# Risk assessment and apportionment studies of particulate pollution at Ankamaly,South India

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**Abstract**
In the present world which is engulfed by the ill-effects of air pollution, stringent permissible emission standards to curb pollution are mandatory. Source and risk apportionment studies help to understand the sources and their contributions. Four parameters, lifetime average daily dose, hazard quotient, hazard index, excess cancer risk helped in assessing the risk at sampling site selected at Ankamaly, Kerala. Lifetime average daily dose was found be in the descending order as Fe> K> Na> Ca. Hazard quotient values were found to be greater than one for Mn and Cr, which conveys the non-carcinogenic effects due to pollution. Cu, Ni, and Zn were within safe limits. Chromium was found to be the main risk causing pollutant. Excess cancer risk (ECR) values shoot up to $6.67\times10^{-3}$ for child and $2.86\times10^{-3}$ for adults, which shows it is alarming. Risk apportionment was done and the highest contributors to risk were found to be smelting activities (92.4%) followed by wood residue burning (4.2%) and paved road dust (3.2%).

**Keywords:** *Human health risk; Excess cancer risk; Inhalation; Chromium; India*

## 1. Introduction

Airborne particles are associated with health problems (Keerthi et al. 2018; Lin et al. 2018). Symptoms can be immediate or long term. Presence of pollutants may cause skin, eye, and nose irritations whereas some others move with the respired air and finally gets into the bloodstreams. Pollution can reduce visibility and interfere with the serenity of nature. A study reported that particulate matter pollution can even cause sleep apnea, premature labor and birth deformities and infertility in adults (Cai et al. 2017). To improve the quality of air, control measures have to be taken at the source itself. For that prioritization of sources has to be carried out which in turn requires source and risk apportionment studies (Ghosh et al. 2018; Murillo et al. 2013; Liu et al. 2008; Yatkin and Bayram 2008). These studies predict critical sources whose emissions when controlled can bring a drastic improvement in the air quality. This paper discusses risk assessment studies being conducted for the first time at Kerala, South-India.

## 2. Materials and Methods

### *2.1. Sampling site, protocol, and analysis*

Sampling was done at Ankamaly (10.1849° N, 76.3753° E), Ernakulam-one of the fastest growing cities in India. This particular site was selected based on certain criteria like wind direction, accessibility, continuous power supply, convenience and according to the standard protocols. Under the Koppen climate classification, Ernakulam comes under a tropical monsoon climate with very little variation. There are two major seasons- summer and monsoon. Summer starts by March and ends by May with the commencement of South-Western Monsoon rain. Sampling was carried out using Dual Channel Ambient Dust Sampler (Instrumex Model No. IPM-FDS-2510) with a flow rate kept at 16.67 Liter per minute. Filter papers collected from the sampler after weighing were properly packed and sent for analysis of elements and ions. Elements (Ca, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Zn, Sn, Sb) were analyzed using Inductively Coupled Plasma Atomic Emission Spectrometer (ICP-AES-Thermo Electron IRIS INTREPID II XSP DUO) and Ions ($K^+$, $Na^+$, $SO_4^{2-}$, $NH_4^+$ and $NO_3^-$) using Ion chromatography (Metro-Ohm® Model:930-COMPACT IC).

### *2.2 Risk assessment*

Under this section the parameters studied for risk assessment will be discussed. (Prakash et al. 2018; Singh and Gupta 2016)

### 2.2.1 Lifetime average daily dose

Lifetime average daily dose $LADD_{inh}$ (mg/(kg day)) is the amount of pollutant which is inhaled by a person when exposed to the pollutant.

$$LADD_{inh} = \frac{C_{pm} \times Inh \times Exp_f \times Exp_d \times CF}{Bwt \times Avg_t} \quad (1)$$

where,

$C_{pm}$ is the metal concentration (μg/m$^3$ calculated per day),

Inh is the rate of inhalation (adult: 20 m$^3$/day, child= 10 m$^3$/day),

$Exp_f$ is the exposure frequency 350 days/year,

$Exp_d$ is the exposure duration in years (adult = 24; child = 6),

CF is the correction factor (0.001),

Bwt is the body weight (adult: 70 kg ; child: 15 kg),

$Avg_t$ is 25,550 days for both adult and child.

### 2.2.2 Non-carcinogenic risk

Hazard quotient and hazard index are the two parameters used to access any inauspicious health effect during a lifetime. Hazard quotient is a comparison of $LADD_{inh}$ with the permissible values $Ref_{inh}$ for each metal obtained from the United States Environment Protection Agency (USEPA). It is given as follows.

$$Haz\ Q = \frac{LADD_{inh}}{Ref_{inh}} \quad (2)$$

If Haz Q < 1, there would not be any adverse health effects but if Haz Q >1, it is likely to cause an adverse effect on the human body. Hazard index is the summation of Haz Q of all metals at a particular sampling site.

$$Haz\ I = \sum Haz\ Q$$

If Haz I < 1, there is no significant non-carcinogenic effects but if Haz I > 1 there is a higher probability of health risk which increases with an increase in the value of Haz I.

### 2.2.3 Cancer risk

The probability of developing cancer over a lifetime exposure to the pollutant was found using excess cancer risk (ECR) expressed as follows.

$$ECR = \frac{C_{pm} \times Inh \times Exp_f \times Exp_d \times CF \times Risk_{inh}}{Bwt \times Avg_t} \quad (3)$$

$Risk_{inh}$ is the unit inhalation risk specified for each element (μg/m$^3$)$^-$1. As suggested by USEPA, values below $10^{-6}$ are acceptable and below $10^{-4}$ are tolerable. But values above $10^{-4}$ shows there is a chance of development of cancer on exposure to the $PM_{10}$ levels and the risk increases with an increase in the value of ECR.

### 2.2.3 Risk apportionment

Risk contributed by a particular source is found using the equation given below.

$$Risk = \sum X_{mn} \times Risk_{inh} \quad (4)$$

where

$X_{mn}$ is the average concentration of m species in source n

## 3. Results and Discussion

Lifetime average daily dose values ($LADD_{inh}$) mg/(kg day) at the sampling site shows that Fe was inhaled the most into the body followed by K > Na > Ca > Pb> Mg in case of both adult and child. $LADD_{inh}$ for adult and child for Fe were obtained as 0.025726 mg kg$^{-1}$ day$^{-1}$ and 0.06 mg kg$^{-1}$ day$^{-1}$ respectively. It was noticed that at all sites $LADD_{inh}$ child was two times that of $LADD_{inh}$ adult. This conveyed that children were more prone to the detrimental effects of particulate pollution.To find the risk associated with species exposure, $LADD_{inh}$ values were compared with the reference acceptable exposure levels. Ref.inh was taken from supplementary information of paper written by Jaiprakash (Prakash et al. 2018). Hazard quotients were found for Cr, Cu, Mn, Ni, and Zn. The values obtained were plotted on a log graph. Figure. 2 shows that, Mn and Cr (both child and adult) values are greater than one, signifies that they may adversely affect human health. Ni, Cu, and Zn showed values lesser than one. Hazard index values were found as 61.2 for adults and 126.18 for child.ECR helps in finding out the chance of developing cancer due to lifetime exposure to the pollutants. Carcinogenic species like Cr and Ni were considered for finding out ECR. Safe limit of $10^{-6}$ was crossed for both adult and child. All the values of ECR can be read from Figure 3. Cr showed a high value of $6.67 \times 10^{-3}$ for child and $2.86 \times 10^{-3}$ for adult. ECR-Ni adult values were within tolerable limits. ECR (child) values were found to be 2 times higher than ECR (adult). Source apportionment gives the percentage of mass contributed by each source to the total measured mass. Similarly, a risk assessment was done to find out the percentage contribution of risk from each source. Almost 92.5% of the risk is due to smelting activities. Remaining risk is caused collectively by wood residue burning and paved road dust.

## 4. Conclusion

Risk assessment studies suggested that the sampling site is not completely safe to live in. Even though Fe is the species which is most inhaled, the health effects are tolerable. Mn and Cr showed non-carcinogenic effects and Cr and Ni values suggested the chance of developing cancer on those who are exposed. In all cases, children were more susceptible to risk compared to adults, almost 2.33 times higher. As they are more sensitive, the smaller dosage of toxic species can interfere with their body functioning. They are more vulnerable to risk than adults according to The World Health Organization. Among the predicted sources from source apportionment, smelting activities were found to be releasing harmful gases which can be detrimental to humans. In this study, not all the species were included. A detailed work considering more sites and species is recommended. However, the present observation provides a firm base for further investigations.

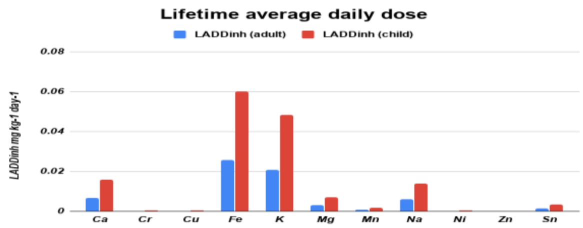


**Figure 1**. Life time average daily dose values

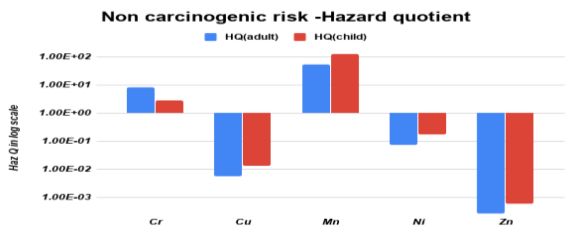


**Figure 2.** Hazard quotient values

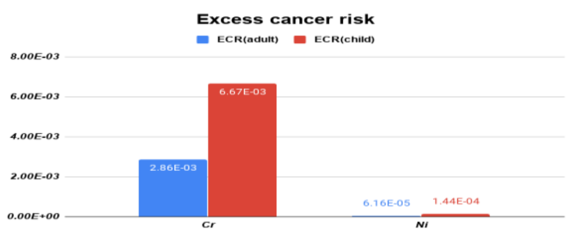


**Figure 3.** Excess cancer risk values

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