CHAPTER 8

Human health risk assessment due to inhalation of particulate matter

In this chapter of this thesis, the average exposure dose of elements and to obtain the value of health risk and hazard index for non-carcinogenic health risk has been discussed. The overall goals of this chapter are to calculate exposure dose and human health risk in the study area.

8.1 Introduction

Ambient air pollutants are a heterogeneous mixture of gases, vapors, and particles **[219,220]**. Scientific evidence on the health effects of ambient air pollution is increasing in recent years. Many questions remain open, but many epidemiological studies have demonstrated the importance of air pollution as a risk factor for death and morbidity. For many specific health termination points and pollutants, associations have been defined and specialty of concentration-reaction relationships. Between these pollutants, suspended particles' role has been investigated in connection with their short-term and long-term effects on death and morbidity. The most scientific evidence is available for the date related to PM_{10} and $PM_{2.5}$ dates (50% of particles with cut-off aerodynamic diameter respectively of <10 and <2.5 m, respectively), although the role of finer particles is of increasing interest. This evidence has inspired the World Health Organization (WHO) to include air pollution and its health effects on its agenda **[221]**. To mark the risk of relevant information on the complete distribution of exposure to the population is required. Measures of central tendencies may be appropriate for estimating the people's overall risk, but dependent on primary measures alone can hide the existence of more highly exposed individuals with unacceptable levels of risk. It is evident that there are exposures in external and some transport environments for external pollutants, but exposure to pollutants in the indoor environment can also be exposed. However, breathing in most external air pollutants is the only route and medium air. Exposure Assessment tools include monitoring equipment and biomarkers for questionnaires and environmental and personal samples to describe air pollution activities. Often, the exposure data is limited, and model-based approaches can be substituted for actual population-based data. Modeling approaches can produce exposure distribution based on exposure models and statistical distributions for key model parameters. However, without validation, the consequences of such exercises are subject to considerable uncertainty **[222]**.

For external air pollution, population risk distribution is generally obtained from concentrations measured by sitting monitors for regulatory purposes. Typically, these monitors have kept representing population risks, although local sources can drive levels, and validation studies are not usually done to describe relationships between measured are and actual population risks. For pollutants with broad regional sources, e.g., Ozone and fine particles, can provide a satisfactory evaluation of one or more monitor risks in a regulatory network. Carbon monoxide, which has more oddly concentrated for other pollutants, cannot be sufficient to evaluate regulatory monitor exposure. In recent years in developing countries, one of the most public health and essential environmental concerns is air pollution, especially the source of various toxic chemical contaminants, including heavy metals **[8,106]**. Particulate matters are common routes to entering the human body by ingesting food containing milk, vegetables, meat, drinking water, soil, dietary sources, coke-oven, iron-foundry, and ingestion inhalation, dermal contact, breathing exhaust fumes, and absorption **[223,224]**. Published analyses have indicated that ambient particulate matter exposure in the concentration is measured in industrialized countries, especially in urban areas, resulting in many adverse health-related incidents. Typically, health burden, or effect, is regulated by the number of adverse health events caused by particulate matter exposure in the population under study. Ambient air pollution has immediate localized impacts on human health and well-being and contributes to regional and global air pollution, especially in developing countries. The present study has been conducted to determine the health risks of atmospheric particulate matter at sampling locations in the study area.

8.2 Element exposure and health risk assessment of air pollutants

8.2.1 Uptake intake of elements through inhalation

Inhalation of toxic heavy metals present in the atmospheric air adversely influences various life forms, especially humans. The concentration of metals in the atmosphere, which constitutes a long-term threat to the general population's health, needs to be estimated. Estimating the intake of heavy metals through air inhalation routes is essential for assessing risks to human health. Actual inhalation rates, which depend on various physical activities in the area, are not available. It is prudent to use either national or international established breathing rates for an adult compared to other studies at the national or international levels. In the present study, for estimating the intake of metals through inhalation exposure pathways, the breathing rate of 22.2 $m^3\ d^{-1}$ for adults (age >17 years) was considered **[225]**. Considering this breathing rate and the concentration of elements in the air, $PM_{2.5}$ and PM_{10} were calculated as inhaled. The range and average intake of the studies element are given in **Table 8.1**.

The intake of these elements through inhalation exposure pathways was found to be less than 1% of the World Health Organization (WHO) tolerable daily intake values, except for Cd and Pb; thus, the Cd is estimated at slightly higher, and Pb is approximately 80% of the World Health Organization (WHO) tolerable daily intake values **[226]**. The intake of Cd, Cr, Mn, Ni, and Pb through inhalation exposure pathways attributable to $PM_{2.5}$ in the Singrauli coalfield was 164.9±56.8 ng d^{-1}, 450.4±100.1 ng d^{-1}, 2.7±1.1 µg d^{-1}, 315.5±60.8 ng d^{-1}, 6.8±0.4 µg d^{-1}, respectively. Similarly, the intake of Cd, Cr, Mn, Ni and Pb through inhalation exposure pathways owing to PM_{10} in the area was 238.1±49.0 ng d^{-1}, 759.3±182.7, ng d^{-1}, 3.2±1.0 µg d^{-1}, 400.9±124.5 ng d^{-1}, 8.81±1.5 µg d^{-1}, respectively, of WHO-recommended tolerable daily intake values of 110.0 ng d^{-1}, 22000.0, ng d^{-1}, 666.0 µg d^{-1}, 22000.0, ng d^{-1}, and 11.1 µg d^{-1}, respectively **[226]**. The air at the Singrauli coalfield location poses no threat to the local population through inhalation.

8.2.2 Inhalation dose and health risk assessment of air pollutants

The total population has been divided into four age group categories, i.e., new-born, children (1-year-old), children (8–10 years old), and adults, with different body weights and breathing rates. Dose rates of Singrauli coalfield in ambient air obtained for four age groups with varying pollutants of breath have been calculated and given in **Table 8.2 and Fig. 8.1.**

Table 8.2 and Fig. 8.1 shows that the pollutant-specific lowest, average, and highest health risks were calculated based on pollutant-specific LOAEL values. **Table 8.2** indicates that the dose rate due to SO_2 is the lowest for all age categories.

Table 8.1: Intake of elements in $PM_{2.5}$ and PM_{10} through inhalation

Element	Units	$PM_{2.5}$		PM_{10}		Limit [226]
		Range	Average	Range	Average	
Ag	ng d^{-1}	2.3-27.1	22.6±4.6	2.3-31.5	27.1±4.6	-
Al	µg d^{-1}	4.8-111.3	52.0±27.2	10.1-351.3	222.5±56.5	-
As	ng d^{-1}	15.8-238.8	91.8±24.9	35.7-254.1	96.6±29.3	-
Br	ng d^{-1}	20.5-122.32	36.6±9.1	2.2-166.7	49.9±31.3	-
Ca	µg d^{-1}	38.4-169.5	84.2±26.8	27.2-450.0	303.5±48.8	-
Cd	ng d^{-1}	12.4-1767.7	164.9±56.8	27.5-1916.0	238.1±49.0	110.0
Co	ng d^{-1}	12.4-303.4	203.2±58.6	12.4-370.0	247.6±57.7	-
Cr	ng d^{-1}	14.7-2249.9	450.4±100.1	9.3-2564.5	759.3±182.7	22000.0
Cu	ng d^{-1}	16.7-4710.4	780.1±352.5	17.7-7780.6	1200.2±628.0	-
Fe	µg d^{-1}	21.7-193.7	70.6±36.0	27.2-571.1	234.2±39.4	-
Hg	ng d^{-1}	0.12-169.2	78.3±25.8	0.14-241.9	131.1±64.9	-
K	µg d^{-1}	20.8-226.3	83.8±24.9	24.5-424.8	254.4±60.9	-
Li	ng d^{-1}	0.62-69.6	23.7±9.3	0.8-114.0	37.7±13.3	-
Mg	µg d^{-1}	2.3-153.3	90.0±40.8	3.9-249.9	162.4±35.2	-
Mn	µg d^{-1}	0.02-8.9	2.7±1.1	0.12-12.0	3.2±1.0	666.0
Na	µg d^{-1}	2.4-222.2	90.6±23.9	12.4-419.2	278.0±86.5	-
Ni	ng d^{-1}	0.7-416.2	315.5±60.8	0.7-658.4	400.9±124.5	22000.0
Pb	µg d^{-1}	0.22-24.1	6.8±0.4	0.27-26.9	8.81±1.5	11.1
Se	ng d^{-1}	1.6-1521.1	1004.7±173.4	4.0-1814.9	1420.9±188.3	-
Si	µg d^{-1}	2.6-54.4	33.8±13.9	5.5-78.6	57.1±11.7	-
Sr	ng d^{-1}	2.9-6785.2	230.2±236.4	6.6-7908.5	395.9±233.3	-
Th	ng d^{-1}	0.02-2.3	1.3±0.5	0.02-3.00	1.8±0.7	-
U	ng d^{-1}	0.01-0.5	0.23±0.02	0.01-0.6	0.27±0.07	-
V	ng d^{-1}	4.7-722.4	85.9±39.0	9.1-977.3	115.8±22.5	-
Zn	µg d^{-1}	0.11-17.5	5.8±1.0	0.18-21.3	7.3.1±1.3	-
C	µg d^{-1}	30.8-420.5	134.7±40.8	63.0-517.1	310.5±44.0	-
H	µg d^{-1}	15.5-348.6	137.4±32.2	23.0-425.5	257.4±32.2	-
N	µg d^{-1}	0.62-229.6	104.7±28.5	1.5-254.2	171.3±29.5	-
S	µg d^{-1}	8.6-174.5	70.7±18.4	19.6-192.1	91.9±34.0	-
Br^-	ng d^{-1}	0.11-4.4	2.3±0.6	0.12-4.8	2.8±0.1	-
Cl^-	µg d^{-1}	11.3-98.9	45.4±15.3	12.2-147.5	74.3±30.3	-
F^-	µg d^{-1}	1.18-107.5	41.6±16.8	1.3-120.8	45.0±10.5	-
NO_2^-	µg d^{-1}	0.53-22.6	10.5±5.8	0.8-27.4	12.5±7.6	-
NO_3^-	µg d^{-1}	3.0-400.0	71.1±22.5	5.5-467.2	139.6±25.2	-
PO_4^{3-}	µg d^{-1}	3.0-102.4	78.1±25.5	3.8-126.8	107.7±39.4	-
SO_4^{2-}	µg d^{-1}	20.1-464.4	135.0±61.4	23.4-604.4	218.3±61.4	-
Ca^{2+}	ng d^{-1}	76.8-339.0	168.5±53.7	54.5-900.0	607.0±97.6	-
K^+	ng d^{-1}	41.7-452.7	167.7±49.8	49.0-849.6	508.9±121.7	-
Mg^{2+}	ng d^{-1}	4.6-306.6	180.1±81.6	7.8-499.9	324.9±70.4	-
Na^+	ng d^{-1}	4.9-444.4	181.2±47.8	24.9-838.5	556.0±173.0	-
NH_4^+	µg d^{-1}	22.8-539.2	253.7±81.2	38.3-693.2	353.9±128.0	-
PM	mg d^{-1}	0.61-3.45	1.79±0.83	0.91-7.80	4.31±1.73	-

± = Standard Deviation; PM = Particulate Matter

In the study area, dose rates for children (1 year) were always higher than those for the other age groups, which indicated that young children might have higher health risks. The absolute values of the dose rates depended on concentrations of the pollutant and exposure profiles for different age groups. Children usually have a higher level of physical activity than adults; hence, the intake of air into the lungs per body weight is much higher per day than for adults. Thus, the children had higher dose rates than other age groups.

The lower values of pollutant specific of the lowest observed adverse effect level (LOAEL) are the higher health risk. Similarly, the higher is the dose rate, the higher is the health risk. Taken together, a Health risk for a given pollutant has estimated as a function that is directly proportional to the dose rates and inversely to the lowest observed adverse effect level values. A comparison of health risk values indicates that children in the Singrauli coalfield from the highest health risk due to particulate matter. The lowest health risk is due to SO_2 for infants in the area, while the highest health risk due to SO_2 is 0.4, once again for children in the area. For $PM_{2.5}$ and PM_{10}, the lowest health risk (0.4 and 0.7, respectively) is for infants in the study area.

A pollutant-wise relative ranking exercise was also done subsequently. Comparison of pollutant-wise highest health risk values shows that PM_{10} is about 12.3 times riskier than SO_2, while health risk due to $PM_{2.5}$ is about 5.8 times higher than that due to SO_2.

Subsequently, when this study does the relative ranking concerning lowest health risks, the results found that PM_{10} is 7.0 times risky than SO_2, while health risk due to $PM_{2.5}$ is four times higher than that due to SO_2.

Considering these highest and lowest health risk values together, the average health risk due to PM_{10} in the study area is about 14.5 times higher than that due to SO_2, and health risk due to $PM_{2.5}$ is about 6.0 times higher than that due to SO_2.

However, particulate matter, which turns out to be the riskiest pollutant in the study area, is an indicator of industrial activities related to air pollutants. Under these circumstances, exposure studies should be designed to identify a specific population at risk, define criteria for people in general, and investigate the long-term effects of a decrease or increase in exposure to a contaminated person **[130,133]**.

This limited the ability to isolate the independent effects of each pollutant. However, it has been concluded that maximum time exposure to outdoor air pollution is associated with increased health risks.

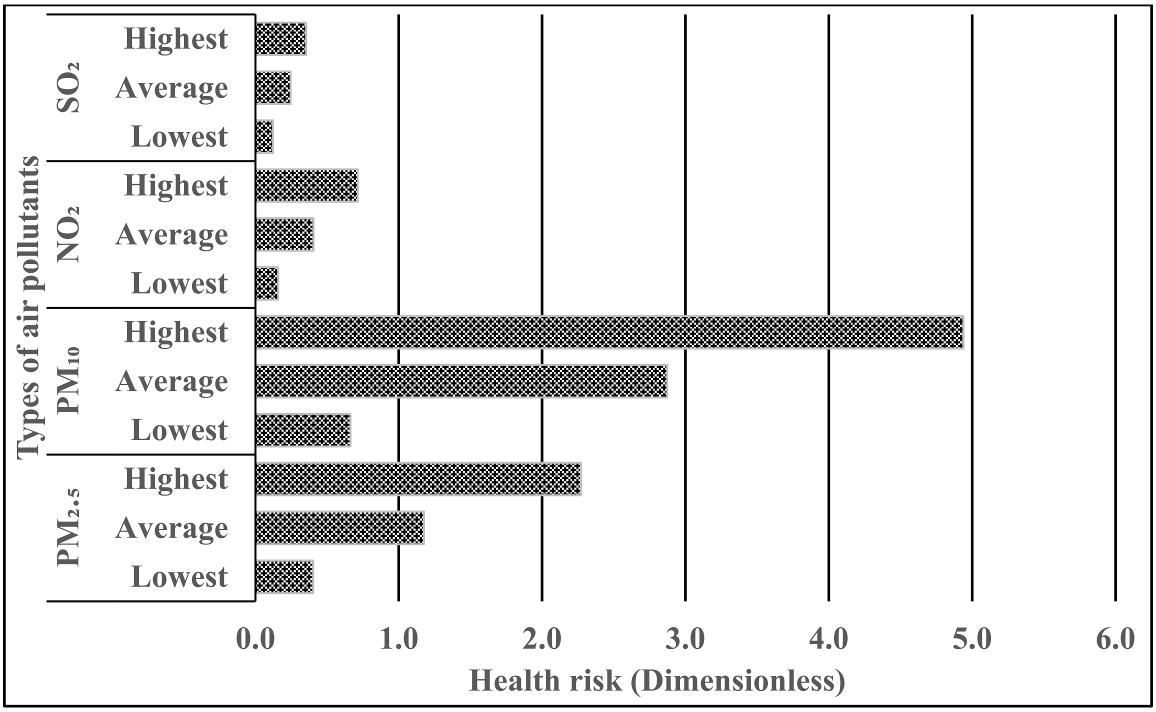

Fig. 8.1: Lowest, average, and highest health risk with due respect to air pollutants

8.3 Risk assessment of element to human health

Assessment of the risk to human health is calculated by estimating the probability of harmful factors on the human body's adverse effects after exposure to such factors. The health effects are then evaluated by adding environmental pollution and human health events **[134]**. According to the EPA Integrated Risk Information Database, National Toxicology Program (NTP), Department of Health and Human Services (DHHS), and International Agency for Research on Cancer (IARC), the pollutants can be divided into non-carcinogens and carcinogens. In this study, these four metals, i.e., As, Cd, Cr(VI), and Ni, are accepted as human carcinogens in one form or another or particular routes of exposure **[135-138]**, while Cu, Hg, Mn, Pb, and Zn are non-carcinogenic, and affect the human immune system through the respiratory system.

The brief of risk assessment of element to human health in carcinogenic and non-carcinogenic effect are discussed here.

8.3.1 Normal average daily dose and lifetime average daily dose assessment of elements in particulate matter

The value of exposure factors averages daily dose and lifetime average daily dose were calculated and shown in **Table 8.3** and **Table 8.4**. These are in the form of normal average daily dose and lifetime average daily dose (mg kg^{-1} d^{-1}) of a pollutant through inhalation. According to the results, inhalation played an important role in the total average daily dose (Normal average daily dose and lifetime average daily dose) of children for most metals, especially for Mn, Pb, and Zn, which accounted for 15.8%, 41.8%, and 35.5 % in $PM_{2.5}$ and 15.4%, 41.9%, and 34.5% in PM_{10}, respectively. The total average daily dose through the inhalation pathway in particulate matter ($PM_{2.5}$ and PM_{10}) contributed less than the 0.3% in $PM_{2.5}$ and 0.3% in PM_{10} in all demographic groups.

Carcinogenic element chromium has been observed the highest percentage of the total average daily dose in both the $PM_{2.5}$ and PM_{10} samples. On the whole, average daily dose values decreased in the order of Pb > Zn > Mn > Cu > Cr > Ni > Hg > Cd > As in $PM_{2.5}$ and PM_{10} in male demographic groups. Thus, similar fluctuation has been found in the female and children demographic groups.

The health index all carcinogenic and non-carcinogenic are vary from 3.9E-06-5.6E-04 and 6.2E-06-6.9E-04 for male, 3.4E-06-4.9E-04 and 5.4E-06-6.0E-04 for female, and 4.2E-06-6.1E-04 and 6.8E-06-7.6E-04 for children in $PM_{2.5}$ and PM_{10} in the study area. However, the higher health index in children and the lowest in females followed by the male demographic groups and similar trends have also been in the PM_{10}. However, several times, the concentration and values of Pb are higher than the permissible limit due to higher industrial activity surrounding the sapling locations **[101,227]**. The lead (Pb) should be paid more attention to the high normal average daily dose and lifetime average daily dose value.

However, exposure to elements and metalloids such as Pb, Cd, Ni, and As could cause serious harm humans, such as cognitive impairment, kidney dysfunction, lung cancer, and chronic bronchitis neurological effects. Due to the large absorption rates and intake and frequent hand-to-mouth activity, children are particularly sensitive to elements and metalloid poisoning. Previous studies conducted human health risk assessments of the elements through various exposure pathways, but little research has been done on the major exposure pathway **[189,222]**.

Table 8.2: Dose rates (μg kg^{-1}) for different population age groups in the study area due to air pollutant

Age group	$PM_{2.5}$		PM_{10}		NO_2		SO_2	
	μg kg^{-1}							
	Range	Average	Range	Average	Range	Average	Range	Average
New-borns	7.4-41.4	21.5±9.4	12.2-89.3	52.3±15.0	2.9-13.1	7.4±3.2	2.3-6.5	4.5±1.1
Children 1 year old	10.5-59.0	30.7±13.4	17.3-127.2	74.5±21.4	4.2-18.7	10.6±4.5	3.2-9.3	6.4±1.6
Children 8-10 year old	9.2-51.8	26.9±11.7	15.2-111.6	65.4±18.7	3.6-16.4	9.3±4.0	2.8-8.1	5.6±1.4
Adults	7.9-44.4	23.1±10.1	13.0-95.7	56.0±16.1	3.1-14.0	8.0±3.4	2.4-7.0	4.8±1.2

± = *Standard Deviation*

Table 8.3: Average daily dose or lifetime average daily dose for elements in the $PM_{2.5}$

Element	Average daily dose or lifetime average daily dose (mg kg^{-1} d^{-1})					
	Male		Female		Children	
	Range	Average	Range	Average	Range	Average
As	6.6E-08-1.0E-06	3.8E-07±1.0E-07	5.7E-08-8.7E-07	3.3E-07±9.1E-08	4.4E-08-6.7E-07	2.6E-07±7.0E-08
Cd	5.2E-08-7.4E-06	6.9E-07±2.4E-07	4.5E-08-6.4E-06	6.0E-07±2.1E-07	3.5E-08-4.9E-06	4.6E-07±1.6E-07
Cr	6.1E-08-9.4E-06	1.9E-06±4.2E-07	5.3E-08-8.2E-06	1.6E-06±3.6E-07	4.1E-08-6.3E-06	1.3E-06±2.8E-07
Ni	2.8E-09-1.7E-06	1.3E-06±2.5E-07	2.4E-09-1.5E-06	1.1E-06±2.2E-07	1.9E-09-1.2E-06	8.8E-07±1.7E-07
Cu	1.6E-07-4.6E-05	7.6E-06±3.4E-06	1.4E-07-4.0E-05	6.6E-06±3.0E-06	1.8E-07-5.1E-05	8.5E-06±3.8E-06
Hg	1.2E-09-1.7E-06	7.7E-07±2.5E-07	1.0E-09-1.4E-06	6.6E-07±2.2E-07	1.3E-09-1.8E-06	8.5E-07±2.8E-07
Mn	1.8E-07-8.6E-05	2.5E-05±1.1E-05	1.6E-07-7.5E-05	2.2E-05±9.5E-06	2.1E-07-9.6E-05	2.8E-05±1.2E-05
Pb	2.2E-06-2.4E-04	6.7E-05±4.5E-06	1.9E-06-2.0E-04	5.8E-05±3.9E-06	2.5E-06-2.6E-04	7.4E-05±5.0E-06
Zn	1.1E-06-1.7E-04	5.6E-05±9.6E-06	9.6E-07-1.5E-04	4.9E-05±8.3E-06	1.2E-06-1.9E-04	6.3E-05±1.1E-05
Health Index	3.9E-06-5.6E-04	1.6E-04±3.0E-05	3.4E-06-4.9E-04	1.4E-04±2.6E-05	4.2E-06-6.1E-04	1.8E-04±3.3E-05

± = *Standard deviation; As, Cd, Cr, and Ni are lifetime average daily dose; Cu, Hg, Mn, Pb, and Zn are Average daily dose*

Table 8.4: Average daily dose or lifetime average daily dose for elements in the PM_{10}

Element	Average daily dose or lifetime average daily dose ($mg\ kg^{-1}\ d^{-1}$)					
	Male		Female		Children	
	Range	Average	Range	Average	Range	Average
As	1.5E-07-1.1E-06	4.0E-07±1.2E-07	1.3E-07-9.2E-07	3.5E-07±1.1E-07	1.0E-07-7.1E-07	2.7E-07±8.2E-08
Cd	1.2E-07-8.0E-06	1.0E-06±2.1E-07	1.0E-07-7.0E-06	8.7E-07±1.8E-07	7.7E-08-5.4E-06	6.7E-07±1.4E-07
Cr	3.9E-08-1.1E-05	3.2E-06±7.7E-07	3.4E-08-9.3E-06	2.8E-06±6.6E-07	2.6E-08-7.2E-06	2.1E-06±5.1E-07
Ni	2.8E-09-2.8E-06	1.7E-06±5.2E-07	2.4E-09-2.4E-06	1.5E-06±4.5E-07	1.9E-09-1.8E-06	1.1E-06±3.5E-07
Cu	1.7E-07-7.6E-05	1.2E-05±6.1E-06	1.5E-07-6.6E-05	1.0E-05±5.3E-06	1.9E-07-8.5E-05	1.3E-05±6.8E-06
Hg	1.4E-09-2.4E-06	1.3E-06±6.4E-07	1.2E-09-2.1E-06	1.1E-06±5.5E-07	1.5E-09-2.6E-06	1.4E-06±7.1E-07
Mn	1.2E-06-1.2E-04	3.2E-05±1.0E-05	1.0E-06-1.0E-04	2.8E-05±8.9E-06	1.3E-06-1.3E-04	3.5E-05±1.1E-05
Pb	2.7E-06-2.6E-04	8.6E-05±1.5E-05	2.3E-06-2.3E-04	7.5E-05±1.3E-05	3.0E-06-2.9E-04	9.6E-05±1.7E-05
Zn	1.8E-06-2.1E-04	7.1E-05±1.3E-05	1.6E-06-1.8E-04	6.2E-05±1.1E-05	2.0E-06-2.3E-04	7.9E-05±1.4E-05
Health Index	6.2E-06-6.9E-04	2.1E-04±4.7E-05	5.4E-06-6.0E-04	1.8E-04±4.0E-05	6.8E-06-7.6E-04	2.3E-04±5.1E-05

± = *Standard deviation; As, Cd, Cr, and Ni are lifetime average daily dose; Cu, Hg, Mn, Pb, and Zn are Average daily dose*

8.3.2 Non-carcinogenic health risk assessment of elements via inhalation exposure

Inhalation exposure is typically the primary route of direct exposure to associated particulate elements **[228]**. Based on the normal average daily dose (ADD) and reference dose (RfD) of each pollutant, the non-cancer risks of metal(loid)s to the male, female, and children were calculated and shown in **Fig. 8.2** and **Fig. 8.3** in $PM_{2.5}$ and PM_{10} in the area. As indicated in the figure, the risk level of the non-carcinogenic metals for exposure through the respiratory system was between 1.45×10^{-13} and 8.71×10^{-09} year^{-1} in $PM_{2.5}$ and 1.71×10^{-13} and 9.73×10^{-09} year^{-1} in PM_{10}, which is lower than the average risk acceptance of 10^{-6} year^{-1} **[228]**. The risk levels of the non-carcinogenic elements to adults and children are near to similar. The risk levels for the non-carcinogenic metals occurred in the following order: Pb > Mn > Hg > Zn > Cu. Non-carcinogenic metals can cause harm to children more easily than in males and females.

8.3.3 Carcinogenic health risk assessment of elements via inhalation exposure

For the investigation of carcinogenic risks in particulate matters four elements (As, Cd, Cr, and Ni) were taken into consideration because these are classified as carcinogenic/ probably carcinogenic/ possibly carcinogenic to humans by EPA Integrated Risk Information Database, National Toxicology Program, Department of Health and Human Services, and International Agency for Research on Cancer **[135-138]**. The risk level of the carcinogenic elements for exposure through the respiratory system in different demographic groups is showing in **Fig. 8.4** for $PM_{2.5}$ and **Fig. 8.5** for PM_{10}. As observed in **Fig. 8.4** and **Fig. 8.5**, the risk level of the carcinogenic elements for exposure through the respiratory system is 1.05×10^{-11} and 2.09×10^{-08} in $PM_{2.5}$ and 6.66×10^{-12} and 3.31×10^{-08} in PM_{10}, which is lower than the average risk acceptance of 10^{-6} year^{-1} **[228]**.

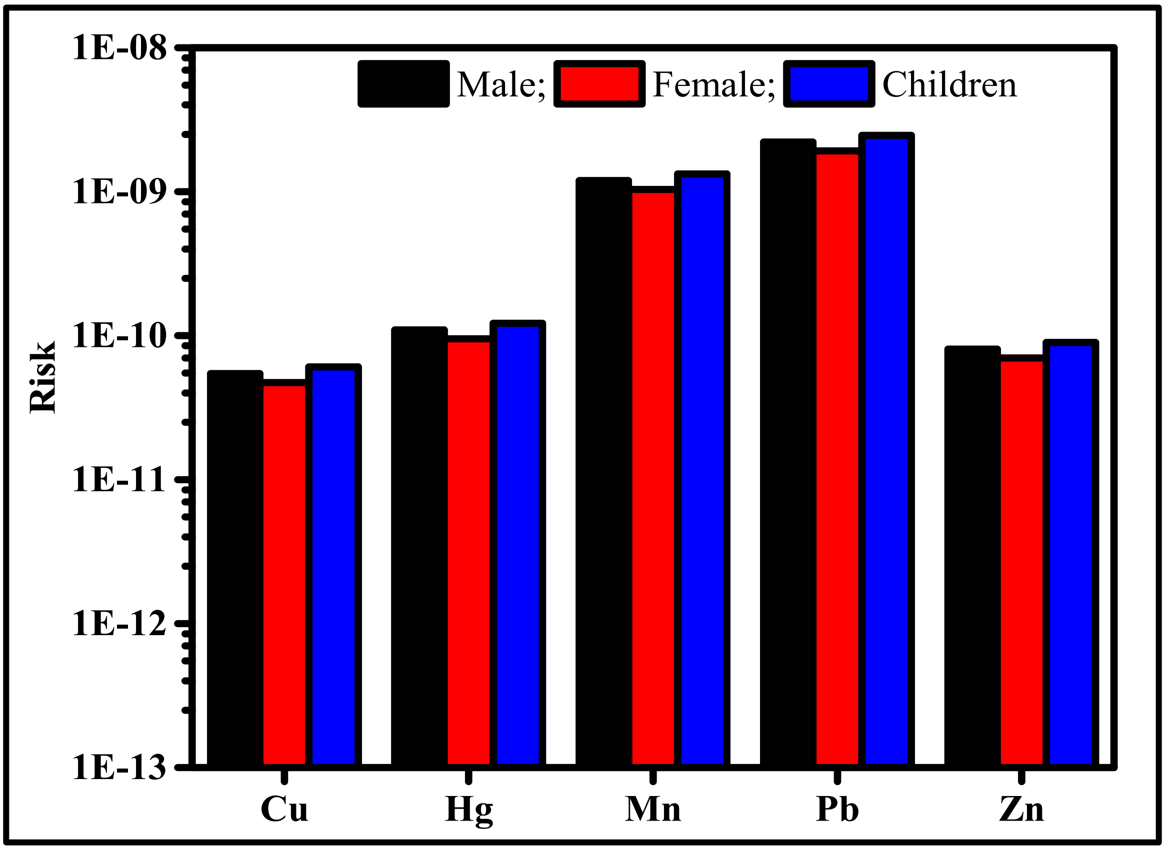

Fig. 8.2: A risk related to non-carcinogen metals components of $PM_{2.5}$ for different demographic groups

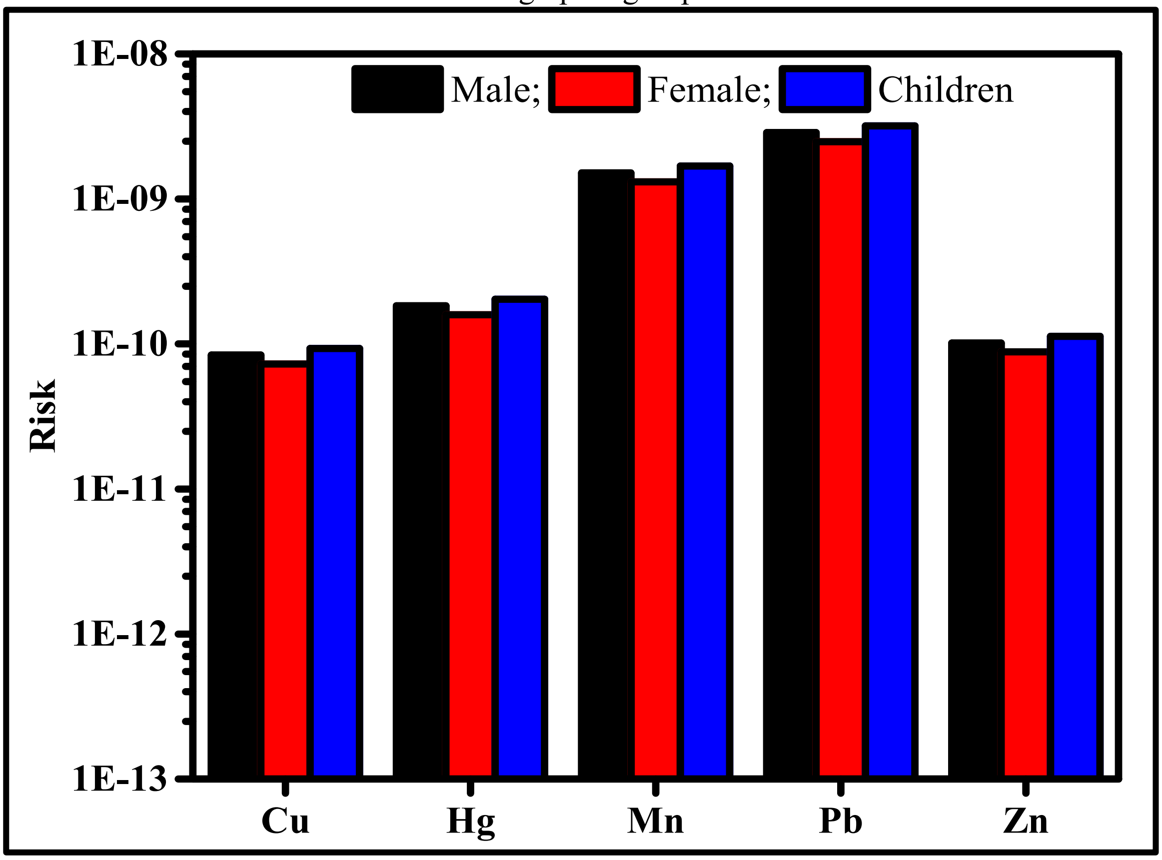

Fig. 8.3: A risk related to non-carcinogen metals components of PM_{10} for different demographic groups

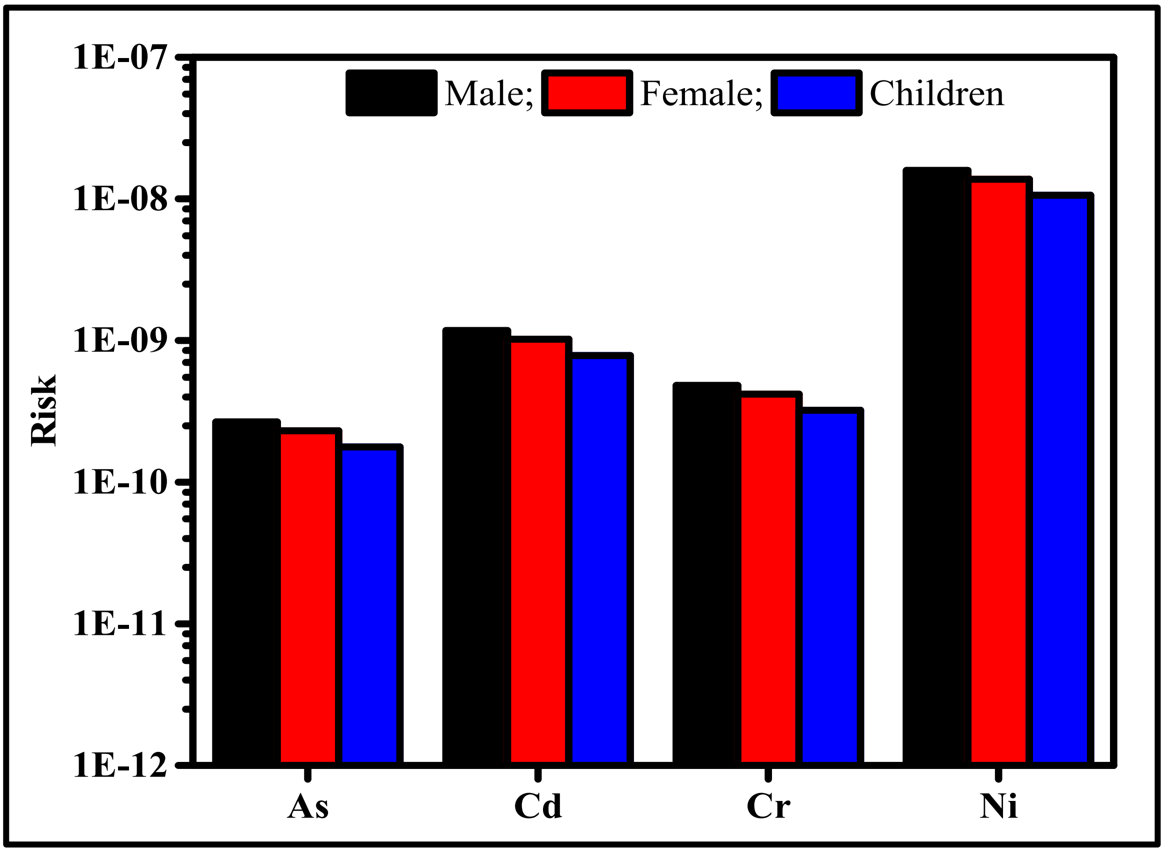

Fig. 8.4: A risk associated with carcinogen metals components of $PM_{2.5}$ for different demographic groups

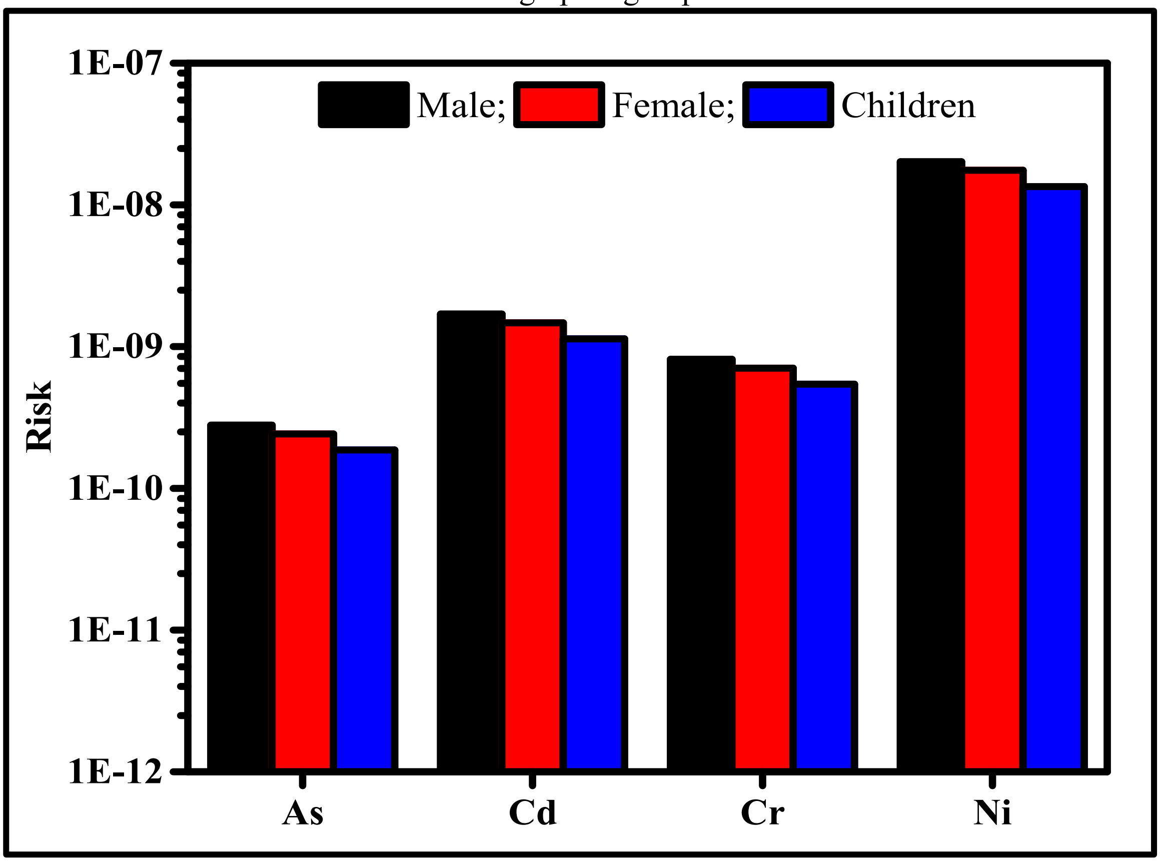

Fig. 8.5: A risk associated with carcinogen metals components of PM_{10} for different demographic groups

The risk levels for the carcinogenic elements occurred in the following increasing order of both types of particulate matter ($PM_{2.5}$ and PM_{10}): As < Cd < Ni < Cr, respectively. However, carcinogenic substances generated a higher cancer risk in males than females and last in children. As in the ambient environment, some previously mentioned were mainly attributed to coal combustion **[189]**. Therefore, considering that the coal-based plant is the sole potential pollution source, As and Cr, in the study area, posing the higher health risks to local children and minimum in male, then followed by the female, would be caused by coal combustion during the burring process in the coal-based plant. However, further research is needed to identify the extent to which coal-based plants increased the risks of exposure to elements and metalloids.

However, the sum of the risk levels generated by the nine elements 2.14×10^{-08} for male, 1.86×10^{-08} for female, 1.59×10^{-08}, for children in $PM_{2.5}$ and 2.77×10^{-08} for male, 2.40×10^{-08} for female, and 2.06×10^{-08} for children in PM_{10}, is relatively lower than the average level of average risk acceptance of 10^{-6} $year^{-1}$, respectively **[228]**. The total sum of risk level was higher in PM_{10} associated elements than the $PM_{2.5}$ related elements. The risk generated by carcinogenic elements is significantly higher than the risk generated by non-carcinogenic objects. The difference in the order of magnitude in the risk levels is between 2 and 3. As a result of individual differences in body weight, respiration rate, and outdoor exposure, the carcinogenic and non-carcinogenic risks to males, females, and children are different.

8.4 Conclusion

The present exercise assesses health risk due to different pollutants ($PM_{2.5}$, PM_{10}, NO_2, and SO_2) for four different age classes (new-borns, Children 1-year-old, Children 8-10-year-old, and Adults) under the industrial cum-residential area of Singrauli coalfield. The values turn out to be quite different for different age groups of the population. Although these studies have not specifically quantified age-specific health risks, their general conclusions agree with our findings.

The present study helps to rank relatively different pollutants in terms of health risk, which they are likely to pose. Results point out that health risks due to air pollution in the area is highest for children. Health risk for PM_{10} is about 12.3 times risky than SO_2, while health risk due to $PM_{2.5}$ is about 5.8 times higher than that due to SO_2. Risk levels of the nine elements to males and children are similar.

The risk level for the metals occurred in the following order: Pb > Zn > Mn > Cu > Cr > Ni > Hg > Cd > As; the risk levels for all elements were lower than the average level of average risk acceptance (10^{-6}). The risk posed by carcinogenic metals was significantly higher than non-carcinogenic metals, indicating that the potential risks of carcinogenic metals were more serious.