 2002).

MATERIALS AND METHODS

Dichotomous and partisol samplers were used in the field sampling as each of these samplers has the ability to collect particulate matter uniformly across the surface of the filters. They were used to determine average ambient particulate matter concentrations over the sampling period. High volume samplers for collecting Total Suspended Particulate (TSP) with aerodynamic diameters less than 100 μm (PM_{100}), 10 μm (PM_{10}) and 2.5 μm ($\text{PM}_{2.5}$) were used in the sampling collection from the ambient air in the study area before and after the open burning of scrap tires.

The mass concentrations of suspended particulates in the ambient air were computed by measuring the mass of collected particulates and the volume of air sampled. After the mass was measured, the filters were ready for extraction to determine the metal concentrations.

Adsorbed materials on particulate filters were used to collect volatile organic and semi-volatile organic samples. Organic components from collected air samples were analyzed using Gas Chromatography/Mass Spectroscopy (GC/MS) and gas chromatography/flame ionization detection units in addition to a High Pressure Chromatography (HPLC) device.

Suspended Particulate Matter (PM): Ambient air samples were collected from the burning scrap tire site during a 24 h period of continuous tire burning. Airborne (PM) samples were collected on a pre-weighted membrane filter 47 mm diameter in an open-faced holder. Twelve samples were collected as filters were replaced every 24 h for twelve consecutive days. Air samples were drawn from ambient air using a vacuum pump with a rate of 5 L min⁻¹ for a 24 h period. The full sampling details and procedure are provided elsewhere (Abdel-Latif *et al.*, 2006; Harrison and Perry, 1986).

Air sampling filters were placed on roofs of buildings 500 m away from the fire source and at 15 m above the ground level. Blank samples were obtained as reference measurements of the ambient air at the burning site 24 h prior the actual burning of scrap tires using separate sampling filters as shown in Table 1. Before use, the filters were pre-conditioned in vacuum desiccators with silica gel for at least 16 h to eliminate humidity. They were weighed before and after sampling with an analytical balance after stabilizing at constant temperature 20±5°C and humidity 40±2%. After exposure, the filters were brought to the laboratory and placed in a desiccator for 8 h to remove any moisture content.

Filters were weighed again to determine the net mass of the particles collected. The mass of PM was determined as the difference in mass before and after the exposure and expressed as µg m⁻³. The meteorological conditions of the burning site during the sampling period are presented in Table 2.

Smoke sampling and measurement: Smoke samples were collected using a low volume vacuum pump. A measured volume of air was drawn through a Whitman filter paper No. 1, at rate of 1.5 L min⁻¹. The darkness of stain was measured by the aid of a reflect meter. The particular instrument employed was the EEL smoke stain reflect meter, designed by Evans Electro Selenium Ltd, England. The air taken into the sampler was drawn first through a

Table 1: Blank samples concentration at the scrap tires burning site

Compound	Conc. (µg m ⁻³)
SO ₂	13.0
PM ₁₀	40.0
Pb	0.2
CO (ppm)	6.0

Table 2: Meteorological conditions of burning scrap tires site during the sampling period

Parameters	Temperature (°C)	Humidity (%)	Wind speed (km h ⁻¹)	Wind direction (Degree)
Mean	17.17	66.4	4.06	113
Highest	20.80	90.0	12.04	280
Lowest	13.00	38.0	0.00	0

white filter paper and samples of smoke stain were brought to the laboratory for analysis. The smoke was determined by measuring with instrument the loss of reflectance of the once-white filter papers with the reflectance values being converted into equivalent smoke concentrations in µg m⁻³.

Heavy metals: A low-volume sampler pump (5.0 L min⁻¹) with a cellulose membrane filter was used to obtain the heavy metal samples. The sampler was placed at a predetermined location in the plume.

Air samples were wet digested using a mixture of nitric acid, perchloric acid and sulphuric acid for 2 h and then filtered. After evaporation of a moist residue to 1.0 mL, the residue was dissolved in 100 mL of 0.1% HNO₃. Concentrations of metals were measured by Graphite-furnace Atomic Absorption Spectrometry (GAAS).

For the Flame Atomic Absorption (FAA) test, the samples were atomized and introduced into the optical beam using an oxide/acetylene flame. Meanwhile, for the Graphite Furnace Atomic Absorption (GFAA) test, a graphite furnace electro thermal atomizer was used as three replicate determinations were made for the elements in each sample. Quality control procedures were applied by using Standard Reference Materials (SRM) from the National Institute of Standards and Technology (Harrison and Perry, 1986; WHO, 2004).

Sulfur dioxide (SO₂): Concentration of sulfur dioxide was estimated at the burning scrap tires site during the fire. West and Geake's method was used to determine SO₂ in ambient air with the concentration ranging from 0.005-5.0 ppm. Air was collected at 1.0 L min⁻¹ for 24 h through a glass bubbler sampler containing 50 mL of absorbing solution (0.1 M Sodium Tetra-chloromercurate) as non-volatile dichlorosulfomercurate ion was formed. Acid bleaching pararosaniline hydrochloride solution was added to dilute aqueous formaldehyde solution to the complex ion. This produced a red purple color of

pararosaniline methyl sulfuric acid which is determined spectro-photometrically at a wave length of 560 μm .

Ammonia (NH_3): Ammonia concentrations were measured using the chlorimetric method. Nessler's reagent was applied and 4.0 mL of the reagent was added to each sample. The adsorption level and color changing after 20 min was evident using a Novaspec II Spectrometer at 460 nm with blank reagent as a reference. Applying the ammonia chloride standard curve and the volume of air sample, the ammonia concentrations in $\mu\text{g m}^{-3}$ was determined (Shakour *et al.*, 2006).

Hydrogen sulfide (H_2S): The Methylene Blue method was used to determine the H_2S concentrations. Collection of air in cadmium sulfate (CdSO_4) solution is in fact a highly sensitive method for measuring H_2S in the atmosphere. The Methylene Blue Colorimetric method has acceptable specificity, accuracy and sensitivity for hydrogen sulfide determination. This method is generally recognized as a standard analytical procedure (Shakour *et al.*, 2006). The H_2S was absorbed in alkaline suspension of $2\text{Cd SO}_4 \cdot 8\text{H}_2\text{O}$ and sodium hydroxide. The intensity of developed methylene blue color was measured using a Novaspec II Spectrometer at 670 nm. The standard curve of hydrogen sulfide and the volume of air sample were then used in the calculation of the concentration of H_2S (WHO, 2004).

Polycyclic Aromatic Hydrocarbons (PAH's): Airborne PM was collected from the open burning scrap tires site. Air samples were collected on pre-weighted glass-fiber filters (Whitman GF/A) 47 mm diameter in an open-faced holder. Samples were drawn using a vacuum pump with a rate of 10 L min^{-1} for 24 h period intervals. Before use, the filters were pre-conditioned in a vacuum desiccator with silica gel for at least 16 h to eliminate humidity and they were weighed before and after sampling with an analytical balance after stabilizing at constant temperature $20 \pm 5^\circ\text{C}$ and humidity $40 \pm 2\%$. The filters were placed in Petri dishes, wrapped in aluminum foil to avoid sample degradation by UV light and stored at -17°C until the extraction time.

Samples preparation: Twelve samples of the filters were cut into small pieces and extracted in a closed glass vessel with 30 mL dichloromethane and 50 μL deuterised standards in ultrasonic equipment for 15 min. The concentration of the standard was measured as $20 \mu\text{g mL}^{-1}$. Filters were once again extracted ultrasonically with 20 mL dichloromethane for 15 min. The two extracts were added together in 50 mL volume. After filtering, the volume was reduced by Rotadest equipment

to 5.0 mL and washed into a conical test tube. The volume of the solution was decreased to 1.0 mL in ultra-pure nitrogen stream.

Chromatographic analysis: The measurements were performed using a gas chromatograph/mass spectrometer. A (GC-MS) Varian 3400 GC unit coupled to a Finnigan Mat SSQ 700 was employed. Quantification was carried out using a HP6890 plus GC unit equipped with FID detector, SE54 capillary column and split less injector mode.

The system was calibrated with a diluted standard solution (EPA 610 Mix.), which contained 16 PAHs in methanol/methylene chloride (1:1 v/v). Concentrations of different PAH's compounds such as: Benzo(ghi) perylene, naphthalene, chrysene, benzo (b) fluoranthene, acenaphthylene, fluorene, indeno (1, 2, 3-cd) pyrene, acenaphthene, methyl-naphthalene and dibenzo (a, h) anthracene were determined.

A quality assurance program was carried out. This program included the following procedures:

- Blank samples were run parallel with each set of sampling analysis
- The calibration program for the equipment was used to verified on each working day by measuring one or more standard
- A random sample was run in triplicate. The efficiency of the extraction was determined by the addition of a known concentration of the internal deuterised standard containing: Acenaphthene-d10, chrysene-d12, naphthalene-d8, perylene-d12 and phenanthrene-d10 solved in methylenechloride

Volatile organic compounds: Sampling tubes in the vertical positions were used to obtain volatile organic compounds from the site as the flow rate gradually reached 4.0 L min^{-1} . Ten to twenty liters of air sample were obtained. The tubes were completely sealed, identified with labels and wrapped in aluminum foil for laboratory analysis.

RESULTS AND DISCUSSION

Particulate matter (PM_{10}): The mean concentration of PM_{10} was calculated as $280 \mu\text{g m}^{-3}$ in the ambient atmosphere at a location 500 m away from the open burning of the scrap tire site and at a height of 15 m above the ground level. This is in comparison to the obtained blank samples of $40 \mu\text{g m}^{-3}$ prior the fire burning of the scrap tires in the same location. Table 3 summarizes the statistical field concentrations of PM_{10} recorded during a

24 h (day and night) period for twelve consecutive days. The maximum measured PM₁₀ concentration reached 370 µg m⁻³, with a minimum concentration of 160 µg m⁻³. These results greatly exceeded the EPA maximum allowable limits standards for PM₁₀ concentration of 120 µg m⁻³. It is worth mentioning that PM₁₀ concentrations varied significantly over the course of the day depending mainly on the meteorological conditions in the study area. It is evident that the outdoor particulate matter in the surrounding environment was attributed to the scrap tire burning emissions.

Comparison of the EPA particulate matter Air Quality Index (AQI) shown in Table 4 with the values obtained for the field measurements in the study area shown in

Table 3: The PM₁₀ and smoke concentrations near the scrap tires burning site during 24 h period for twelve consecutive days in (µg m⁻³)

Parameters	PM ₁₀ conc. (µg m ⁻³)			Smoke conc. (µg m ⁻³)		
	Full day	Day	Night	Full day	Day	Night
Mean	280.0	158.0	95.0	138.2	233.2	183.0
±SD	84.1	14.5	24.4	60.1	35.6	29.0
Minimum	160.0	135.0	50.0	47.0	201.9	158.5
Maximum	370.0	179.0	124.0	220.0	279.0	214.0

Table 4: Particulate matter Air Quality Index (AQI) and health concerns (EPA, 2000)

AQI values (µg m ⁻³)	Air quality descriptor	Frequency occurrence (%)
0-50	Good	0.0
51-100	Moderate	0.0
101-150	Unhealthy (sensitive groups)	14.3
150-200	Unhealthy	28.5
201-300	Very unhealthy	14.3
301-500	Hazardous	42.9

Table 3 which indicate that the ambient air can be identified as hazardous for 42.9% of the study period and characterized as very unhealthy air quality. Particulate Matters (PM's) are carcinogen factors, harmful to lung tissues and worsen respiratory and cardiovascular problems.

Recent researchers have also linked exposure to relatively high concentrations of particulate matter with premature death. The elderly and people with pre-existing respiratory or heart disease could be at greatest risk (Carleton *et al.*, 2003; EPA, 2000).

Heavy metals: Analyses of ash produced as a by-product of burning tires typically shows the presence of heavy metals. High levels of heavy metal concentrations in the atmosphere would cause adverse effects on human health and the surrounding environment (Carrasco *et al.*, 2002). The analysis of the results of this study indicated high concentrations of heavy metals such as zinc, lead, copper and iron in comparison to other heavy metals found and exceeded the maximum allowable standards. The maximum, minimum and mean concentrations of heavy metals in air samples collected from the plume of the burning scrap tires site are presented in Fig. 1.

The mean concentrations of heavy metals including Pb, Cd, Zn, Ni, Cu, Mn, Cr, Fe, As, Co were 2.06, 0.06, 3.0, 0.29, 2.0, 0.44, 0.3, 1.5, 0.3 and 0.2 µg m⁻³, respectively. Zinc reached the highest mean concentration of 3.00 µg m⁻³. This could be attributed to the fact that zinc is the common curing element which is usually used in the tire manufacturing process. Copper reached more

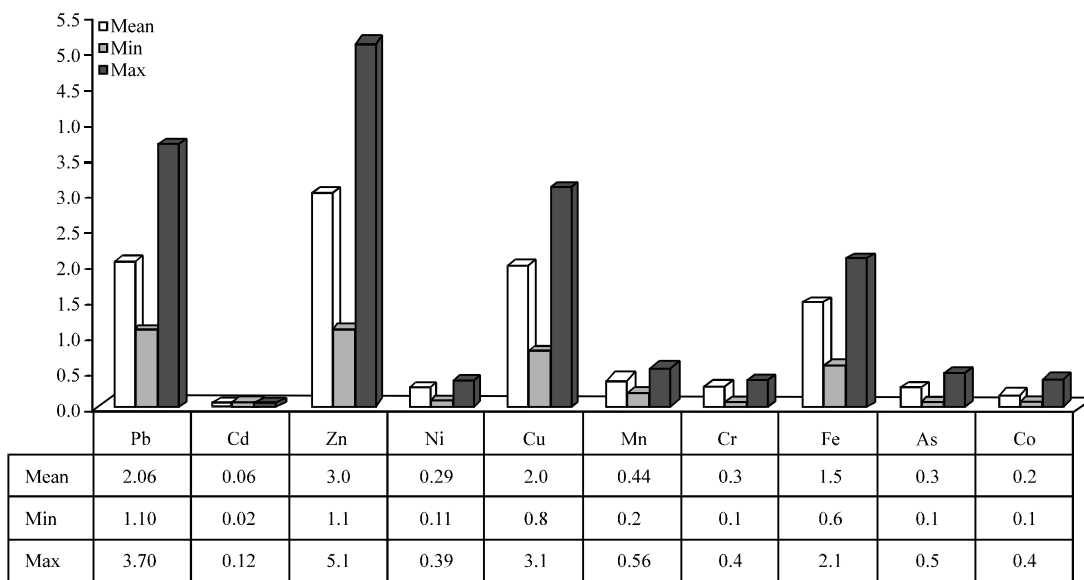


Fig. 1: Concentration of heavy metals measured at the scrap tires burning site

than $2.0 \mu\text{g m}^{-3}$ which poses a major threat to human health and the environment. All other metals were present at less than $2.0 \mu\text{g m}^{-3}$ except copper, lead and zinc.

Smoke concentration: Smoke usually disperses into ambient air as a result of incomplete combustion processes. It consists of a suspension of fine solid particles in air and it arises principally from the incomplete combustion of domestic, industrial or motor vehicle fuels. The maximum smoke concentration reached an average of $220 \mu\text{g m}^{-3}$ for full day measurements, recording a $279.0 \mu\text{g m}^{-3}$ during the day and $214.0 \mu\text{g m}^{-3}$ at night as shown in Table 3. The variation in the smoke concentrations between day and night measurements can be attributed to the metrological conditions in the study area.

Gases: Ammonia (NH_3), hydrogen sulfide (H_2S) and sulfur dioxide (SO_2) were the three major gases measured at the study area during the scrap tire burning. Over a twelve day period, twelve measurements were recorded and the minimum, mean and maximum concentrations were calculated. The concentration of NH_3 was in the range of $57\text{-}210 \mu\text{g m}^{-3}$ with a mean concentration of $116 \mu\text{g m}^{-3}$.

Figure 2 shows a comparison of the mean concentrations among measured gasses at the site. The concentrations of hydrogen sulfide (H_2S) in the study area were in the range of $34.0\text{-}250 \mu\text{g m}^{-3}$ with a mean concentration of $149 \mu\text{g m}^{-3}$. The World Health Organization (WHO) reported that hydrogen sulfide (H_2S) concentrations in unpolluted areas should not exceed $0.1 \mu\text{g m}^{-3}$ as it is a hazardous and lethal gas (WHO, 2003; EPA, 2010; Carrasco *et al.*, 2002).

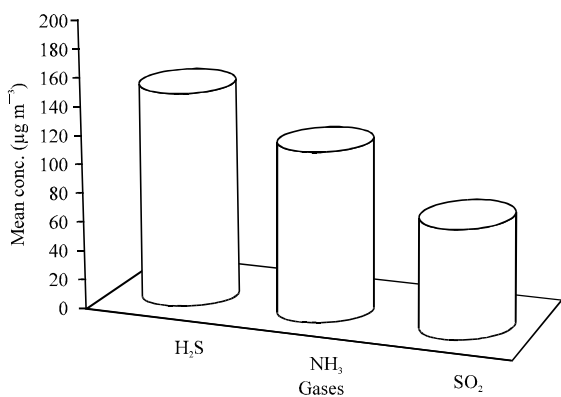


Fig. 2: Comparison between the mean concentrations of gases emitted from scrap tires burning at the study area

As a result and according to the WHO guidelines, the investigated area can be considered as contaminated with toxic air pollution. The concentrations of sulfur dioxide (SO_2) were in the range of $2.3\text{-}188.7 \mu\text{g m}^{-3}$ with a mean concentration of $72.71 \mu\text{g m}^{-3}$. It should be noted that the obtained blank sample prior the scrap tires burning did not exceed $13.0 \mu\text{g m}^{-3}$.

According to the USA Environmental Protection Agency (EPA, 2010), the concentration of sulfur dioxide (SO_2) in the ambient air of an unpolluted area should not exceed $60.0 \mu\text{g m}^{-3}$. In comparison, it can be concluded that the sulfur dioxide emission from the open burning of scrap tires exceeded the EPA standards by three fold leading to be a major concern for human health and air pollution in the study area.

Carbon monoxide (CO) concentrations were measured using a Flue Gas Analyzer Testo 300XL. The concentrations of CO were in the range of $7.3\text{-}10.3$ ppm in a comparison with the obtained blank sample prior the scrap tire burning of 6.0 ppm. Such values exceeded the EPA allowable standards of 9.0 ppm in an 8 h period.

Polycyclic Aromatic Hydrocarbons (PAHs): Figure 3 shows the mean concentrations of atmospheric PAH's in $\mu\text{g m}^{-3}$ over four different measurements in the investigated area. The relative distribution of individual PAH compounds during the measurement were within similar range. Additionally, higher the molecular weight of PAH's compounds, the higher the level of contribution. This is in a full agreement with the results of (Hassanien, 2007; Chien *et al.*, 2003). The lighter compounds with two to four rings were less abundant in the surroundings. The summation of the total means of all PAH's compounds concentration reached $2918 \mu\text{g m}^{-3}$, indicating a high level of PAH's concentrations.

Volatile Organic Compounds (VOCs): Toluene, benzene, ethyl benzene and m, p, o-Xylene are the four major compounds of VOC's that were measured in the study area. Four measurements were obtained during the study period. The mean concentration of toluene, benzene, ethyl benzene and xylene were 175.5 , 94.3 , 63.1 and $28.5 \mu\text{g m}^{-3}$, respectively as shown in Fig. 4. Such compounds are mainly released from traffic vehicles and open burning fires and are widely recognized as a human carcinogen (Haines *et al.*, 2010). The results of VOC's obtained are similar to other researchers (Hassanien, 2007; Baldasana *et al.*, 2003), indicating alarming pollution levels and the necessity for mitigation measures.

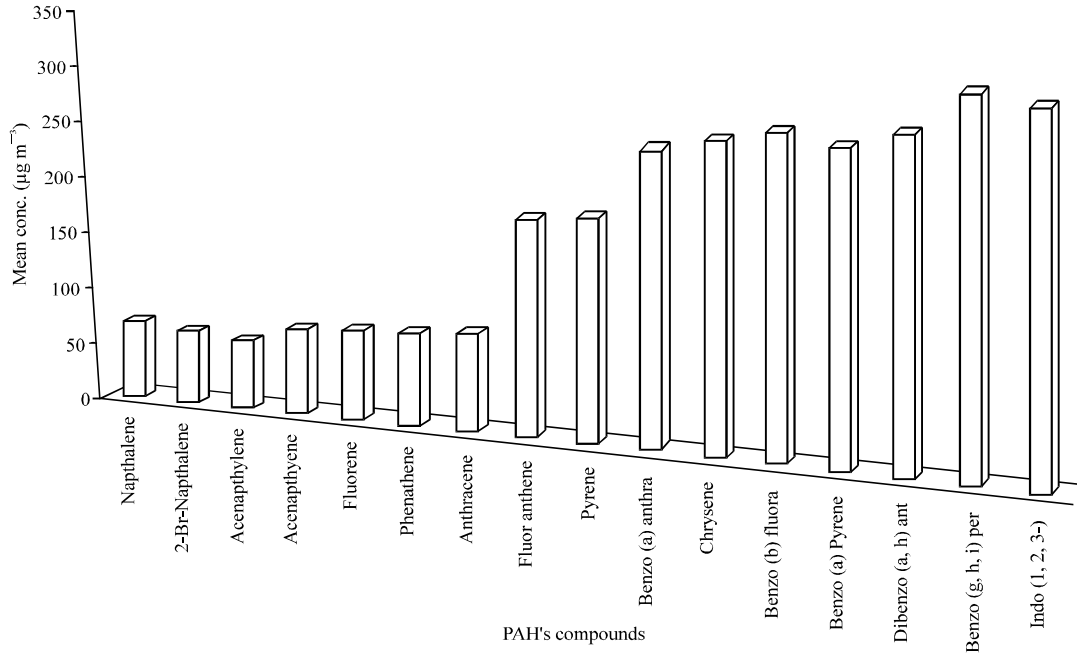


Fig. 3: Mean concentrations of atmospheric PAHs emitted from scrap tires burning at the study area

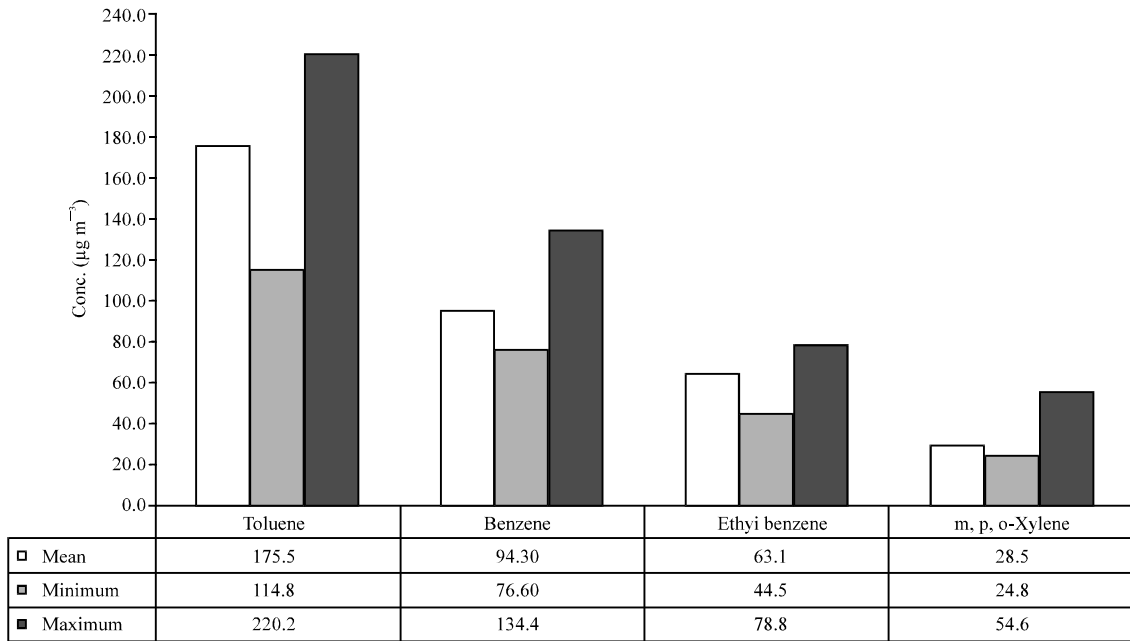


Fig. 4: Concentrations of volatile organic compounds at the scrap tires burning site

CONCLUSION

Qualitative and quantitative results of this study are a model representation of pollution from the open burning of scrap tires. Pollutants such as, Volatile Organic Compound (VOC), heavy metals, smoke, gases and

Polycyclic Aromatic Hydrocarbon (PAH) were measured in the ambient air and evaluated in comparison with international standards.

The results of this study provided strong evidence of the significant amount of air pollution that could be added to the atmosphere from the open burning

of scrap tires including hazardous compounds that directly impact human health and the surrounding environment.

As a result integrated scrap tire management involving reduction, reuse, recycling, energy recovery and disposal should be adopted along with compliance with international regulations.

RECOMMENDATIONS

Recommendations for scrap tire management are listed below:

- Develop regulations and standards enforced by laws regarding the disposal and reuse of scrap tires
- Develop public awareness of the health and safety hazards and the environmental risk of the open burning of scrap tires
- Minimize the number of scrap tires by extending the life of tires. Follow tire manufacturers' instructions to achieve the longest life out of tires. Also encourage the usage of public transportation
- Establish a specific agency within the ministry of concern in order to regulate and monitor the disposal of scrap tires
- Encourage research on air pollution by establishing a sufficient up to date data base and provide useful information from different authorities
- Apply the Best Management Practice (BMP) to eliminate future contamination and air pollution

ACKNOWLEDGMENTS

The authors would like to thank the Tafila Technical University for all the technical support with the laboratory equipment used in this research. Additionally, we would like to thank Dr. Karl Murray from Abu Dhabi Men's College for his editing and support with final drafting of the publication.

REFERENCES

Abdel-Latif, N.M., M.A. Hassanien, A.A. Shakour and Y.H. Ibrahim, 2006. Fuels combustion influence on outdoor and indoor air pollution in an urban area, Cairo, Egypt. *J. Applied Sci.*, 21: 439-453.

Air Resources Board, 2005. Report on air emissions from waste tire burning in California. California Environmental Protection Agency, July 1, 2005. http://www.arb.ca.gov/ei/tire/2005_tire_burning_report.pdf

Anderson, M.E., K.H. Kirkland, T.L. Guidotti and C. Rose, 2006. A case study of tire crumb use on playgrounds: Risk analysis and communication when major clinical knowledge gaps exist. *Environ. Health Perspect.*, 114: 1-3.

Asthana, S.R. and R.K. Patil, 2006. Use of alternative fuels in Indian cement industry. *Adv Energy Res.*, 1: 347-350.

Baldasana, J.M. and E. Valera and P. Jimenez, 2003. Air quality data from large cities. *Sci. Total Environ.*, 307: 141-165.

Blackman, A. and A. Palma, 2002. Scrap tires in Ciudad Juarez and El Paso: Ranking the risks. Discussion Paper 02-46, Washington, DC. <http://ageconsearch.umn.edu/bitstream/10583/1/dp020046.pdf>

Blumenthal, M., 2005. The use of scrap tires in rotary cement kilns. Scrap Tire Management Council, Washington, DC. http://www.rma.org/download/scrap-tires/tire_derived_fuel/TDF-052%20-%20The%20Use%20of%20Scrap%20Tires%20in%20Rotary%20Cement%20Kilns.pdf

Carleton, L.E., R. Giere, S.T. Lafree and J.K. Tishmack, 2003. Investigation of atmospheric emissions from co-combustion of tire and coal. Proceedings of the Geological Society of America Seattle Annual Meeting, November 2-5, 2003, Seattle, Washington.

Carrasco, F., N. Bredin and M. Heitz, 2002. Gaseous contaminant emissions as affected by burning scrap tires in cement manufacturing. *J. Environ. Q.*, 31: 1484-1490.

Chien, Y.C., S. Ton, M.H. Lee, T. Chia, H.Y. Shu and Y.S. Wu, 2003. Assessment of occupational health hazards in scrap-tire shredding facilities. *Sci. Total Environ.*, 309: 35-46.

EPA, 2000. Air quality index: A guide to air quality and your health. Environmental Protection Agency (EPA). http://www.njaqinow.net/App_AQI/AQI.en-US.pdf

EPA, 2010. Science and technology, scrap tires. Innovative Uses for Scrap Tires. <http://www.epa.gov/epawaste/conservation/materials/tires/science.htm>

Haines, G., M. McCulloch and R. Wong, 2010. End-of-life tire management LCA: A comparative analysis for Alberta recycling management authority. The Pembina Institute. <http://www.albertarecycling.ca/docs/about-us/lifecycle-assessment-final-report---tires.pdf?Status=Temp&sfvrsn=2>

Harrison, R.M. and R. Perry, 1986. Handbook of Air Pollution Analysis. 2nd Edn., Chapman and Hall, London, New York, ISBN: 9780412244100, pp: 149-546.

- Hassanien, M.A., 2007. Risk assessment of atmospheric toxic pollutants over Cairo, Egypt. *Cairo Univ. J. Environ. Sci.*, 5: 37-57.
- Karagiannidis, A. and T. Kasampalis, 2010. Resource recovery from end-of-life tyres in Greece: A field survey, state-of-art and trends. *Waste Manage. Res.*, 28: 520-532.
- Kirk, B.L., 2000. Potential dioxin release associated with tire derived fuel use in a cement Kiln Gallatin county, Montana. University of Idaho, Principles of Environmental Toxicology. http://www.webpages.uidaho.edu/etox/resources/case_studies/dioxtir3.pdf
- Lemieux, M.P., 2002. Research and development emissions of organic air toxics from open burning. EPA-600/R-02-076, U.S. Environmental Protection Agency, USA.
- Luch, A., 2005. The Carcinogenic Effects of Polycyclic Aromatic Hydrocarbons. Imperial College Press, London, ISBN: 9781860944178, Pages: 489.
- Mattima, M.J., M. Isleyen, W. Berger and S. Ozdemir, 2007. Examination of crumb rubber produced from recycled tires. AC005 (8/07) Department of Analytical Chemistry, The Connecticut Agricultural Experiment Station.
- Nova Scotia Environment, 2008. Interdepartmental committee on used-tire management in Nova Scotia. Report to the Minister of Environment, September 26, 2008. <http://www.novascotia.ca/nse/waste/docs/TireStrategy.pdf>
- Pehlken, A. and E. Essadiqi, 2005. Canmet materials technology laboratory: Scrap tire recycling in Canada. MTL2005-08 (CF). August 2005. <https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/mineralsmetals/pdf/mms-smm/busi-indu/rad-rad/pdf/scr-tir-rec-peh-eng.pdf>
- Reisman, J.I., 1997. Air emissions from scrap tire combustion. EPA/600/SR-97/115, National Risk Management Environmental Protection Research Laboratory.
- Shakour, A., Y.H. Ibrahim, M.A. Hassanien and N.M. Abdel-Latif, 2006. H₂S-and NH₃-induced hazard in the surrounding of a dump site. *Cent. Eur. Occu. J. Environ. Med.*, 12: 269-277.
- WHO, 2003. Concise international chemical assessment document 53. Human Health Aspects, Hydrogen Sulfide.
- WHO, 2004. Outdoor air pollution: Assessing the environmental burden of diseases at national and local levels. Environmental Burdens of Disease Series No. 5, World Health organization (WHO).