Project Completion Report

Project Title

"PREPARATION OF A DATA BANK ON GENERAL HEALTH STATUS OF THE POPULATION IN THE OPEN CAST COAL MINING AREAS OF ASSAM VIS-À-VIS THEIR EXPOSURE TO DUST IN AMBIENT AIR."

Sponsored by

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Executive Summary

- There is a large body of evidence suggesting that exposure to air pollution, even at very minor levels, leads to adverse health effects. In particular, exposure to pollutants such as particulate matter has been found to be associated with increases in hospital admissions for cardiovascular and respiratory disease and mortality in many countries.

- Increasingly sensitive epidemiological studies in several countries under the auspices of WHO have identified adverse effects from air pollution at increasingly lower levels. It is found that the threshold value for a particular air pollutant like PM is a function of the endpoint (death, diminished pulmonary function, etc.), the nature of the responding population (from the most healthy to the most ill), as well as the time at which the response is measured (immediate vs. delayed or accumulated).

- The present study examines the mortality patterns of coal miners i.e. whether there is an excess mortality generally or for some diseases among the coal miners or whether the open cast mining contributes towards the increase in mortality rates of the coal miners.

- North Eastern Coalfields, Coal India Limited in Tinsukia district of Assam was selected as the study location.

- The potential sources of air pollution in the area are Drilling and blasting,Loading and unloading of coal and overburden (OB),The movement of heavy vehicles on haul roads, Dragline operations,Crushing of coal in feeder breakers, Wind erosion, Presence of fire and Exhaust of heavy earthmover machinery (HEMM).

- Total suspended particulate matter (SPM) concentration was found to be as high as 1035 µg/m3 and respirable particulate matter (PM_{10}) 265.85 µg/m3. During the monsoon for the month of September and October and when there was no coal mining activities the SPM concentration was found to be the lowest and consequently PM_{10} values also.

- The concentration of PM_{10} exceeded the permissible limit (150 µg/m3) during the winter and during that time coal mining was operated actively. Karl Pearson's co-efficient of correlation was conducted to test the correlation between SPM and PM_{10}. T-test was conducted to test the significance of the correlations. It was observed during the study that the variations of 24-h simultaneous SPM and PM10 concentrations data were most highly correlated during March, 2012 ($r=0.94$, $t=7.29$, $P<0.0002$).

- More than 8000 patients records maintained by the hospital authority were collected from the three hospitals Viz. ESIC Hospital, Mergherita Civil Hospital and Health centre of Margherita Coal mining area of Assam. Confounding Factors were patients with minor diseases like Cough, cold, dysentery etc.Patients having major diseases like Brain Tumour, Gold Bladder Stone, Eye disorders etc were considered along with the Lung diseases and skin diseases

- Out of the total patients suffering from lung disease the highest percentage was found in health centre(43%) whereas out of the total patients suffering from skin disease the highest percentage was reported from in ESIC(47.47%).

- Results indicate that PM10 and associated metals are one of the major causes for deterioration of ambient air quality

- The present study suggests that it is necessary to monitor the air quality as well as the health effects at regular intervals at strategic locations.

- Awareness programme for open cast coal mining activities must be conducted.

- Considering the severe non response from the respondents, a well planned strategy must be prepared for collection of effective primary data.

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Introduction

Title: Preparation of a data bank on general health status of the population in the open cast coal mining areas of Assam vis-à-vis their exposure to dust in ambient air.

There is a large body of evidence suggesting that exposure to air pollution, even at very minor levels, leads to adverse health effects. In particular, exposure to pollutants such as particulate matter has been found to be associated with increases in hospital admissions for cardiovascular and respiratory disease and mortality in many countries. Recent studies have tried to quantify the health effects caused by ambient air pollution; e.g., within the "Global Burden of Disease" project of the World Health Organization (WHO) it has been estimated that worldwide, close to 6.4 million years of healthy life are lost due to long-term exposure to ambient particulate matter.

Increasingly sensitive epidemiological studies in several countries under the auspices of WHO have identified adverse effects from air pollution at increasingly lower levels. It is found that the threshold value for a particular air pollutant like PM is a function of the endpoint (death, diminished pulmonary function, etc.), the nature of the responding population (from the most healthy to the most ill), as well as the time at which the response is measured (immediate vs. delayed or accumulated).

Airborne particulate matter represents a complex mixture of organic and inorganic substances. Mass and composition in urban environments tend to be divided into two principal groups: coarse particles and fine particles. The barrier between these two fractions of particles usually lies between 1 µm and 2.5 µm. However, the limit between coarse and fine particles is sometimes fixed by convention at 2.5 µm in aerodynamic diameter (PM2.5) for measurement purposes. The smaller particles contain the secondarily formed aerosols (gas-to-particle conversion), combustion particles and recondensed organic and metal vapours. The larger particles usually contain earth crust materials and fugitive dust from roads and industries. The fine fraction contains most of the acidity (hydrogen ion) and mutagenic activity of particulate matter, although in fog some coarse acid droplets are also present. Whereas most of the mass is usually in the fine mode (particles between 100 nm and 2.5 µm), the largest number of particles is found in the very small sizes, less than 100 nm. As anticipated from the relationship of particle volume with mass, these so-called ultrafine particles often contribute only a few % to the mass, at the same time contributing to over 90% of the numbers.

Particulate air pollution is a mixture of solid, liquid or solid and liquid particles suspended in the air. These suspended particles vary in size, composition and origin. It is convenient to classify particles by their aerodynamic properties because:

a) These properties govern the transport and removal of particles from the air;
b) They also govern their deposition within the respiratory system and
c) They are associated with the chemical composition and sources of particles.

These properties are conveniently summarized by the aerodynamic diameter that is the size of a unit density sphere with the same aerodynamic characteristics. Particles are sampled and described on the basis of their aerodynamic diameter, usually called simply the particle size. The size of suspended particles in the atmosphere varies over four orders of magnitude, from a few nanometres to tens of micrometers. The largest particles, called the coarse fraction, are mechanically produced by the break-up of larger solid particles. These particles can include wind-blown dust from agricultural processes, uncovered soil, unpaved roads or mining operations. Traffic produces road dust and air turbulence that can stir up road dust. Near coasts, evaporation of sea spray can produce large particles. Pollen grains, mould spores, and plant and insect parts are all in this larger size range. The amount of energy required to break these particles into smaller sizes increases as the size decreases, which effectively establishes a lower limit for the production of these coarse particles of approximately 1 μm. Smaller particles, called the fine fraction, are largely formed from gases. The smallest particles, less than 0.1 μm, are formed by nucleation, that is, condensation of low-vapour-pressure substances formed by high-temperature vaporization or by chemical reactions in the atmosphere to form new particles (nuclei). Four major classes of sources with equilibrium pressures low enough to form nuclei mode particles can yield particulate matter:

- heavy metals (vaporized during combustion),
- elemental carbon (from short C molecules generated by combustion),
- organic carbon and
- sulfates and nitrates.

Particles in this nucleation range grow by coagulation of two or more particles to form a larger particle, or by condensation of gas or vapour molecules on the surface of existing particles. Coagulation is most efficient for large numbers of particles, and condensation is most efficient for large surface areas. Therefore the efficiency of both coagulation and condensation decreases as particle size increases, which effectively produces an upper limit such that particles do not grow by these processes beyond approximately 1 μm. Thus particles tend to "accumulate" between 0.1 and 1 μm, the so-called accumulation range.

Sub micrometer-sized particles can be produced by the condensation of metals or organic compounds that are vaporized in high-temperature combustion processes. They can also be produced by condensation of gases that have been converted in atmospheric reactions to low vapour- pressure substances. For example, sulphur dioxide is oxidized in the atmosphere to form sulphuric acid (H2SO4), which can be neutralized by NH3 to form ammonium sulfate. Nitrogen dioxide (NO2) is oxidized to nitric acid (HNO3), which in turn can react with ammonia (NH3) to form ammonium nitrate (NH4NO3). The particles produced by the intermediate reactions of gases in the atmosphere are the secondary particles. Secondary sulphate and nitrate particles are usually the dominant component of fine particles. Combustion of fossil fuels such as coal, oil and petrol can produce coarse particles from the release of non-combustible materials, i.e. fly ash, fine particles from the condensation of materials vaporized during combustion, and secondary particles through the atmospheric reactions of sulphur oxides and nitrogen oxides initially released as gases.

It has been found in Europe that sulfate and organic matter are the two main contributors to the annual average PM10 and PM2.5 mass concentrations, while in some places mineral dust (including trace elements) can also be a main contributor to PM10. On days when PM10 > 50 μg/m3, nitrate becomes also a main contributor to PM10 and PM2.5. Black carbon contributes 5–10% to PM2.5 and somewhat less to PM10.

Epidemiological studies so far have shown an increase in mortality with an increase in fine PM and sulfate. Studies by the American Chemical Society have found significant increases of relative risks for cardiopulmonary and lung cancer deaths with increasing levels of PM2.5. TSP and coarse particles

(PM15 – PM2.5) in ambient air. Significant effects of PM10 on nonmalignant respiratory deaths in men and women and on lung cancer mortality in men have also been reported. The relationship between air pollution and lung cancer has also been reported in a large number of case studies. It has also been shown that lung function growth in children is reduced in areas with high PM concentrations and that the lung function growth rate changes in step with relocation of children to areas with higher or lower PM concentrations than before.

The mortality and morbidity studies in many parts of the world, particularly in USA and Europe have shown, much more clearly than before, that cardiovascular deaths and morbidity indicators are related to ambient PM levels. Recent works on relations between PM and arteriosclerosis provides an interesting background to observed relations between PM and mortality. Possibly, ultrafine particles (smaller than 100 nm) play a role here, as these may be relocated from the respiratory system. The general conclusion from these studies is that long-term exposure to PM may lead to a marked reduction in life expectancy, which is primarily due to increased cardio-pulmonary and lung cancer mortality. Increases are also likely in lower respiratory symptoms and reduced lung function in children, and chronic obstructive pulmonary disease and reduced lung function in adults.

Epidemiological studies on large populations have been unable to identify a threshold concentration below which ambient PM has no effect on health. It is likely that within any large human population, there is such a wide range in susceptibility that some subjects are at risk even at the lowest end of the concentration range. In short-term studies, elderly subjects, and subjects with pre-existing heart and lung disease have been found to be more susceptible to effects of ambient PM on mortality and morbidity. Thus, asthmatics have been shown to respond to ambient PM with more symptoms, larger lung function changes and with increased medication use than non-asthmatics. In long-term studies, it has been found that socially disadvantaged and poorly educated populations respond more strongly in terms of mortality. No consistent differences have been found between men and women.

There is strong evidence to conclude that fine particles (< 2.5 _m, $PM_{2.5}$) are more hazardous than larger ones (coarse particles) in terms of mortality and cardiovascular and respiratory diseases. This does not imply that the coarse fraction of PM_{10} is innocuous. In toxicological and controlled human exposure studies, several physical, biological and chemical characteristics of particles have been found to elicit cardiopulmonary responses. Amongst the characteristics found to be contributing to toxicity in epidemiological and controlled exposure studies are metal content, presence of PAHs, other organic components, endotoxin and both small (< 2.5 μm) and extremely small size (< 100 nm).

There is increasing evidence that soluble metals may be an important cause of the toxicity of ambient PM. Water-soluble metals have consistently been shown to contribute to cell injury and inflammatory changes in the lung. The transition metals are also important components concerning PM-induced cardiovascular effects. Transition metals enhance the inflammatory effect of ultrafine particles. However, it has not been established that the small metal quantities associated with ambient PM in most environments are sufficient to cause health effects. Metals considered to be relevant are iron, vanadium, nickel, zinc and copper. In a comparative study of pulmonary toxicity of the soluble metals found in urban particulate dust, it has recently been reported that zinc, and to a lesser degree copper, induced lung injury and inflammation, whereas the responses to nickel, iron, lead and vanadium were minimal.

Many studies have shown that coal-processing chemicals, equipment powered by diesel engines, explosives, toxic impurities in coals, and even dust from uncovered coal trucks, coal dumps and open cast mining can cause negative affect on health. The people in coal mining communities have

- 70 percent increased risk for developing kidney disease,
- 64 percent increased risk for developing chronic obstructive pulmonary disease (COPD) such as emphysema and
- 30 percent more likely to report high blood pressure (hypertension).

In India, coal production will have to be increased to meet the energy demand over the next 20–25 years at the rate of 20–25 Mt/year. To meet the energy demand and overall coal production, opencast coal mining has grown at a phenomenal rate, and in 1995–96, when the country produced 274 Mt, the opencast mines accounted for 68% of the coal production in the country (Kumar 1995). By 2000, the coal production from surface mining rose to 250 Mt, which was about 70% of the total coal production. In underground coal mining, the miners suffer from coal dust inside the workings but, in surface mining, the air pollution problem is much more acute, particularly with respect to dust pollutants. In opening an opencast mine, massive overburden (OB) has to be removed to reach the mineral deposit (Ghose 1989). This may require excavators, loaders, dumpers, and conveyor belts,which results in massive discharge of fine particulates from OB material. Similarly, normal operation will require excavation, size reduction, waste removal,transportation, loading, and stockpiling. All will release particulate matter. Closure of the mine is similar to that of opening, but for a shorter period. It is reported (Cowherd 1979) that vehicular traffic on haul roads of mechanized opencast mines could contribute as much as 80% of the dust emitted. It has been estimated (Chadwick et al. 1987) that about 50% of total coal dust released is during journey time on an unpaved haul road, while 25% is released during loading and unloading of dumpers. Drilling is perhaps the next important source of fugitive dust (Nair and Sinha 1987). Finally, another major source of fugitive dust is due to wind erosion from coal stockpiles. Generally, the fines produced by surface coal mining operations contain coal particles, shale and dust particles (Addis et al. 1984). The average size of fines produced depends on different working sites. It has also been reported that coal mining particulates are respirable in nature and hazardous to human health. Lead concentration in total suspended particulate matter (TSP) were also found to be hazardous to human health. As the production of coal by opencast mining is growing, it is essential to evaluate its impact on the air environment and also to assess the characteristics of the emitted airborne dust, which is harmful to human health and vegetation. (Ghosh and Majee 2007)

Objective of the project

To analyze the mortality patterns of coal miners i.e. whether there is an excess mortality generally or for some diseases among the coal miners or whether the open cast mining contributes towards the increase in mortality rates of the coal miners.

Methodology including target population and sample size:

Work zone air quality monitoring stations were selected near the operating sources of air pollution. Work zone (around the source of air pollution) air quality had been studied to assess the impact on the workers performing their duties in the work zone and also to see how much dust generated is getting dispersed into the atmosphere to increase levels of ambient air pollution. As the study is surrounded by a number of coal mines and their allied activities it is essential to know the background air pollution level in order to assess the actual contribution of pollutants by this study.

The Study Area: Coal mining in Margherita coalfield (MCF)

Coal exploration started intensively in Tinsukia district of Assam in 1925. Coal mining activities of North Eastern Coalfields, Coal India Limited are at present confined to Makum coalfields in Tinsukia District of Assam. Out of 259.37 Million tonnes of proved coal reserve in Assam, Makum Coalfields has 249.65 Million tonnes of coal reserved. Minning of Coal in the Makum Coal fields was started by the Assam Railways & Trading Company at Ledo Colliery in 1882. The Coal Mines were Nationalized in 1973 under coal Mines (Nationalisation) Act1973 and the coal Mines in Makum coalfields went under Coal Mines Authority Ltd. Coal India Ltd. was formed in November 1975 and since then the coal mines in the Makum coalfields are being managed by Coal India Ltd.

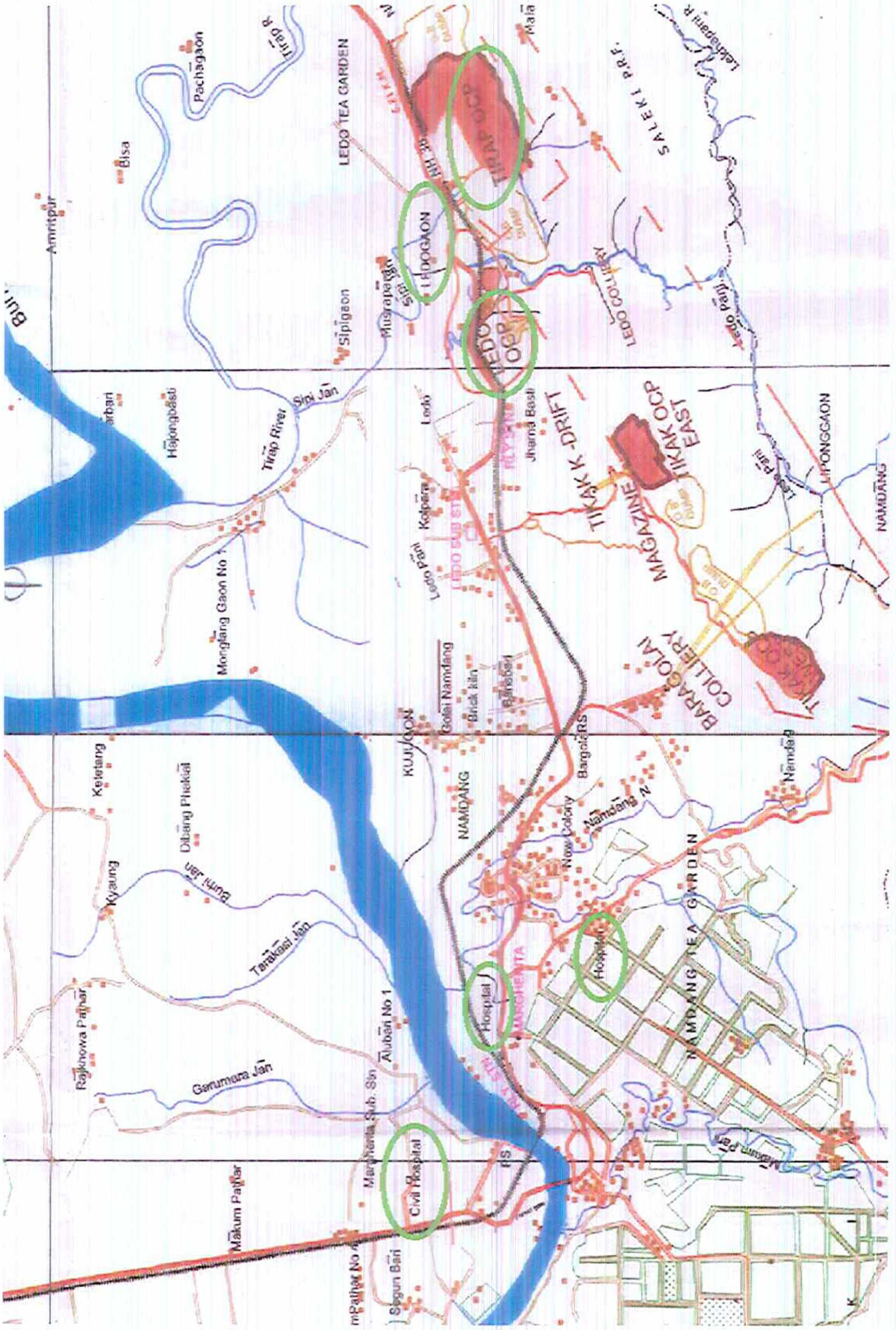


Fig. 1 Locations of the ambient air monitoring stations in the study area

NEC coal is of Tertiary age (Eocene to Oligocene, 40-55 million years) younger than the deposits of Jharkhand belt, Bihar. The coal with high calorific value ranging from 6500-7500 kcal/kg (Grade A) is of high quality characterized by very low ash content, high sulphur, high volatile matter and high coking index. Hence, it has got high demand for coal liquefaction plant and as blendable coal in steel industry. Out of total 257 BT Indian coal reserves, only 0.94 BT occur in the North Eastern Region which constitutes 0.37% share of Indian coal reserves (up to 1200 m. depth as in 2007). After nationalization, the mining operations were confined to Makum and Dilli-Jeypore Coalfields of Margherita Area in Assam. At present there are fove working mines, 1 underground and 4 opencast mines.

The area experiences sultry humid simmer during the months of May and June and a fairly cold weather during December and January. The minimum temperature in the winter falls up to 4^0 C and the maximum summer temperature rises up to 42^0C. The average humidity ranges from 87 to 91 % during the wet months. The area experiences a very high annual precipitation from 300 to 425 cm and bulk of the precipitation is in the months from April to September. However, except for December, January and February all the rest months experience certain amount of rainfall either in the form of torrential showers or drizzles.

The potential sources of air pollution in the area are

- Drilling and blasting
- Loading and unloading of coal and overburden (OB)
- The movement of heavy vehicles on haul roads
- Dragline operations
- Crushing of coal in feeder breakers
- Wind erosion
- Presence of fire
- Exhaust of heavy earthmover machinery (HEMM).

Ambient air quality monitoring with respect to PM10 and SPM and trace metals associated with PM10 has been done at two stations located in one open cast coal mining field viz., Ledo coal field and one residential area of Ledo coal mining zone. Air samples were collected for 24 h in three 8-h periods corresponding to daytime, evening and night time for nine days in a month (Merefield et al. 1995). For the collection of PM10 samples and SPM samples , glass fiber ambient (GF/A) filter paper was used in a Respiratory dust sampler (RDS) IS: 5182 (Part IV), 1987 manufactured by M/S Envirotech, New Delhi. The collected PM10 was analyzed for metals like Cu,Cd,Cr,Mn,Zn,Ni,,Fe,Pb.

Picture1: Respiratory Dust Sampler set up at LEDO OCP

Picture 2: Destructive area of LEDO OCP due to open cast coal mining

Picture 3: Coal dumping area at Ledo

Picture 4: Acid mine drainage due to open cast mining

Picture 5: Underground Coal mining and transportation of coal from underground

Picture 6: Coal mining Workers being interviewed

Extraction of metals from PM 10 filter paper

Acid digestion, required for the metals determination by Atomic absorption spectrophotometer (Atomic Absorption Spectrophotometer Shimadzu-7000) was carried out according to a standard procedure.. Following the procedure recommended by International Organization for Standardization, ISO 11466 (Melaku et al., 2005). After a 16-h room temperature digestion, samples were further digested at 130 _C, for 2 h under reflux conditions. Finally, the suspensions were filtered with ashless Whatman filter papers 42 and the filtrates were diluted to a final volume of 100 ml with 0.5 M HNO3 prior to further analysis.

A series of blanks were prepared using the same digestion method. Metals and reagents used for standard solutions were of AR grade.

The concentration of individual elements in the solution was determined by comparing the absorbance of the standard metal solution. Samples were directly introduced into the frame of continuous aspiration through polyethylene tubing and the concentration of the object element (μg/mL) was obtained from the calibration plot. The concentration of an element in the atmosphere is obtained from the following relation (Sinha and Banerjee, 1997):

$$C\left(\frac{\mu g}{m^3}\right) = \frac{\text{Concentration of the element in the digested sample } \left(\frac{\mu g}{mL}\right)}{Volume\ of\ air\ sample\ (m^3)} \times \frac{Total\ value\ of\ the\ sample\ (mL)}{Percent\ of\ filter\ area\ used\ for\ analysis}$$

Sample size

Secondary Data

More than 8000 patients records maintained by the hospital authority were collected from the three hospitals Viz. ESIC Hospital, Mergherita Civil Hospital and Health centre of Margherita Coal mining area of Assam. Confounding Factors were patients with minor diseases like Cough, cold, dysentery etc. Patients having major diseases like Brain Tumour, Gold Bladder Stone, Eye disorders etc were considered along with the Lung diseases and skin diseases.

Primary Data

A well structured questionnaire was prepared for collection of primary data from the selected sampling area .Accordingly 133 workers of the coal mining area were interviewed. However an extreme non response in case of disease suffer was faced from the respondent. Only nine out of the total respondents reported about disease suffering. In fact even the health facilities in the coal mining area maintained no record of relevant diseases. Because of this drawback the prevalence of the disease could not be ascertained.

Analysis of Data

Total suspended particulate matter (SPM) concentration was found to be as high as 1035 µg/m3 and respirable particulate matter (PM_{10}) 265.85 µg/m3. During the monsoon for the month of September and October and when there was no coal mining activities the SPM concentration was found to be the lowest and consequently PM_{10} values also. It is supported by various studies (Ravichandran et al., 1998; Kumar and Ratan, 2003; Sinha and Sreekesh, 2002; Reddy and Ruj, 2003; Huertas et al., 2012) that in coal mining areas SPM and PM10 are exceeding the standards (Table 1).Karl Pearson's co-efficient of correlation was conducted to test the correlation between SPM and PM_{10}. T-test was conducted to test the significance of the correlations. It was observed during the study that the variations of 24-h simultaneous SPM and PM_{10} concentrations data were most highly correlated during March, 2012 ($r=0.94$, $t=7.29$, $P<0.0002$ [two-tailed t-test for significance of correlation coeffeicient]. Correlation between SPM and PM_{10} were found to be significant (Table 1, 2 and 3) for all the moths except for the months of June and September. However, most probably it is because during that time there was no open cast mining because there is no open cast mining from the month of June upto the month of October due to rainy season. However there is heavy dumping of casted coal in all the surrounding areas of the mine and transportation is heavier during this time as there is no casting activity. Due to this reason the pollution does not decrease significantly despite no casting and rainfall. This is reflected in the correlation values of July which have been found to be significant ($r=0.79$, $t=2.88$, $P<0.03$). In recent years, epidemiological studies have shown association between ambient particulates matter concentration and health. Exposure to increased levels of particulate matter concentrations is related to increased mortality and a number of pulmonary effects, both acute and chronic (Roosli et al 2001 , Pagano et al 1998). It is worthy to note that mortality and respiratory and cardiovascular diseases will largely increase due to the presence of the higher concentrations of chemical pollutants in air in inversion occurs along with this condition.

Table 1. Results of PM10 concentrations in different urban cities

Locations	**PM10 (μg/m3)**	**Reference**
Colombo, Sri Lanka	50	Seneviratne et al. (2011)
Hongkong	105	He and Lu (2012)
Panzhihua, China	137	Yong-hua et al. (2010)
Zagreb, Croatia	36	Cackovic et al. (2008)
Oxford, USA	16	Wojas and Almquist (2007)
Nepal	61-120	Giri et al. (2007)
Kanpur, India	226	Gupta (2007)
Padampur OCP Chandrapur District, Maharashtra, India	103-226	Trivedi et al. (2007)
Erzurum, Turkey	31	Bayraktar et al. (2006)
Mumbai, India	61	Kumar and Joseph (2006)
Amsterdam, Finland	36	Vallius (2005)
Ibvalley, Orissa, India	46-291	Chaulya (2004)
Qalabotjha, South Africa	90	Engelbretch etal. (1999)

Table 2: Ambient air quality at Ledo OCP during July and September in the year 2011

Date	*PM (µg/m3)*	**SPM (µg/m3)**	Date	**PM (µg/m3)**	**SPM (µg/m3)**
15.07.11	*74.26*	121.03	20.09.11	94.25	152.23
17.07.11	*64.26*	110.20	22.09.11	72.20	123.25
19.07.11	*71.26*	106.35	24.09.11	54.26	105.63
21.07.11	*65.24*	108.26	26.09.11	65.23	106.52
23.07.11	*59.68*	110.32	28.09.11	84.26	112.03
Correlation Coefficient=0.49 t=0.97 , p=0.402				Correlation Coefficient=0.80 t=2.31,p=0.104	

Table 3: Ambient air quality at Tirap OCP during July and September in the year 2011

Date	***PM (µg/m3)***	**SPM (µg/m3)**	**Date**	**PM (µg/m3)**	**SPM (µg/m3)**
15.07.11	84.26	132.56	20.09.11	78.85	122.69
17.07.11	69.53	106.50	22.09.11	92.56	136.56
19.07.11	59.68	96.69	24.09.11	69.56	109.65
21.07.11	96.25	118.59	26.09.11	75.58	105.56
23.07.11	69.56	109.85	28.09.11	86.56	122.32
Correlation Coefficient=0.77 t=2.09 , p=0.13				Correlation Coefficient=0.89 t=3.38,p=0.043	

Table 4: Ambient air quality at Ledo OCP during different months

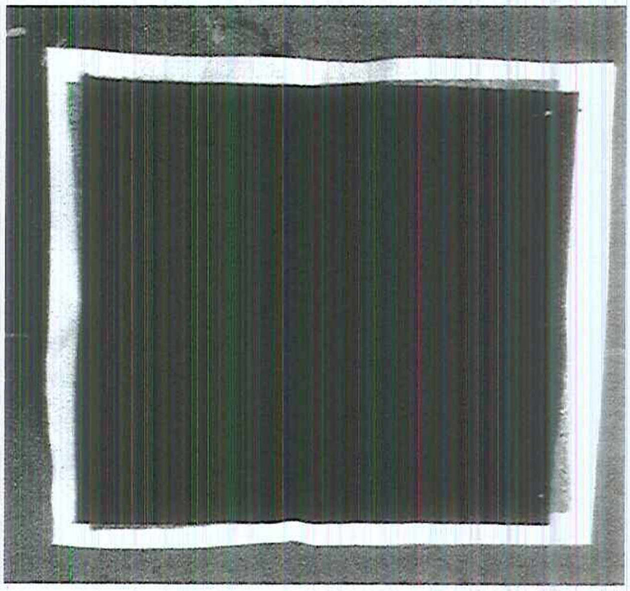
Date	PM (μg/m3)	SPM (μg/m3)	Date	PM (μg/m3)	SPM (μg/m3)
13.11.11	205.05	842.45	14.12.11	242.00	939.35
15.11.11	235.35	883.80	16.12.11	249.35	948.75
17.11.11	257.25	901.80	18.12.11	200.80	909.40
19.11.11	221.90	849.10	20.12.11	263.45	945.30
21.11.11	172.40	826.25	22.12.11	188.60	880.05
23.11.11	265.85	1035.50	24.12.11	201.85	909.15
25.11.11	241.05	884.65	26.12.11	174.35	838.15
27.11.11	225.65	859.35	28.12.11	188.50	879.25
29.11.11	232.40	879.90	30.12.11	237.80	943.70
Correlation Coefficient=0.78 t=3.3 , p=0.01			Correlation Coefficient=0.93 t=6.69,p=0.0002		
06.01.12	159.90	835.10	13.02.2012	174.80	813.55
08.01.12	214.25	905.80	15.02.2012	189.75	916.75
10.01.12	207.30	849.65	17.02.2012	168.15	801.40
12.01.12	159.95	808.90	19.02.2012	212.15	914.70
14.01.12	207.60	883.75	21.02.2012	162.50	709.70
16.01.12	213.70	905.70	23.02.2012	171.45	816.15
18.01.12	236.80	918.45	25.02.2012	185.30	845.80
20.01.12	230.85	919.65	27.02.2012	188.60	933.60
22.01.12	242.45	932.15	29.02.2012	180.20	853.30
Correlation Coefficient =0.93 t=6.69,p=0.0002			Correlation Coefficient =0.84 t=4.1,p=0.005		

Table 5: Ambient air quality at Ledo OCP during different months

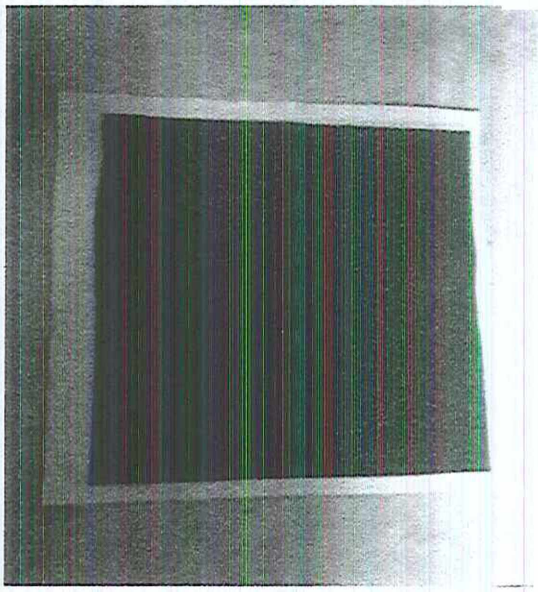
Date	PM (µg/m3)	SPM (µg/m3)	Date	PM (µg/m3)	SPM (µg/m3)
03.03.2012	193.20	814.90	03.04.2012	190.60	847.45
05.03.2012	205.30	846.90	05.04.2012	253.10	819.60
07.03.2012	192.90	833.10	07.04.2012	162.55	821.40
09.03.2012	186.65	802.30	09.04.2012	196.35	824.40
11.03.2012	199.15	811.05	11.04.2012	186.70	817.90
13.03.2012	212.00	857.70	13.04.2012	128.25	763.40
15.03.2012	166.70	733.70	15.04.2012	200.15	831.55
17.03.2012	192.45	813.55	17.04.2012	195.40	852.55
19.03.2012	198.65	812.90	19.04.2012	193.70	820.95
Correlation Coefficient=0.94 t=7.29,p=0.0002				Correlation Coefficient=0.56 t=1.79,p=0.1	
02.05.2012	192.30	827.60	05.06.2012	173.40	854.50
04.05.2012	237.35	888.65	07.06.2012	167.80	911.60
06.05.2012	196.20	823.60	09.06.2012	156.90	830.30
08.05.2012	188.60	835.05	11.06.2012	149.15	802.55
10.05.2012	187.15	853.75	13.06.2012	160.50	830.45
12.05.2012	191.70	779.40	15.06.2012	188.85	809.05
14.05.2012	179.80	838.35	17.06.2012	136.80	746.50
16.05.2012	180.85	845.85	19.06.2012	183.30	827.80
18.05.2012	150.30	801.00	21.06.2012	161.50	791.05
Correlation Coefficient =0.63 t=2.15, p=0.07				Correlation Coefficient =0.47 t=1.41,p=0.2	

Table 6: Ambient air quality at Ledo OCP during different months

Date	PM (µg/m3)	SPM (µg/m3)	Date	PM (µg/m3)	SPM (µg/m3)
17.07.12	44.66	112.00	06.09.12	92.28	138.50
19.07.12	43.55	141.00	09.09.12	97.81	200.00
21.07.12	63.05	166.00	13.09.12	88.81	165.00
23.07.12	46.00	147.50	17.09.12	88.43	129.50
25.07.12	52.15	152.50	20.09.12	96.06	152.00
27.07.12	71.85	169.00	Correlation Coefficient =0.64 t=1.44, p=0.25		
29.07.12	50.42	147.00			
Correlation Coefficient =0.79 t=2.88, p=0.03					



Picture 7: Shows high amount of PM10 deposit



Picture 8: Less amount of PM10 deposit

Airborne particulate matter, which is composed of a broad class of chemically and physically diverse substances are variable in size, chemical composition, formation, origin and concentration, and is variable across space and time. Health effects associated with particulate matter (PM) are linked to respiratory, cardiovascular problems and premature mortality (Callen et al., 2009). The particulates may include a broad range of chemical species, ranging from metals to organic and inorganic compounds (Tsai and Cheng, 2004; Park and Kim, 2005). Among the inorganic compounds, most important ones are the trace metals, which are emitted by various natural and anthropogenic sources such as crustal materials, road dust, construction activities, motor vehicles, coal and oil combustion, incineration and other industrial activities (Watson et al., 2002; Quiterio et al., 2004; Arditsoglou and Samara 2005; Shah et al., 2006; Shah and Shaheen 2010). The airborne particulates and related trace metals have been linked with both acute and chronic adverse health effects which mostly include respiratory diseases, lung cancer, heart diseases and damage to other organs (Prieditis and Adamson, 2002; Magas et al., 2007; Wild et al., 2009). Numerous epidemiological studies have shown a correlation between elevated levels of airborne particulates and increased rate of morbidity and mortality (Pope, 2000; Shah, 2009). A number of studies conducted in the coal mining areas showed higher ambient particulate concen-trations (Ghose and Majee, 2002; Sinha and Sreekesh, 2002; Suman et al., 2007).In our study on the average,PM10 associated elemental concentration trend was: Fe>Zn>Cu>Mn>Cr> Pb>Ni >Cd.

Table 7: Concentration of metal (µg/m3) in the month of July 2011 associated with PM10 at Ledo OCP

July 11								
PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
74.26	0.985	0.005	0.006	0.002	0.046	0.437	0.004	0.026
64.26	0.711	0.004	0.004	0.001	0.046	0.345	0.004	0.022
71.26	0.980	0.003	0.005	0.003	0.035	0.365	0.010	0.021
65.24	0.683	0.005	0.005	0.003	0.030	0.244	0.006	0.006
59.68	0.896	0.002	0.005	0.003	0.040	0.362	0.004	0.016

Table 8 : Concentration of metal (µg/m3) in the month of September 2011 associated with PM10 at Ledo OCP

September 2011								
PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
94.25	1.280	0.008	0.008	0.004	0.043	0.95	0.009	0.037
72.2	0.608	0.003	0.002	0.002	0.046	0.314	0.004	0.027
54.26	0.950	0.004	0.006	0.004	0.040	0.585	0.005	0.026
65.23	0.783	0.005	0.005	0.004	0.030	0.365	0.007	0.016
84.26	0.863	0.004	0.006	0.004	0.032	0.326	0.005	0.016

Table 9 : Concentration of metal (µg/m3) in the month of July 2011 associated with PM10 at Tirap OCP

July 2011								
PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
84.26	0.985	0.005	0.007	0.004	0.035	0.371	0.006	0.030
69.53	0.711	0.003	0.004	0.003	0.029	0.450	0.006	0.022
59.68	0.980	0.003	0.006	0.003	0.028	0.365	0.007	0.021
96.25	1.088	0.003	0.006	0.003	0.031	0.444	0.008	0.026
69.56	0.896	0.002	0.006	0.004	0.040	0.362	0.004	0.016

Table 10 : Concentration of metal (µg/m3) in the month of September 2011 associated with PM10 at Tirap OCP

September 2011								
PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
78.85	0.965	0.007	0.008	0.002	0.049	0.637	0.005	0.026
92.56	1.02	0.006	0.008	0.003	0.039	0.645	0.008	0.030
69.56	0.69	0.004	0.006	0.003	0.026	0.365	0.007	0.021
75.58	0.98	0.006	0.005	0.003	0.030	0.544	0.006	0.006
86.56	0.85	0.005	0.006	0.003	0.021	0.518	0.007	0.016

Table 11: Concentration of metal (µg/m3) in the month of December 2011 associated with PM10

Dec 11								
PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
242.00	8.51	0.040	0.106	0.046	0.263	3.05	0.088	1.59
249.35	8.79	0.021	0.535	0.066	0.392	3.88	0.090	1.63
200.80	7.24	0.008	0.130	0.058	0.131	3.26	0.101	1.56
263.45	9.02	0.010	0.084	0.065	0.412	3.71	0.195	2.59
188.60	8.10	0.008	0.058	0.050	0.405	3.46	0.102	1.59
201.85	7.29	0.017	0.054	0.065	0.337	3.66	0.102	1.61
174.35	6.70	0.010	0.088	0.059	0.358	2.02	0.097	1.62
188.50	9.95	0.009	0.077	0.067	0.336	3.63	0.112	1.59
237.80	8.16	0.007	0.067	0.064	0.345	2.49	0.097	1.36

Table 12: Concentration of metal (µg/m3) in the month of January2012 associated with PM10

Jan '12								
PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
159.90	7.78	0.008	0.063	0.029	0.170	2.50	0.150	1.09
214.25	7.14	0.006	0.070	0.027	0.129	2.13	0.171	1.11
207.30	7.74	0.016	0.091	0.032	0.146	1.56	0.152	1.08
159.95	7.12	0.008	0.085	0.040	0.190	2.31	0.091	1.01
207.60	7.48	0.011	0.070	0.039	0.211	3.04	0.109	1.03
213.70	7.05	0.015	0.071	0.035	0.108	2.58	0.110	1.03
236.80	7.94	0.010	0.081	0.036	0.171	2.83	0.130	1.01
230.85	7.82	0.008	0.091	0.033	0.255	3.04	0.133	1.20
242.45	7.92	0.020	0.094	0.042	0.245	3.10	0.190	1.50

Table 13 : Concentration of metal (µg/m3) in the month of February 2012 associated with PM10

Feb'12								
PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
174.80	7.77	0.013	0.051	0.022	0.226	2.88	0.152	1.08
189.75	7.38	0.011	0.083	0.017	0.358	3.39	0.158	1.02
168.15	7.97	0.022	0.072	0.018	0.375	2.74	0.124	1.01
212.15	8.93	0.028	0.091	0.022	0.377	3.48	0.162	1.13
162.50	7.69	0.011	0.061	0.022	0.374	3.24	0.153	1.00
171.45	7.30	0.008	0.044	0.019	0.315	3.24	0.140	1.07
185.30	9.14	0.015	0.057	0.024	0.394	2.98	0.157	1.02
188.60	7.68	0.022	0.069	0.022	0.310	3.51	0.153	1.21
180.20	6.77	0.023	0.041	0.017	0.422	3.47	0.130	1.03

Table 14 : Concentration of metal (µg/m3) in the month of March 2012 associated with PM10

March'12								
PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
193.20	6.63	0.018	0.066	0.014	0.191	3.41	0.110	1.19
205.30	7.40	0.026	0.080	0.020	0.178	3.08	0.248	1.24
192.90	5.87	0.011	0.068	0.023	0.252	3.43	0.210	1.13
186.65	6.78	0.023	0.042	0.016	0.193	2.96	0.204	1.34
199.15	7.49	0.012	0.066	0.028	0.210	3.30	0.250	1.18
212.00	7.75	0.025	0.081	0.029	0.289	3.52	0.266	1.25
166.70	6.26	0.015	0.070	0.024	0.205	2.62	0.160	1.03
192.45	5.88	0.015	0.075	0.021	0.285	2.59	0.265	1.12
198.65	5.31	0.018	0.064	0.025	0.202	3.62	0.212	1.21

Table 15: Concentration of metal (µg/m3) in the month of April 2012 associated with PM10

April'12								
PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
190.60	5.44	0.025	0.068	0.028	0.270	2.16	0.510	1.12
253.10	7.93	0.021	0.083	0.028	0.254	3.79	0.546	1.18
162.55	6.40	0.009	0.067	0.027	0.243	2.64	0.341	1.09
196.35	7.24	0.011	0.032	0.030	0.270	3.22	0.225	1.15
186.70	6.90	0.010	0.030	0.030	0.175	3.53	0.551	1.07
128.25	6.27	0.008	0.034	0.024	0.230	2.34	0.095	1.08
200.15	7.32	0.010	0.080	0.020	0.205	2.51	0.294	1.14
195.40	5.70	0.009	0.033	0.023	0.258	2.95	0.102	1.02
193.70	6.70	0.009	0.030	0.020	0.270	2.20	0.098	1.02

Table 16 : Concentration of metal (µg/m3) in the month May 2012 associated with PM10

May'12								
PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
192.30	4.43	0.101	0.030	0.045	0.215	3.15	0.511	1.03
237.35	6.90	0.092	0.035	0.040	0.196	3.52	0.456	1.27
196.20	6.31	0.129	0.022	0.047	0.175	2.94	0.302	1.05
188.60	6.11	0.079	0.034	0.051	0.212	1.80	0.204	1.06
187.15	5.90	0.060	0.039	0.059	0.229	2.81	0.575	1.21
191.70	5.37	0.080	0.031	0.046	0.150	3.23	0.403	0.93
179.80	5.47	0.082	0.031	0.049	0.215	2.71	0.550	1.04
180.85	6.26	0.082	0.024	0.037	0.208	2.76	0.111	1.06
150.30	5.53	0.067	0.021	0.032	0.165	2.14	0.113	1.02

Table 17: Concentration of metal (µg/m3) in the month of June 2012 associated with PM10

June'12								
PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
173.40	5.78	0.063	0.036	0.054	0.205	2.71	0.113	1.07
167.80	5.65	0.066	0.030	0.045	0.260	2.79	0.104	1.08
156.90	6.03	0.065	0.038	0.057	0.270	2.29	0.102	1.18
149.15	5.62	0.051	0.032	0.047	0.248	3.08	0.104	1.02
160.50	5.79	0.060	0.039	0.041	0.235	2.35	0.175	1.01
188.85	5.61	0.056	0.047	0.041	0.244	3.57	0.193	1.24
136.80	4.07	0.057	0.032	0.049	0.193	3.04	0.095	1.10
183.30	5.11	0.066	0.047	0.061	0.227	3.64	0.111	1.07
161.50	5.44	0.046	0.021	0.032	0.228	3.09	0.113	1.00

Table 18: Concentration of metal (µg/m3) in the month of July 2012 associated with PM10

	July'12							
PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
44.66	0.799	0.003	0.007	0.006	0.046	0.237	0.004	0.013
43.55	0.808	0.004	0.005	0.001	0.036	0.345	0.004	0.022
63.05	0.903	0.003	0.006	0.003	0.035	0.365	0.010	0.011
46.00	0.897	0.005	0.005	0.002	0.030	0.244	0.006	0.006
52.15	0.779	0.008	0.005	0.002	0.040	0.362	0.004	0.016
71.85	0.875	0.012	0.007	0.004	0.043	0.472	0.005	0.030
50.42	0.880	0.006	0.003	0.004	0.038	0.467	0.004	0.012

Table 19: Concentration of metal (µg/m3) in the month of September 2012 associated with PM10

	Sep'12							
PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
92.28	0.838	0.009	0.045	0.002	0.032	0.305	0.015	0.032
97.81	0.914	0.013	0.071	0.002	0.063	0.348	0.006	0.038
88.81	0.717	0.012	0.053	0.003	0.032	0.348	0.019	0.028
88.43	0.516	0.013	0.048	0.003	0.080	0.360	0.004	0.014
96.06	0.672	0.016	0.052	0.003	0.072	0.324	0.027	0.020

The data pertaining to the PM10 and metal correlations provided in Table 20- 31.* indicates significant at 5% and ** indicates significant at 1% of two tailed correlation coefficient.In our study it has been observed that there is a significant correlation between PM10 and Fe,Cd,Pb,Zn,Cr and Cu except Ni and Mn in all cases indicating heavy contamination by open cast coal mining.

Table No 20: Ledo July-2011: Co-relation coefficient matrix for PM10 And Trace metal

	PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
PM10	1	0.554*	0.579*	0.561*	0.125	0.193	0.505*	0.430*	0.555*
Fe		1	-0.246	0.802	0.325	0.254	0.812	0.361	0.642
Cd			1	0.163	0.072	-0.030	-0.149	-0.120	-0.090
Pb				1	0.686	-0.031	0.523	0.156	0.236
Ni					1	-0.734	-0.221	0.360	-0.491
Mn						1	0.770	-0.498	0.830
Zn							1	-0.063	0.924
Cr								1	0.046
Cu									1

Table 21: Ledo Sept-2011: Correlation coefficient matrix for PM10 and Trace metal

	PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
PM10	1	0.505*	0.504*	0.458*	0.027	0.093	0.422*	0.587*	0.473*
Fe		1	0.862	0.913	0.544	0.094	0.937	0.796	0.636
Cd			1	0.682	0.402	0.083	0.881	0.981	0.625
Pb				1	0.790	-0.260	0.717	0.647	0.287
Ni					1	-0.742	0.273	0.407	-0.276
Mn						1	0.389	-0.024	0.814
Zn							1	0.786	0.847
Cr								1	0.517
Cu									1

Table 22: Tirap July-2011: Correlation coefficient matrix for PM10 and Trace metal

	PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
PM10	1	0.552*	0.443*	0.454*	0.168	0.167	0.440*	0.474*	0.682**
Fe		1	0.191	0.792	0.191	0.084	-0.243	0.582	0.447
Cd			1	0.564	0.260	0.054	-0.207	-0.003	0.818
Pb				1	0.656	0.492	-0.587	0.058	0.472
Ni					1	0.967	-0.619	-0.676	-0.101
Mn						1	-0.480	-0.728	-0.260
Zn							1	0.410	0.228
Cr								1	0.507
Cu									1

Table 23: Tirap Sept-2011: **Correlation coefficient matrix for PM10 and Trace metal**

	PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
PM10	1	0.606*	0.580*	0.596*	0.164	0.151	0.696**	0.501*	0.421*
Fe		1	0.913	0.325	-0.330	0.607	0.939	-0.096	0.094
Cd			1	0.570	-0.500	0.770	0.983	-0.218	0.288
Pb				1	-0.525	0.659	0.608	0.375	0.924
Ni					1	-0.935	-0.438	0.173	-0.545
Mn						1	0.726	-0.161	0.566
Zn							1	-0.048	0.351
Cr								1	0.586
Cu									

Table No 24:Dec 11: Corelation coefficient matrix for PM10 And Trace metal

	PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
PM10	1	0.427*	0.403*	0.498*	0.138	0.182	0.416*	0.409*	0.476*
Fe		1	0.105	0.195	0.243	0.324	0.561	0.346	0.290
Cd			1	0.275	-0.490	-0.160	0.106	-0.310	-0.088
Pb				1	0.244	0.137	0.356	-0.226	-0.053
Ni					1	0.266	0.251	0.348	0.225
Mn						1	0.148	0.341	0.352
Zn							1	0.321	0.368
Cr								1	0.950
Cu									1

Table 25: Jan12: Correlation coefficient matrix for PM10 and Trace metal

	PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
PM10	1	0.488*	0.434*	0.452*	0.168	0.246	0.409*	0.410*	0.483*
Fe		1	0.266	0.413	0.098	0.567	0.319	0.465	0.448
Cd			1	0.482	0.471	0.088	0.058	0.354	0.576
Pb				1	0.436	0.524	0.018	0.202	0.519
Ni					1	0.520	0.511	-0.306	0.270
Mn						1	0.667	0.113	0.581
Zn							1	-0.068	0.381
Cr								1	0.740
Cu									1

Table 26: Feb12: Correlation coefficient matrix for PM10 and Trace metal

	PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
PM10	1	0.464*	0.552**	0.625**	0.111	0.154	0.546**	0.565**	0.523**
Fe		1	0.266	0.479	0.701	0.111	-0.275	0.510	0.100
Cd			1	0.372	-0.009	0.389	0.248	-0.159	0.403
Pb				1	0.004	0.148	0.195	0.479	0.233
Ni					1	-0.266	-0.181	0.570	0.310
Mn						1	0.261	-0.210	-0.438
Zn							1	0.339	0.460
Cr								1	0.332
Cu									1

Table 27: March 12: Correlation coefficient matrix for PM10 and Trace metal

	PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
PM10	1	0.446*	0.442*	0.398*	0.271	0.265	0.642**	0.576**	0.564**
Fe		1	0.500	0.228	0.188	-0.035	0.099	0.290	0.407
Cd			1	0.079	-0.191	-0.193	0.102	0.172	0.716
Pb				1	0.469	0.442	0.044	0.355	-0.410
Ni					1	0.425	0.253	0.570	-0.266
Mn						1	-0.031	0.529	-0.216
Zn							1	-0.029	0.377
Cr								1	0.230
Cu									1

Table 28: April'12: Correlation coefficient matrix for PM10 and Trace metal

	PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
PM10	1	0.545**	0.529**	0.437*	0.129	0.196	0.582**	0.472**	0.426*
Fe		1	-0.037	0.282	0.090	-0.249	0.614	0.261	0.559
Cd			1	0.565	0.409	0.339	0.119	0.684	0.574
Pb				1	-0.013	-0.002	0.033	0.546	0.688
Ni					1	-0.031	0.579	0.641	0.419
Mn						1	-0.265	-0.317	0.012
Zn							1	0.486	0.344
Cr								1	0.559
Cu									1

Table 29: May 12: Correlation coefficient matrix for PM10 and Trace metal

	PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
PM10	1	0.474**	0.407*	0.503**	0.170	0.134	0.678**	0.436*	0.607**
Fe		1	0.084	0.079	-0.082	-0.008	0.024	-0.277	0.614
Cd			1	-0.402	-0.084	-0.199	0.380	0.020	-0.102
Pb				1	0.693	0.531	0.201	0.692	0.537
Ni					1	0.485	-0.019	0.628	0.185
Mn						1	-0.114	0.386	0.504
Zn							1	0.572	0.277
Cr								1	0.330
Cu									1

Table 30: June'12: Correlation coefficient matrix for PM10 And Trace metal

	PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
PM10	1	0.4128	0.415*	0.591**	0.110	0.187	0.452*	0.515**	0.407*
Fe		1	0.172	0.101	-0.054	0.700	-0.431	0.296	0.064
Cd			1	0.568	0.736	0.211	-0.234	-0.091	0.333
Pb				1	0.529	0.090	0.280	0.526	0.583
Ni					1	-0.027	0.007	-0.418	0.269
Mn						1	-0.252	0.118	0.274
Zn							1	0.125	0.177
Cr								1	0.308
Cu									1

Table 31: July'12: Correlation coefficient matrix for PM10 and Trace metals

	PM10	Fe	Cd	Pb	Ni	Mn	Zn	Cr	Cu
PM10	1	0.453*	0.658**	0.409*	0.151	0.210	0.651**	0.406*	0.523**
Fe		1	0.073	-0.078	-0.084	-0.509	0.265	0.572	-0.234
Cd			1	0.078	0.031	0.231	0.665	-0.347	0.657
Pb				1	0.31	0.39	-0.32	0.320	0.35
Ni					1	0.823	-0.007	-0.178	0.104
Mn						1	0.146	-0.361	0.491
Zn							1	-0.079	0.560
Cr								1	-0.321
Cu									1

HEALTH EFFECTS

At elevated levels, all the pollutants including metals have adverse effects on human and environmental health. Accumulation of pollutants in the human body through inhalation of air is an important route. Results of the present study revealed that higher level of particulate matter especially the PM10 are more dangerous for human health and responsible for several cardiovascular and respiratory diseases such as asthma, bronchitis, reproductive development, increased risk of preterm birth and even mortality and morbidity rate. It is reported that the total daily mortality increased by approximately 1% for every 10 ug/m3 increase in PM10 concentration.

Human exposure to particulate air pollution has been identified as a risk factor for human mortality and morbidity and many countries have revised the limits for PM10 as previously defined. Nevertheless, PM thresholds levels to which exposure does not lead to adverse effects on human health have not yet been clearly identified and there is a substantial inter-individual variability in exposure and in the response and it difficult to established a standard or guideline value that will lead to a complete protection of every individual against all possible adverse health effects of particulate matter.

The effect of PM depends on the mass and number concentration, shape and size and the composition and concentration of other inorganic and organic pollutants associated with it. We also estimated the trace metals associated with PM10. The inorganic components constitute a small portion by mass of the particulates; however, it contains some trace elements such as Cd, Cr, Ni, Pb which are human or animal carcinogens even in trace amounts. The high level of Pb can induce severe neurological and hematological effects on the exposed population especially children, whereas Cd and Ni are known for inducing carcinogenic effects in humans through inhalation. Occupational exposure to Cd is a risk factor for chronic lung diseases. Cr (VI) is known to have toxic and carcinogenic effects. Mn exposure leads to increased neurotoxic impairments.

Primary Data Analysis

The sample size for primary data collection was calculated using the standard formula for calculation of sample size as given below:

Sample Size

$$ss = \frac{Z^2 * (p) * (1-p)}{c^2}$$

Where:
Z = Z value (e.g. 1.96 for 95% confidence level)
p = percentage picking a choice, expressed as decimal
(.5 used for sample size needed)
c = confidence interval, expressed as decimal
(e.g., .04 = ±4)

Correction for Finite Population

$$\text{new ss} = \frac{ss}{1 + \frac{ss-1}{pop}}$$

Where: pop = population

The population of the Margherita coal mining (Ledo and Tirap OCP) surrounding area was estimated to be approximately 10,000. So considering that as the population size, the sample size was calculated with 95% confidence level and confidence interval 5, and was found to be 370. Considering 30 more for non – response, the sample size was finally decided to be 400

Now out of 400 samples collected the breakup for collection from different locations was as follows:

Sl. no.	Study locations	Estimated population	Sample size
1	From workers working in mines	1330	133
2	From workers working at the mine office	500	50
3	From villagers of the nearby areas	1000	100
4	From people beyond the impact zone (control)		117 (remainder of 400)

A well structured questionnaire was prepared for collection of primary data from the selected sampling area. Table 13 below shows the demographic and health status of the respondents interviewed.

Table 32: Demographic and health status of the respondents interviewed.

Particulars 1	Particulars 2	Workers at the mines	Workers at the mine office	Villagers of the nearby area	Control	TOTAL
		133	50	100	117	400
Sex	Male	125	47	54	67	293
	Female	8	3	46	50	107
Age (years)	20-30	12	5	19	11	46
	31-40	27	10	20	24	82
	41-50	43	16	27	38	124
	51-60	51	19	33	45	148
Religion	Hindu	125	45	81	80	331
	Muslim	5	3	14	30	52
	Christian	3	2	5	7	17
Service (Years)	0-10	29	11			
	11- 20	32	12			
	21-30	39	15			
	31-40	23	9			
Distances between working place and coal mining area (km)	0-10	108	41			
	11- 20	4	2			
	21-30	21	8			
Suffering from diseases	Yes	9	10	19	18	56
	No	124	40	79	99	342
	Diabetic	1	1	6	7	15
	Eye vision problem	4	4	8	5	21
	Brain tumour	1	0	0	0	1
	Malaria	1	0	0	2	3
	Neck problem	1	0	0	1	2
	Anaemia	1	2	2	2	7
	Skin disease	0	2	1	1	4
	Lung disease	0	1	2	0	3

This survey reveals very few conclusions and it appears that out of 183 workers, only 19 are suffering from some disease (10.38%) – this is even lower than that in a non-mining area where out of 217 respondents 37 were found to be suffering from some disease (17.05%). The general health survey may not have been flourishing due to the following reasons:

(i) The workers are unwilling to speak freely,

(ii) They feel that if they speak freely, they will be deprived of some facilities,

(iii) They feel that speaking the truth will debar their children from getting jobs in the mines, and

(iv) In many cases, the workers are also not aware of their health conditions.

Secondary Data analysis

More than 6750 patients records maintained by the hospital authority were collected from the three hospitals Viz. ESIC Hospital, Margherita Civil Hospital and Health centre of Margherita Coal mining area of Assam. Confounding Factors were patients with minor diseases like Cough, cold, dysentery etc. Patients having major diseases like Brain tumour, GallBladder Stone, Eye disorders etc were considered along with the Lung diseases and skin diseases. Table shows the % of patients with lung disease per hospital and % of patients with skin disease per hospital. Out of the total patients suffering from lung disease the highest percentage was found in health centre(43%) whereas out of the total patients suffering from skin disease the highest percentage was reported from in ESIC(47.47%).

Table 33 : Percentage occurrence of lung diseases

Hospitals	Total number of disease found as per questionnaire	Total Number of disease of lung	% of patients with lung disease per hospital	% of patients with lung disease per hospital in respect of total lung disease patients
ESIC Hospital	1648	425	25.79	29.99
Margherita Civil Hospital	2016	387	19.2	27.31
Health centre	1712	605	35.33	42.70

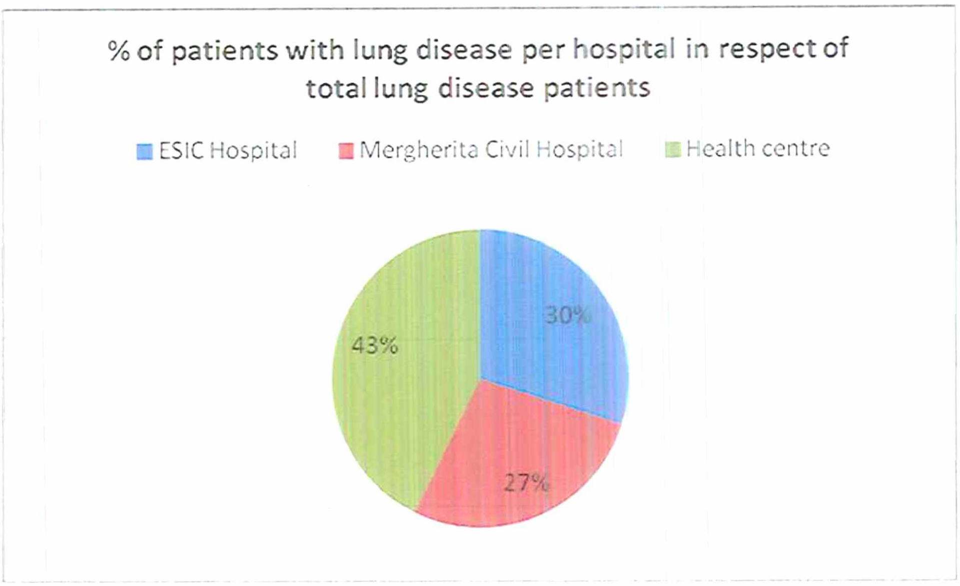
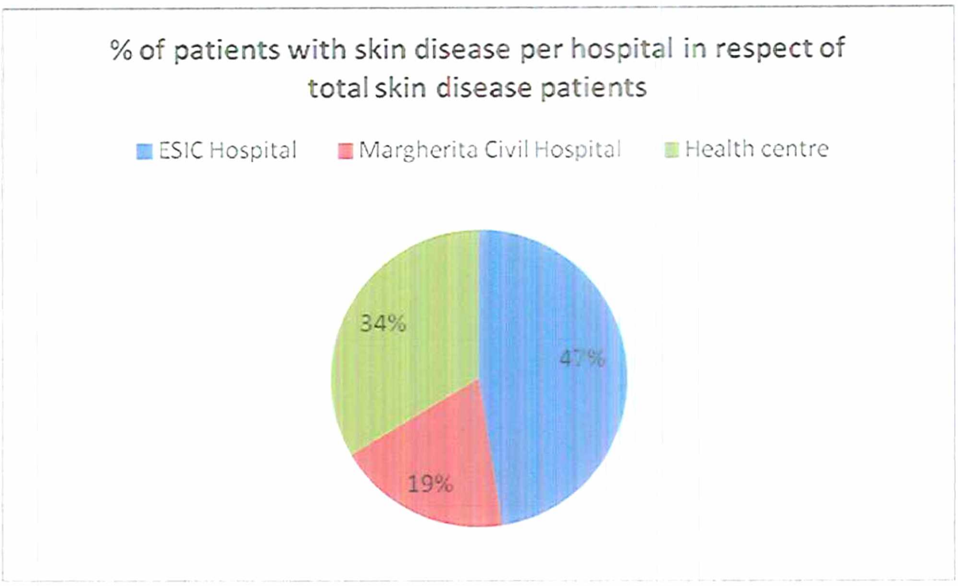


Table 34 : Percentage occurrence of Skin diseases

Hospitals	Total number of disease found as per questionnaire	Total number of skin diseases	% of patients with skin disease per hospital	% of patients with skin disease per hospital in respect of total skin disease patients
ESIC Hospital	1648	235	14.25	47.47
Margherita Civil Hospital	2016	94	4.66	18.99
Health centre	1712	166	9.69	33.54



The present study attempted to explore the health condition and health awareness among the local inhabitants residing near the coalmine areas of North Eastern Coalfields, Margherita, Assam and the study revealed that due to lack of awareness and negligence on the causes and the impacts of environmental pollution the local inhabitants residing near the collieries make them susceptible to severe health hazards.

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Conclusions and recommendations

We have monitored air pollutants such as PM_{10}, SPM and some element associated with PM10 and our data showed the following

- Due to opencast coal mining, the work zone as well as ambient air were found to be highly polluted with respect to dust in the study area.
- The PM10 and SPM were found to be alarmingly high and may affect human health.
- Dispersion of these finer particles creates serious problems in and around mining complexes. More stringent air quality standards should be adopted for coal mining areas to prevent harmful effects to human health and vegetation.
- These data may be useful for the effective design of air pollution control equipment for coal mining areas. Broader discussion of the problem suggests that the social and the environmental cost must outweigh the economic benefits of mining.
- This study should make mine officials aware of the contribution of airborne dust by opencast coal mining and their characteristics, and should enable them to take appropriate steps for environmental management.
- Results indicate that PM10 and associated metals are one of the major causes for deterioration of ambient air quality.
- Overall, continuous accumulation of different types of pollutants and their exposure to human being needs emergency attention of the policy maker, researchers and regulatory agencies.
- The present study suggests that it is necessary to monitor the air quality as well as the health effects at regular intervals at strategic locations.
- Awareness programme for open cast coal mining activities must be conducted.
- Considering the severe non response from the respondents, a well planned strategy must be prepared for collection of effective primary data.

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