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Assessment of Carbon Monoxide Emissions from Vehicles in Rajshahi City: Effects on Health and Environment

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Abstract

Transport plays a crucial role in modern life, but vehicle emissions pose significant environmental and health risks. This study was conducted in Rajshahi, one of Bangladesh's six metropolitan cities, to assess carbon monoxide (CO) emissions from the transport sector and determine human exposure levels within the city. The research involved instrumental testing of vehicle emissions using a portable Carbon Monoxide Meter (Model: AS8700A). Field observations targeted 3 cars, 3 motorcycles, 3 buses (petrol engines), and 6 trucks (both petrol and diesel engines) to measure CO levels in the surrounding environment. Results showed that CO emissions from diesel engine trucks ranged from 257 ppm to 680 ppm, while petrol engine trucks emitted 159 ppm to 570 ppm, with diesel engines producing significantly higher emissions due to their high carbon content. Petrol-powered cars emitted between 100 ppm and 310 ppm CO. Motorcycles and petrol-engine buses had CO emissions ranging from 80 ppm to 265 ppm and 175 ppm to 410 ppm, respectively. The highest CO emissions were recorded from diesel engine trucks, while motorcycles had the lowest. The recorded emission levels were notably high, likely due to the carbon content in fuels, the presence of heavy vehicles, and surrounding environmental factors. These excessive emissions contribute to environmental degradation and pose serious health risks to city residents. To mitigate these impacts, regular monitoring, stricter emission standards, and sustainable transportation policies are essential to ensure air quality and a healthier urban environment.

Keywords: Air pollution, Carbon monoxide, Vehicle emission

Introduction

Pollution is being witnessed as one of the major problems created due to rapid urbanization and industrialization (Bolan *et al.*, 2014) and road traffic emissions are a major source of air pollution in urban areas with subsequent adverse human health effects (Colvile *et al.,* 2001). Ambient carbon monoxide (CO) is primarily a result of incomplete combustion and has a considerable influence on the climate (Seinfeld and Pandis, 2016). Though carbon monoxide does not cause climate change directly, its presence affects the abundance of greenhouse gases such as methane and carbon dioxide (Kweku *et al.,* 2018). The transportation sector is the largest producer of GHGs emissions in the United States (EPA, 2019), generating 29% of the total. CO is a ubiquitous atmospheric trace gas produced by natural and anthropogenic sources and human activities being responsible for ~60% of its emissions (Cordero *et al.,* 2019).

CO sometimes termed a "silent killer" (Byard, 2019) as well as the unnoticed poison of 21st century. Carbon monoxide poisoning is the most common type of fatal air poisoning in many countries (Tikuisis *et. al.*, 1992) with most common symptoms like headache, nausea, and dizziness. Other common presenting symptoms include vomiting, malaise, ataxia, seizures, loss of consciousness, and/or shortness of breath. Early clinical findings may include increased blood pressure, heart rate, and respiratory rate (Lakhani *et al*., 2010; Bledsoe *et al.,* 2009; Ide *et al.,* 2009). The effect of inhaling CO can cause hypoxic injury, neurological break, and even death (Dey and Dhal, 2019), cases of homicide by CO poisoning have also been reported (Yoshioka *et al.,* 2014). Each year, more than 20,000 people visit emergency rooms and over 400 die from accidental COP (Dupras, 2020). The annual number of COP deaths in Japan is about 2000–5000 and it is a major cause of poisoning deaths (Can *et al*., 2019; Ito and Nakamura, 2010) while in the case of the USA, it is approximately 2700 deaths, according to the Centers for Disease Control and Prevention (Ruth-Sahd *et al.,* 2011).

Many of our ecosystems are also under stress from climate change and air pollution due to the higher rate of carbon monoxide presence. Research is needed to understand the ecological impacts of CO to support the secondary National Ambient Air Quality Standards (NAAQS), which provide public welfare protection and should also be directed toward prevention of air pollution problems by investing more in green technology. The outdoor air pollution is a global public health problem and therefore research networking between developed and developing countries should be prioritized. The present study was therefore undertaken to explore new data of the emissions rate of CO from transport systems and to focus on the impacts of carbon monoxides on the environment and human health.

Materials and Methods

Study area

Rajshahi city was selected for the study which is the divisional headquarters of Rajshahi division as well as the administrative district that bears its name and is one of the six metropolitan cities of Bangladesh. Often referred to as Silk City and Education City, Rajshahi is located at 24.40°N 88.50°E and is situated on the northern banks of the river Padma. It consists of nine upazilas, 14 pourasavas and 71 unions (Rajshahi Local Government Engineering Department). The city has a population of over 2,595,197.

Experimental period

The experiment was carried out during the period from 1st December 2020 to 28th March 2021.

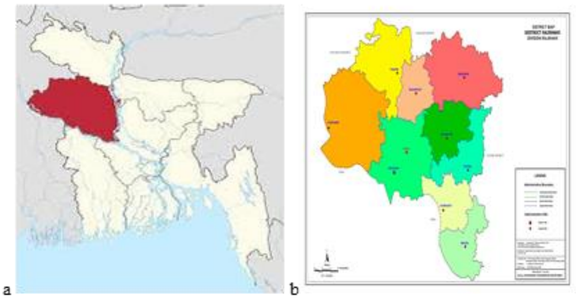

Fig. 1. (a) A map showing the experimental site of Rajshahi in Bangladesh's map. (b) A map showing the experimental site of Rajshahi (Local Government Engineering Department).

Description of the instrument

A carbon monoxide meter (Model no.: AS8700A) was used in the study which is a highly accurate, easy-to-operate, portable, compact sized, and lightweight instrument for measuring carbon monoxide concentration in the air. It can continuously monitor the CO gas concentration in the surrounding environment with a 1000 measuring range and has a large LCD display and °C/°F switch. Once the gas concentration reaches the level of the alarm, the alarm will sound. Auto power off in 10 minutes without any operation is also available (Smart sensor store). It is widely used in petroleum, chemical, coal, metallurgy, paper, fire, municipal, telecommunications, food, textile, and other industries.

Sampling

This research targeted a sample size of 3 cars, 3 motorcycles, 3 buses of petrol engine, and 6 trucks (both diesel and petrol engine).

Field observation

Field observation was carried out to evaluate the condition of the existing situation in selected sites. The instrument was taken from place to place and the exposure time duration was selected to be 2 hours at a time per a place. The average values for each type of source from different locations were computed. During winter high-pressure situations, cold air, low wind speed, and the radiative cooling of the surface resulted in stable atmospheric stratification persisting for several days is called a cold-air pool episode. During such an episode, pollutants are emitted from the surface and accumulate in the atmosphere due to the limited atmospheric mixing.

Data Collection

The amount of carbon monoxide in the atmosphere was measured by the instrument on the ground using the detector tube method. In which, air sample was continuously drawn from different sources e.g. motorcycles, cars, buses and trucks. The data collection involved actual visitation of Shantir more, Gondagari, Kasiadanga, Bahorompur, Vodra, Binodpur within Rajshahi city. The instrument was held for 10 seconds beside vehicles gas emitter every time. Data were recorded the 7th time within 2 hrs with 20 minutes interval.

Statistical analysis

Descriptive analysis was done accordingly after data collection and tabulation. Other necessary statistical analyses and relationships among the carbon monoxide concentrations and other related parameters were analyzed by Microsoft Office Excel 2016. Different tables, graphs, and charts were used for the presentation of the findings.

Results and Discussion

CO Emissions from Different Sources

CO Emissions from Trucks (Diesel Engine): In this study, the reading of carbon monoxide emissions recorded for 2 hours at a time from three trucks operating with diesel engines in Rajshahi city is presented in **Fig. 2**. The range of carbon monoxide emissions from trucks 1, 2, and 3 was 257 ppm to 680 ppm. At the starting point (0 min.), the CO emissions rate was 360, 315, and 355 ppm for trucks 1, 2and 3, respectively. The emission rate was maximum after 40 minutes for trucks 1 and 3 then the rate started to decrease having the lowest emission after 120 minutes excluding truck 2. In the case of truck 2, emission continued increasing even after 40 minutes reaching its peak of 680 ppm after 60 minutes. The average carbon monoxide emission from diesel engine trucks was 383.9 ppm in 2 hours with the highest average of 412 ppm from truck 2. In an analogous study by Mckee *et al.* (2012), the hydrocarbon determinations were made with a mass spectrometer and showed average concentrations from 90 to 390 ppm for diesel-powered vehicles, depending on engine operating conditions. The maximum single value for diesel was 610 ppm, obtained with one of the vehicles during deceleration. In a case study on Dhaka city, it was found that only 24.6% of the trucks satisfied the existing limit value of 65 HSU, and about 65% of trucks emitted smoke with opacity greater than 85 HSU. Heavy-duty trucks and buses which are allowed to enter Dhaka City after 10.00 pm mainly the reason for this situation. On the other hand, a large number of vehicles waiting outskirts of the city in the evening rush into the city at 10:00 pm, stimulating ambient air pollution in the city (Rana *et al.,* 2020). Diesel-powered engines have been the dominant choice for heavy-duty trucks for decades (Torrey and Murray, 2015) and one commercial truck uses up to 20,000 gallons of fuel in one year (estimated with a driving distance of 230,000 km) (Barradas, 2013) justifying the huge emissions of CO from diesel trucks.

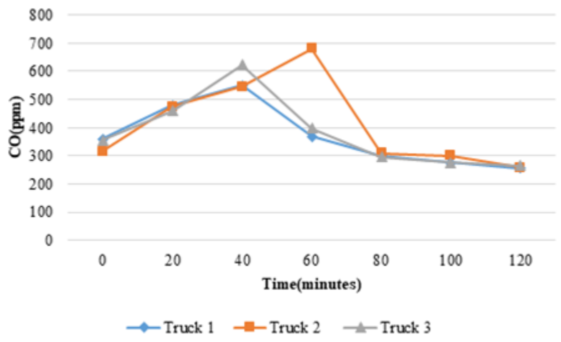

Fig. 2. CO emission from diesel trucks

CO Emissions from Trucks (Petrol Engine)

The rate of emissions of CO from trucks operating with petrol engines ranged from 159 ppm to 570 ppm. The highest average emission was found from truck 4 which was 327.14 ppm. But considering individual emissions both the highest and lowest were obtained from truck 6. Truck 5 showed less emission compared to truck 4 and 6 (**Fig. 3**). From the starting point to 40 minutes, emission revealed increasing to peak then steady declination to the lowest emission after 120 minutes except for the fact that the increasing emission continued after 60 minutes for truck 6 which was also highest with value of 570 ppm among all three trucks. Tabassum *et al.* (2023) in their study, saw that truck was the main contributor to CO emissions. The emission was about 1321.97 kg/day comprising 43% of the total CO emissions from different vehicles. However, Hossain *et al.* (2012) found non-diesel vehicles to be reportedly the major sources of CO in the air (about 82%), and compared with diesel vehicles, petrol vehicle emissions are higher in carbon monoxide which is quite the opposite of the present study.

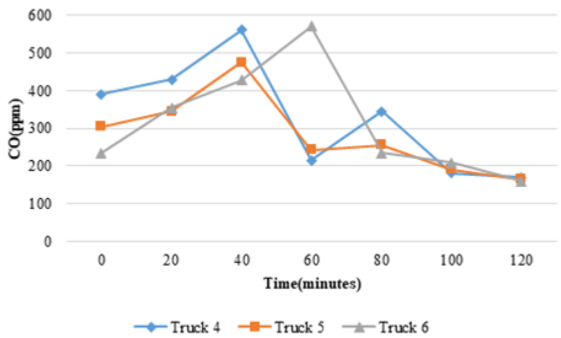

Fig. 3. CO emission from trucks operating with petrol engine

CO Emissions from Cars (Petrol Engine)

The readings of CO emissions were recorded from Cars 1, 2, and 3 for 2 hours at a time per place. From **Fig. 4**, it can be seen that the range of CO emissions from cars in the atmosphere was between 100 ppm to 310 ppm which was coincidently also the range of car 1. Average CO emissions from cars 1, 2, and 3 were 217.14 ppm, 229.57 ppm, and 218.14 ppm, respectively in 2 hours. The graph shows an upward and downward trend resulting from fluctuation and a decreased emission rate could be seen after 100 mins activity of car engine. According to Żaba *et al.* (2019), readouts showed high concentrations of CO, from 167 to 790 ppm (203–974 mg/m^3), while the constant level of results was maintained at 45–200 ppm (55.5–247 mg/m^3) and 0–250 ppm (0–308 mg/m^3). About 70% of the cars emitted CO concentrations less than 0.3 % (v); 77% of them passed the existing limit value of 1 % (v) ranking 2nd among the non-diesel vehicles in Dhaka (Rana *et al.*, 2020). One of the oldest passenger car fleets in Europe, with an average age of more than 12 years in Turkey (TurkStat, 2018) tends to have higher emissions and higher fuel consumption than modern vehicles (Yang, 2014). In China, with the sustained and rapid development of the national economy, the number of motor vehicles owned by families in cities is rapidly growing so are the problems of traffic congestion and air pollution (Wang *et al.*, 2021).

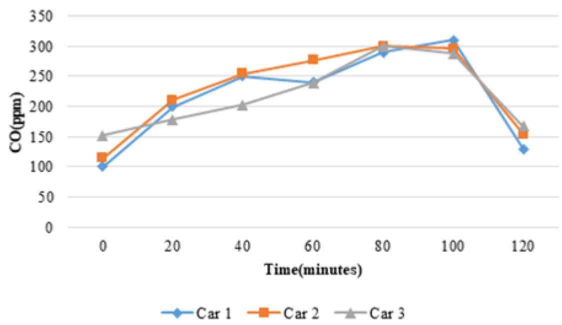

Fig. 4. CO emission from cars

CO Emissions from Motorcycles (Petrol Engine): From the findings, the range of CO emissions from motorcycles in the atmosphere was 80 ppm to 268 ppm. The average CO emission from petrol engines was 172.71 ppm in 2 hours. From the starting point (0 min.), motorcycles 2 and 3 showed an increasing rate of CO emission for up to 80 minutes, after that the emission decreased. But in the case of motorcycle 1, the graph presented an upward and downward trend resulting from fluctuation. From **Fig. 5**, it was found that CO emission decreases after 40 minutes of activity of the engine and again increases after that. Motorcycles were found as the worst polluters and the results showed that only 40% of the motorcycles exited emissions with CO concentrations ≤ 4.5% (v), the existing limit value for motorcycle emission while 60% of the being unsuccessful in satisfying the corresponding limit value. About 36.5% of these vehicles emitted CO greater than 7.0% (v), which may be considered very high emission and highly polluting (Rana *et al.*, 2020). A higher range of CO emissions from motorcycles was recorded from a minimum value of about 300 ppm to a maximum value of about 435 ppm in the study of John and Feyisayo

(2013). About 321,000 tons of CO are emitted each year in Rio de Janeiro Metropolitan Area from motorcycles. Among approximately 500,000 motorcycles in Egypt, of which more than 95% have two-stroke engines, Greater Cairo has about 170,000 emitting around 15,000 tons of CO annually (USAID, 2000).

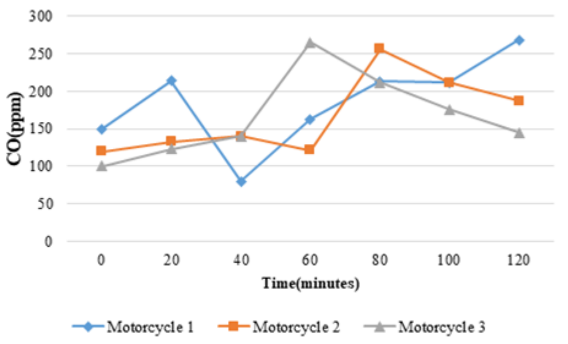

Fig. 5. CO emission from motorcycles operating with petrol engine

CO Emissions from Buses (Petrol Engine)

From the 2 hours recording of CO emission from buses the range was 175 ppm to 410 ppm with an average of 261.9 ppm. The average emissions from individual buses (buses 1, 2, and 3) were 220.29 ppm, 260 ppm, and 305.4 ppm, respectively. All three buses showed a similar pattern of emissions (**Fig. 6**), it can be seen that CO emission rate was highest at the starting point then the emission steadily decreased till 60 minutes. Again, the rate started increasing after 60 minutes which continued after 120 minutes from starting. Bus 3 showed the highest CO emission among the three buses. In the study of Tabassum *et al.* (2023), the bus has the third highest CO emission occupying almost 13% of the total emission. District bound heavy duty buses as well as minibuses plying within Dhaka City were found highly polluter. As most of the minibusses converted to CNG systems, still some fragmentation uses diesel as fuel. They couldn't meet the national limit value of 65 HSU opacity and more than 70% of buses emitted smoke with opacity greater than 85 HSU (Rana *et al.*, 2020). Cooper *et al.* (2012) found similar results in which the buses emitted higher CO at the starting point and the average emission was 384 ppm then. After that the emissions started going downward. Public transport bus service is extended in big cities and cleaner bus fleets are encouraged to reduce greenhouse and air pollutant emissions in high populated areas (Gómez *et al.*, 2021).

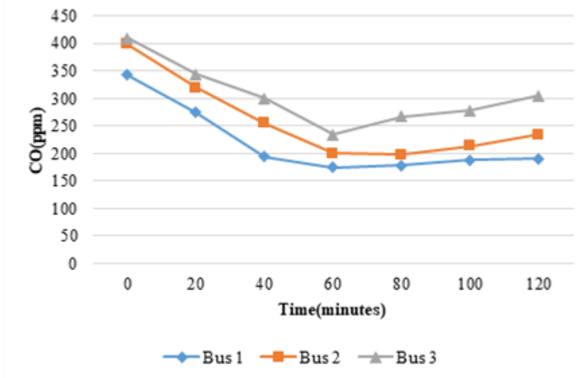

Fig. 6. CO emissions from buses with petrol engine

Comparison among average CO emissions from different vehicles

Fig. 7 shows graphical representations of the average values for CO emissions from different sources in Rajshahi City. Many factors can affect emissions such as drive cycle affects emissions. Generally, the values recorded during the fieldwork fluctuated periodically. The figure includes values from trucks, cars, motorcycles, and buses. CO emissions recorded ranged from a minimum value of about 80 ppm to a maximum value of about 680 ppm where the lowest emission was observed from motorcycles and the highest from trucks operating with diesel engines. Overall, petrol engines showed lesser emissions than diesel engines which were evident from the recorded data. Diesel vehicles were found as the worst polluters in the vehicle sector; about 75% of the diesel vehicles had opacity of emission more than the national limit value for emissions from diesel vehicles (Rana *et al.*, 2020). According to Tabassum *et al.* (2023), for the Chittagong-Rangamati Highway trucks were the main contributor to CO pollution and the role of motorcycles in such pollution was relatively less. John and Feyisayo (2013) also observed that trucks produce the highest values of carbon monoxide gas as recorded by the Detector in comparison to the other sources. The reason could be due to the type of engine and the fuel used (diesel). High values of emissions in diesel trucks could be due to aging and it could be because diesel has a very high carbon content than petrol fuels. Road traffic emissions are a major source of air pollution in urban areas with subsequent adverse human health effects. Although improvements in vehicle technology play a significant role in reducing traffic emissions at the source, air pollution abatement will remain a challenge because of the increasing demand for transportation (Potoglou and Kanaroglou, 2005).

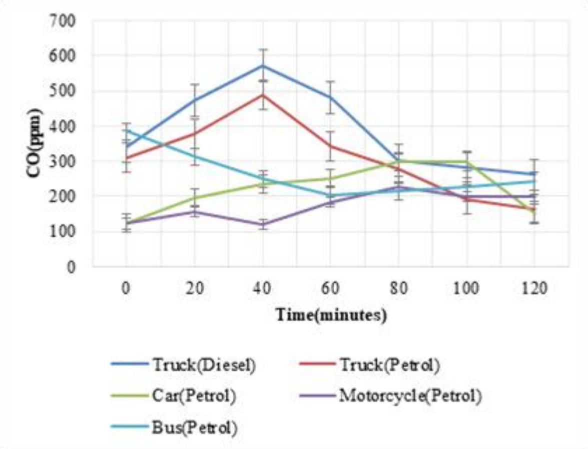

Fig. 7. Comparison of average CO emissions from different vehicles

Health and environmental hazards of CO

Health hazards of CO

In Rajshshi, the emission rates of CO from different vehicles varied from 80 ppm to 624 ppm. Emissions from trucks dominated over other vehicles operated by both diesel and petrol engines followed by buses. The contribution of cars was also higher while motorcycles showed relatively lower emissions. Kinoshita *et al, (*2020) stated that CO has been recognized as a toxic substance as well as a signalling gas, and the harmfulness of CO is dependent on both, the concentration of the gas and the exposure time (Jan *et al.*, 2010). According to a World Bank report, air pollution causes the death of 15,000 Bangladeshis and another 100,000 to suffer various respiratory diseases every year. The report also stated that the country could save between 200 million and US $ 800 million a year - about 0.7 to 3.0 percent of its gross national product by cutting down air pollution in its four major cities (Pollution Issues, 2009). According to the United States Consumer Product Safety Commission, if CO levels increase and remain above 70 ppm, symptoms such as headache, fatigue, and nausea become more noticeable. At concentrations above 150 to 200 ppm, disorientation, unconsciousness, and death are possible. Chronic conditions associated with CO poisoning are usually neuropsychiatric such as personality change, memory loss, and concentration impairment (Nicki, Brian, & Stuart, 2010). Lungs inhale CO into the bloodstream. When CO binds to a haemoglobin subunit, other binding sites show an increased affinity for the oxygen molecule (Tomaszewski *et al.*, 2010). Acute CO poisoning decreases the oxygen transport capacity, resulting in insufficient oxygenation at the tissue level (Ghosh *et. al.* 2016). Tissue hypoxia due to CO potentiates vascular permeability and causes increased accumulation of interstitial fluid with decreased circulating blood volume affecting multiple organs. This includes brain edema with neurological symptoms and disorders of consciousness; pulmonary edema with respiratory failure; decreased myocardial contractility, arrhythmias, and heart failure; and renal failure (Tomaszewski *et al.*, 2010). In Japan CO is a major cause of poisoning deaths (Baselt *et al.*, 2017) which is not always accidental: it is also used deliberately as a means of suicide.

Environmental hazards of CO

The emissions from diesel trucks ranged from 259 ppm to 680 ppm with an average of 370.57, 412, and 382.14 ppm from trucks 1, 2, and 3, respectively. Petrol Engine Trucks emission rate ranged from 159 ppm to 570 ppm. The result indicates that diesel trucks have larger emissions of carbon monoxide than petrol trucks because diesel fuels have a very high carbon monoxide content. Average CO emissions from Car 1, Car 2, and Car 3 were 217.14 ppm, 229.57 ppm, and 218.14 ppm in 2 hours duration respectively at different places in Rajshahi. The ranges of CO emissions in the atmosphere were between 80 pp

m to 268 ppm for motorcycles and 175 ppm to 410 ppm for buses with petrol engines. Rapid growth in the number and use of motor vehicles are accountable for the increase in emission of both local pollutants and greenhouse gases (Azad and Kitada, 1998). According to Aktar (2001) and Karim (2001), the trend of vehicular emissions is rapidly rising due to the high growth rate of vehicles which estimated to be double in the 20 years from 2000 to 2020. Elevated CO emissions are the primary product of vehicles that can be a precursor to both CO_2 and ozone, two significant greenhouse gases (Nylund *et al.*, 2004). Cars, vans, trucks, and buses produce more than 70 % of the overall EU's greenhouse gas emissions from transport and are a major contributor to climate change (EEA, 2020). Climate change is being counted as a global environmental threat which is viewed as the second most serious issue that the world faces (European Commission, 2011). The major effects are average 0.8 °C global warming above pre-industrial levels, 0.09 °C warming, and acidifying of the ocean since the 1950s. Besides, 3.2 cm sea-levels rising per decade, an exceptional number of extreme heat waves in the last decade, and drought affecting food crop growing areas are the consequence of this (Levitus *et al.*, 2012; Meyssignac and Cazenave 2012; Heyder *et al*., 2011). Except for the implementation of current mitigation, commitments, and pledges the negative effects of climate change will go on leading to a warming of 4 °C and a sea-level rise of 0.5–1 m as early as 2060s (Huddleston, 2012). CO pollutants can also influence the quality of soil and water bodies by polluting precipitation, and falling into water and soil environments (CDC 2016). Another effect of CO poisoning is the decay of vegetation life and depletion of the ozone layer (Dey and Dhal, 2019).

Conclusions

Emission testing for on-road vehicles was carried out on 15 vehicles of 5 different types in 6 spots of Rajshahi City from December 2020 to March 2021. The study also probed into both local and global perspectives on the health and environmental impact of CO emissions. Among different vehicles CO emission of Diesel Engine was found highest. Besides, the emission from trucks (both diesel and petrol engines) ruled over the other vehicles like buses, cars and motorcycles. The highest CO emissions were found at 680 ppm with an average of 412 ppm from truck 2 operating with a diesel engine and the lowest at 80 ppm from the motorcycle among the vehicles under consideration. From the results, vehicles dominated other sources of carbon monoxide within the ambient environment. As long as fossil fuels are being used, carbon monoxide will be emitted into the environment thereby making it unsafe and highly toxic to the human body. This study concisely described the emission level of CO from different vehicles and its poisoning effects on our environmental components. Given the severity of the current transportation, the Government needs to take pivotal steps towards an adequate enlightenment program accordingly to reduce air pollution, especially in metropolitan areas, and curb the destruction via this menace.

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References

Aktar, J., 2001. Traffic Contribution to Air Pollution: A case study of Dhaka. *Unpublished Thesis, Environmental Science Discipline, Khulna University, Khulna*.

American Chemical Society 2006: Motorcycles Emit 'Disproportionately High' Amounts Of Air Pollutants. ScienceDaily.

Azad, A.K. and Kitada, T., 1998. Characteristics of the air pollution in the city of Dhaka, Bangladesh in winter. *Atmospheric Environment*, *32*(11), pp.1991-2005.

Barradas, S., 2013. The Real Cost of Trucking—Per Mile Operating Cost of a Commercial Truck. *The Truckers Report, accessed Oct*, *13*, p.2020.

Baselt RC 2017: Disposition of Toxic Drugs and Chemicals in Man. Biochemical Publications 11.

Bledsoe, B. and McEvoy, M., 2009. Where there’s CO; there’s not always fire: how pulse CO-oximetry serves as an important assessment and triage tool. *JEMS*, *34*, pp.5-8.

Bolan, N., Kunhikrishnan, A., Thangarajan, R., Kumpiene, J., Park, J., Makino, T., Kirkham, M.B. and Scheckel, K., 2014. Remediation of heavy metal (loid) s contaminated soils–to mobilize or to immobilize?. *Journal of hazardous materials*, *266*, pp.141-166.

Byard, R.W., 2019. Carbon monoxide–the silent killer. *Forensic Science, Medicine and Pathology*, *15*(1), pp.1-2.

Can, G., Sayılı, U., Aksu Sayman, Ö., Kuyumcu, Ö.F., Yılmaz, D., Esen, E., Yurtseven, E. and Erginöz, E., 2019. Mapping of carbon monoxide related death risk in Turkey: a ten-year analysis based on news agency records. *BMC Public Health*, *19(9)*, pp.1-7.

CDC (Centre for Disease Control and Prevention) 2016. Carbon Monoxide Poisoning. Atlanta, United States: Centre for Disease Control and Prevention.

Colvile, R.N., Hutchinson, E.J., Mindell, J.S. and Warren, R.F., 2001. The transport sector as a source of air pollution. *Atmospheric environment*, *35*(9), pp.1537-1565.

Cooper, E., Arioli, M., Carrigan, A. and Jain, U., 2012. Exhaust Emissions of Transit Buses. Sustainable Urban transportation fuels and Vehicles. *World Resources Institute*, *2*.

Cordero, P.R., Bayly, K., Man Leung, P., Huang, C., Islam, Z.F., Schittenhelm, R.B., King, G.M. and Greening, C., 2019. Atmospheric carbon monoxide oxidation is a widespread mechanism supporting microbial survival. *The ISME journal*, *13*(11), pp.2868-2881.

Dey, S. and Dhal, G.C., 2019. Materials progress in the control of CO and CO2 emission at ambient conditions: An overview. *Materials Science for Energy Technologies*, *2*(3), pp.607-623.

Dupras, D. 2020. Do you know the sings of Carbon monoxide poisoning. Primary Truck in Rochester and Kasson.

EC (European Commission) 2011. Climate change: report. Brussels, Europe. Directorate-General for Communication. Brussels, Belgium: European Commission.

EEA (European Environmental Agency) 2020. Transport. Copenhagen, Denmark: European Environmental Agency.

EPA (United States Environmental Protection Agency) 2019. Air pollutant emissions trends data 1970–2017. Washington D C, United States: United States Environmental Protection Agency.

Ghosh, A., Banerjee, S., Mitra, A., Muralidharan, M., Roy, B., Banerjee, R., Mandal, A.K. and Chatterjee, I.B., 2016. Interaction of p-benzoquinone with hemoglobin in smoker’s blood causes alteration of structure and loss of oxygen binding capacity. *Toxicology Reports*, *3*, 295-305.

Gómez, A., Fernández-Yáñez, P., Soriano, J.A., Sánchez-Rodríguez, L., Mata, C., García-Contreras, R., Armas, O. and Cárdenas, M.D., 2021. Comparison of real driving emissions from Euro VI buses with diesel and compressed natural gas fuels. *Fuel*, *289*, p.119836.

Heyder, U., Schaphoff, S., Gerten, D. and Lucht, W., 2011. Risk of severe climate change impact on the terrestrial biosphere. *Environmental Research Letters*, *6*(3), p.034036.

Hossain, K.M. and Easa, S.M., 2012. Pollutant dispersion characteristics in Dhaka city, Bangladesh. *Asia-Pacific Journal of Atmospheric Sciences*, *48*, pp.35-41.

Huddleston, N. 2012. Climate change: evidence, impacts and choices. National Research Council.

Ide, T. and Kamijo, Y., 2009. The early elevation of interleukin 6 concentration in cerebrospinal fluid and delayed encephalopathy of carbon monoxide poisoning. *The American journal of emergency medicine*, *27*(8), pp.992-996.

Ito, T. and Nakamura, Y., 2010. Death from carbon monoxide poisoning in Japan between 1968-2007 through data from vital statistics. *Journal of Japanese Society for Emergency Medicine*, *13*, pp.275-282.

Jan, M.F., Habib, Q., Irfan, M., Murad, M., Yahya, K.M. and Hassan, G.M., 2010, October. Carbon monoxide detection and autonomous countermeasure system for a steel mill using wireless sensor and actuator network. In *2010 6th International Conference on Emerging Technologies (ICET)* (pp. 405-409). IEEE.

John, K.S. and Feyisayo, K., 2013. Air pollution by carbon monoxide (CO) poisonous gas in Lagos Area Southwestern Nigeria. *Atmospheric and Climate Sciences*, *2013*.

Karim, M.M., 2001, June. Status of air quality and State-of-art control measures in Dhaka, Bangladesh. In *94th Annual Conference and Exhibition of Air and Waste Management Association, Orlando, Florida, USA, June*.

Kinoshita, H., Türkan, H., Vucinic, S., Naqvi, S., Bedair, R., Rezaee, R. and Tsatsakis, A., 2020. Carbon monoxide poisoning. *Toxicology reports*, *7*, pp.169-173.

Lakhani, R. and Bleach, N., 2010. Carbon monoxide poisoning: an unusual cause of dizziness. *The Journal of Laryngology & Otology*, *124*(10), pp.1103-1105.

Levitus, S., Antonov, J.I., Boyer, T.P., Baranova, O.K., Garcia, H.E., Seidov, D., Yarosh, E.S. and Zweng, M.M., 2012. World ocean heat content and thermosteric sea level change (0–2000 m), 1955–2010. *Geophysical Research Letters*, *39*(10).

Mckee, H.C., Clark, J.M. and Wheeler, R.J., 1962. Measurement of diesel engine emissions. *Journal of the Air Pollution*, *12*(11), pp.516-546.

Meyssignac, B. and Cazenave, A., 2012. Sea level: a review of present-day and recent-past changes and variability. *Journal of Geodynamics*, *58*, 96-109.

Nicki, R.C., Brian, R.W. and Stuart, H.R., 2010. Davidson's principles and practice of medicine. *Churchill Livingstone Elsevier*.

Nylund, N.O., Erkkilä, K., Lappi, M. and Ikonen, M., 2004, October. Transit bus emission study: comparison of emissions from diesel and natural gas buses. In *IANGVA Conf, Buenos Aires*.

Pollution Issues 2009. Effect of Traffic Emission. Retrieved October 26, 2009, from http://pollutionissues.co.uk/traffic-emissions.html.

Potoglou, D. and Kanaroglou, P.S., 2005. Carbon monoxide emissions from passenger vehicles: predictive mapping with an application to Hamilton, Canada. *Transportation Research Part D: Transport and Environment*, *10*(2), pp.97-109.

Rana, M.M., Khan, M.H., Azad, M.A.K., Rahman, S. and Kabir, S.A., 2020. Estimation of Idle Emissions from the On-Road Vehicles in Dhaka. *Journal of Scientific Research*, *12*(1).

Ruth-Sahd, L.A., Zulkosky, K. and Fetter, M.E., 2011. Carbon monoxide poisoning: case studies and review. *Dimensions of critical care nursing*, *30*(6), pp.303-314.

Seinfeld, J.H. and Pandis, S.N., 2016. *Atmospheric chemistry and physics: from air pollution to climate change*. John Wiley & Sons.

Tabassum, N., Khan, A.F.S. and Arefin, A., 2023, April. Estimating the contribution of vehicle composition on air pollution–A case study in Chittagong-Rangamati Highway. In *AIP Conference Proceedings* (Vol. 2713, No. 1). AIP Publishing.

Tikuisis, P., Kane, D.M., McLellan, T.M., Buick, F. and Fairburn, S.M., 1992. Rate of formation of carboxyhemoglobin in exercising humans exposed to carbon monoxide. *Journal of Applied Physiology*, *72*(4), pp.1311-1319.

Tomaszewski C. Carbon monoxide. In: Nelson LS, Lewin NA, Howland MA, et al., 2010. editors. Goldfrank’s toxicological emergencies. 9th ed. New York (NY): McGraw Hill; p. 1658–1670.

Torrey, W.F. and Murray, D. 2015. An Analysis of the Operational Costs of Trucking: 2015 Update. Research Associate American Transportation Research Institute Atlanta.

TurkStat. 2018. Number of road vehicles: TurkStat

USAID (United States Agency for International Development) 2000. Motorcycle Emissions. Washington DC, United States: United States Agency for International Development.

Wang, W., Zhong, H., Zeng, Y., Liu, Y. and Chen, J., 2021. A carbon emission calculation model for roadside parking. *International Journal of Environmental Research and Public Health*, *18*(4).

Yang, Z., 2014. Improving the conversions between the various passenger vehicle fuel economy/CO2 emission standards around the world. *The International Council on Clean Transportation (ICCT): Berlin, Germany*, *9*, p.509.

Yoshioka, E., Hanley, S.J., and Saijo, Y., 2014. Epidemic of charcoal burning suicide in Japan. *The British Journal of Psychiatry*, *204*(4), pp.274-282.

Żaba, C., Pluta-Hadas, K. and Urbaniak, M., 2019. Suicidal carbon monoxide poisoning using motor vehicle exhaust in an open space. *Medical principles and practice*, *28*(5), pp.490-492.