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# Using Air Pollution Health Risk Assessment For Future Land Use Planning In Korba, India

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**Abstract**

Health effects of air pollution are investigated to provide an impetus for implementation of air pollution mitigation strategies and policies and estimation of benefits for the same. The present paper demonstrates the use of human health data as a guide for urban land use planning at the Korba planning area located in the state of Chhattisgarh in India. Korba is identified as the fifth most polluting city in India based on the Comprehensive Environmental Pollution Index (CEPI) by the Central Pollution Control Board (CPCB) of India. The major contributors to the high levels of suspended particulate matter (SPM) and respiratory suspended particulate matter (RSPM) in the city are the thermal power plants, abandoned and operating fly ash dykes/bunds and the three open-cast coal mines at Gevra, Kusmunda and Dipka. A detail cross-sectional household survey was conducted in the Korba planning area (KPA) on incidence of diseases commonly linked with air pollution as an alternative to measuring the ambient air quality at multiple locations and to understand the severity of the problem at the same time. Analyzing the data spatially (ward wise) showed that the air pollution related disease morbidity rate for certain wards were found to be much higher than the national average. These wards were then checked for their proximity to the different thermal power plants, ash dykes etc. and their location in conjunction with the prevailing wind direction. The results of this analysis indicated the severity of the problems of air pollution (measured by incidence of different air pollution related diseases) at different distances and directions from the existing identified contributors of air pollution. This was finally used to formulate strategies for air pollution reduction and spatial planning of future land use and residential area allocation at the Korba planning area.

## 1. Introduction

Health effects of air pollution are investigated to provide an impetus for implementation of air pollution mitigation strategies and policies. The present paper demonstrates the use of human health data as a guide for urban land use planning at Korba planning area(KPA) located in the state of Chhattisgarh in India. Korba is often referred as the industrial hub and the “power capital” of Chhattisgarh and houses several coal mines and thermal power plants. Coal burning in thermal power plants results in fly ash emissions and highly reactive secondary particulate pollutants after the oxidation of sulphur and nitrogen oxides (Sharma/ Pervez 2005). Coal-fired power plants are a major industrial emission source of ambient RSPM (Sharma/ Pervez 2005). The present research envisages to spatially relating the different sources of air pollution in Korba with the results of a household survey on incidence of diseases linked to air pollution. Finally, different strategies and recommendations are proposed to both reduce the emission of air pollutants and to select the locations for future land uses to reduce the exposure of the population to ambient air pollution in KPA.

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## 2. Background of research

Research on health effects of PM (Particulate matter) at different time scales of exposure and exploration of the dose response function that relate ambient levels of air pollutants to impacts on certain aspects of health undertaken by different researchers has been comprehensively reviewed by Pope and Dockery (2006). Cohort studies have also linked long term PM exposure and air pollution in general with respiratory illness in children (Gauderman/Gilliland/Vora 2002), cardiopulmonary mortality in adults, reduced lung function and respiratory symptoms etc. Many of these studies are based on observed data and have been also criticized for the use of inappropriate statistical techniques, inability to account for other factors such as meteorology, co-pollutants etc., lack of biological plausibility and other arguments against the causal association between air pollution and adverse health impacts (Vedal 1997). In spite of these criticisms, the growing volume of research findings provide convincing evidence that exposure to air pollution and particularly fine particulate matter (PM) has adverse health impacts on the exposed population (Pope III/Dockery 2006). In general, the health effects due to air pollution are identified as respiratory illnesses like asthma and chronic obstructive pulmonary disease, upper and lower respiratory tract infections, cardiovascular diseases, physiologic changes in lung function, lung cancer, pregnancy complications, low birth weight and pre-term delivery, wheezing, chest tightness, cough/phlegm, skin, eye, nose and throat irritations (WHO 2000; ATS 2000; Pope III/Dockery 2006; Singh/Pal/Tiwari 2007).

Both public health and urban land use planning originated from the same objective of providing safe healthy environment for the population and prevention of outbreaks of infectious diseases in the urban area (Coburn 2004). However, the links between these two fields gradually got disconnected. During the last few decades, environmental impact assessment (EIA) became an integral part of urban planning which reconnected urban planning with ecological and human health. Subsequently, various researches and reports have highlighted the need to either regulate air pollutant emission in the urban areas or to locate sensitive land uses such as residences, schools, medical facilities etc. away from proximate air pollution sources to reduce the exposure of the population (CEPA, CARB 2005, Perrotta 2011).

## 3. Study area and data collection

### 3.1 Study area

Korba planning area is located in the district of Korba in the newly formed state of Chhattisgarh in India. KPA had a population of 315,690 in the year 2001 and currently estimated to be 501,568 in the year 2011. The Korba planning area comprises of 322.6 square kilometers which includes 250 square kilometers of municipal area which is again divided into fifty-eight administrative zones or wards as shown in Figure 4. The topography is undulating with elevation ranging from 90 to 332 meters above the mean sea level. The slope is towards east. River Hasdeo flows within the city almost dividing the city into two equal halves and is the main perennial source of water for the city. The climate is dry to moist tropical with summer from April to June and rainy season from July to September and with average rainfall of 1265 mm. The temperature ranges from 48° C in May to about 7° C in December.

Korba is referred to as the industrial and mining hub of Chhattisgarh due to the presence of large thermal power plants and vast coal reserves. It is also one of the major industrial clusters in the country with tremendous growth potential. In a recent study Central Pollution Control Board (CPCB) of India identified the Korba industrial cluster/area as the fifth most polluted area in the country out of a list of eighty-eight industrial clusters based on a Comprehensive Environmental Pollution Index (CEPI) with critical level of pollution identified for all three domains namely air, water and land (CPCB 2009).

## 3.2 Data collection

The data used in this study was collected through various primary surveys which included reconnaissance survey of the Korba urban area, detail land use survey, household survey, transportation survey, commercial establishment survey, industrial survey, environmental survey along with collection of secondary source information from relevant organizations and through conducting personal interviews with administrators and city officials, industry representatives, doctors etc. using a team of 33 students of the Department of Architecture and Regional Planning of Indian Institute of Technology, Kharagpur over a period of 12 days. The data collected was organized and analyzed using MSExcel and MSAccess software and maps were prepared using the ArcGIS software.

### 3.2.1 Demographic characteristics

KPA had a population of .125 million in 1991 and .315 million in 2001(Census 2001) of which 64 % are urban and 36 % rural households. The sex ratio (females per 1000 males) in KPA is 923(Census 2001), which is significantly lower than the state average of 989 and the national urban average. This is mainly due to the influx of migrant workers who are mostly single male. The percentage of children (0-6 years) in the population is about 17%. The infant mortality rate in Korba is 85 (per 1000 births) as per 2001 data which is considerably high compared to the state (73) and national average (68) which again highlights the poor health situation in Korba. The ward wise population density in KPA ranges from 21,444 persons to 296 persons per square kilometre.

### 3.2.2 Economic characteristics

The Korba district has one of the largest coal reserves in India with an estimated reserve of 10115.21 million tonnes as on 31/03/2007. The three opencast mines at Gevra, Kusmunda and Dipka produces 70 million tonnes of coal per annum with Gevra being the largest open-cast mine in Asia. The coal found in this area has an ash content of 40% by volume thus increasing the amount of fly ash produced in the thermal power plants. The drilling, blasting, transfer of coal in open containers and other related activities in the open-cast mines are also a major contributor to the air pollution in Korba (Singh/Pal/Tiwari 2007).

The proximity to coal and bauxite mines have attracted a lot of investment from heavy industries mainly thermal power plants and aluminum smelters. Thermal power plants are considered to be a major emitter of air pollutants (Sharma/Pervez 2005) in the form of boiler ash, boiler flue gases containing suspended particulate matter (SPM), sulphur dioxide ($SO_2$), oxide of nitrogen (NOx) etc., fugitive dust generated during coal/solid fuel handling and processing and effluents from the chemical water treatment plant which usually results in high concentration of suspended particulate matter (SPM) and respiratory suspended particulate matter (RSPM) in the surrounding area (Sharma/ Pervez 2005). Table 1 lists the different heavy industries, their location, products, quantity produced, investment, employment and date of commencement of operation in the KPA area. The thermal power plants together generate 5010 MW of electricity which meets the power need for Chhattisgarh as well as the neighboring states. Seven new power plants with an additional capacity of 3470 MW are also either proposed or at various stages of construction in the surrounding area in addition to the augmentation of capacity of the existing power plants which will further enhance the emission of air pollutants in Korba.

About 9.75 million tonnes of fly ash is generated annually by the thermal power plants at present in Korba out of which 4.65 million tonnes are utilized and the rest is dumped in fly ash dykes either within or in the vicinity of the KPA area. Many of these are abandoned after capacity has been reached. The fly ash dykes located within the urban area are without any top cover which results in dispersion of the fly ash in the surrounding area. The transportation of the coal and fly ash in open containers to and from the power plants are also responsible for air pollution in KPA.

Table 1: Heavy industries in the KPA area

| Name and Location of Industry | Product(s) | Quantity | Investment (Rs. crores) | Employment | Commencement of operation |
|---|---|---|---|---|---|
| M/s Bharat Aluminium Company Ltd.(BALCO), Vidyut Nagar, Korba | Aluminium Rod | 35000 MT | 1136.61 | 6107 | Jun-75 |
| | Aluminium Roll | 4000 MT | | | |
| | Exclusion | 7000 MT | | | |
| | Ingot and others | 18000 MT | | | |
| M/s IBP Co. Ltd., Kusmunda | S. M. S. Bulk Explosive | 500 MT | 1.2 | 40 | 24-05-1994 |
| M/s Hasdeo Thermal Power Station, Vidyut Nagar, Korba | Electricity | 840 MW | 6.5 | 2511 | 21-06-1983 |
| M/s NTPC, Jamnipali | Electricity | 2100 MW | 1481.45 | 2090 | 01-08-1983 |
| M/s IBP Co. Ltd., Gopalpur | Industrial Explosive | 31000 MT | 16.58 | 320 | 08-02-1978 |
| M/s Korba East Thermal Power Station | Electricity | 400 MW | 274.58 | 2490 | 05-09-1966 |
| M/s CSEB (W) | Electricity | 2 x 250 MW | 2240 | 445 | 27-01-2008 |
| M/s Bharat Aluminium Company Ltd. (BALCO), Korba | 1. Aluminium Smelter | 245000 MT | 3869.2 | 4912 | 31-03-2005 |
| | 2. (a) Electricity | 135 MW | | | 17-06-2005 |
| | (b) Electricity | 135 MW | | | 13-08-2005 |
| | (c) Electricity | 135 MW | | | 04-11-2005 |
| | (d) Electricity | 135 MW | | | 14-12-2005 |
| M/s Himadri Chemicals and Industries | Coal Tar Pitch | 30000 MT | 9.14 | 23 | 13-01-2008 |
| M/s Aryan Coal Beneficiation (Pvt.) Ltd. | Electricity | 30 MW | 110 | 225 | 27-02-2007 |
| M/s LANCO Amarkantak Power (Pvt.) Ltd. | Electricity | 600 MW | 4485.09 | | 01-05-2009 |

### 3.2.3 Ambient air pollution and meteorology

Data on air pollution levels in Korba for the year 2009 and 2010 was obtained from the Chhattisgarh Environment Conservation Board (CECB) office in the city. The ambient air quality data collected at three monitoring stations located within the city and at five stack locations of the thermal power plants were used to initially check the level of air pollution at different zones in Korba. All the three monitoring stations within the city exhibited higher levels of SPM and RSPM concentration than Indian National Ambient Air Quality Standards (NAAQS) (24 hour average: 200 $\mu g/m^3$ (SPM), 100 $\mu g/m^3$(RSPM)). Figure 1 shows the minimum and maximum concentration of SPM, RSPM, SOx and NOx during the year 2009 at the three monitoring stations within the city namely; a) Near “Thehsil office” which is a low density area with government offices, b) “Pragatinagar, Jamnipali” which is the residential township of the NTPC thermal power plant and c) “ITI Rampur” which is a busy intersection within the city. “ITI Rampur” and the “Thehsil office” location exhibited significantly higher levels of SPM and RSPM and are located in close proximity to the BALCO captive thermal power plant and in the leeward side whereas, "Pragatinagar" which is located at a considerable distance from the NTPC Plant and at the windward side exhibited relatively lower level of SPM and RSPM concentration. NOX and SOX levels were found to be much below the permissible limits at all the three monitoring stations.

Pollutant concentration depends both on the rates of emission and prevailing meteorological conditions. The predominant wind direction in Korba is from north-west to south-east with velocity ranging from 0.57 to 9.30 kilometer per hour. The wind flow during the months of January to March and October to December is from north to south, and during the rest of the year from west. Calm periods are observed throughout the year for a total of 127 days with excessive calm periods during October-November and minimum calm period in April. Considering pollutant dispersal, April and July is identified as the best period and January and October the worst (Pandey/Murty/Das 2008).

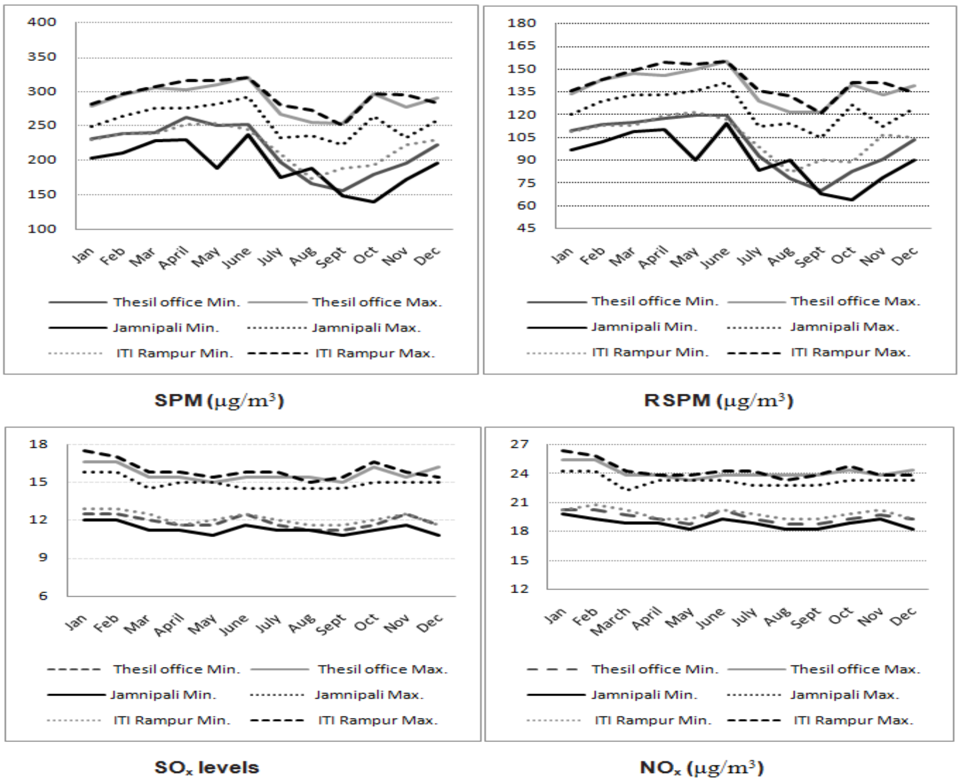


Figure 1
Concentration of SPM, RSPM, SOx and NOx for the year 2009

### 3.2.4 Land use characteristics

Figure 2 and Table 2 shows the distribution of land use in the KPA area during the year 2011. The light and the deep grey shaded areas indicate abandoned mines & ash dykes and operational mines respectively in the KPA. Industrial land use is shown in magenta and residential in yellow. The predominant land uses are Agricultural and Forest areas which cover about 61% of the land area. Korba exhibits a unique urban structure with planned townships of NTPC, BALCO, CSEB etc. for their employees located adjacent to the plants on one hand and a municipal town on the other. Korba also exhibits a dispersed and sporadic growth pattern due to the presence of coal mines, protected forest land, canals and the existing industrial boundaries.

Table 2 Land use distribution in KPA (2011)

| **Land use** | Residential | Mixed | Industrial | Comm-ercial | P&SP | Utilities | Recreat-ional | Agricul-tural | Forest | Mining Area | Water body | Transport-ation | Open Land |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Area (sq. km) | 32.68 | 2.07 | 11.01 | 0.63 | 0.88 | 0.22 | 1.57 | 126.9 | 65.86 | 30.15 | 9.45 | 4.49 | 27.66 |
| Percentage | 10.42 | 0.66 | 3.51 | 0.2 | 0.28 | 0.07 | 0.5 | 40.47 | 21 | 9.62 | 3.01 | 1.43 | 8.82 |

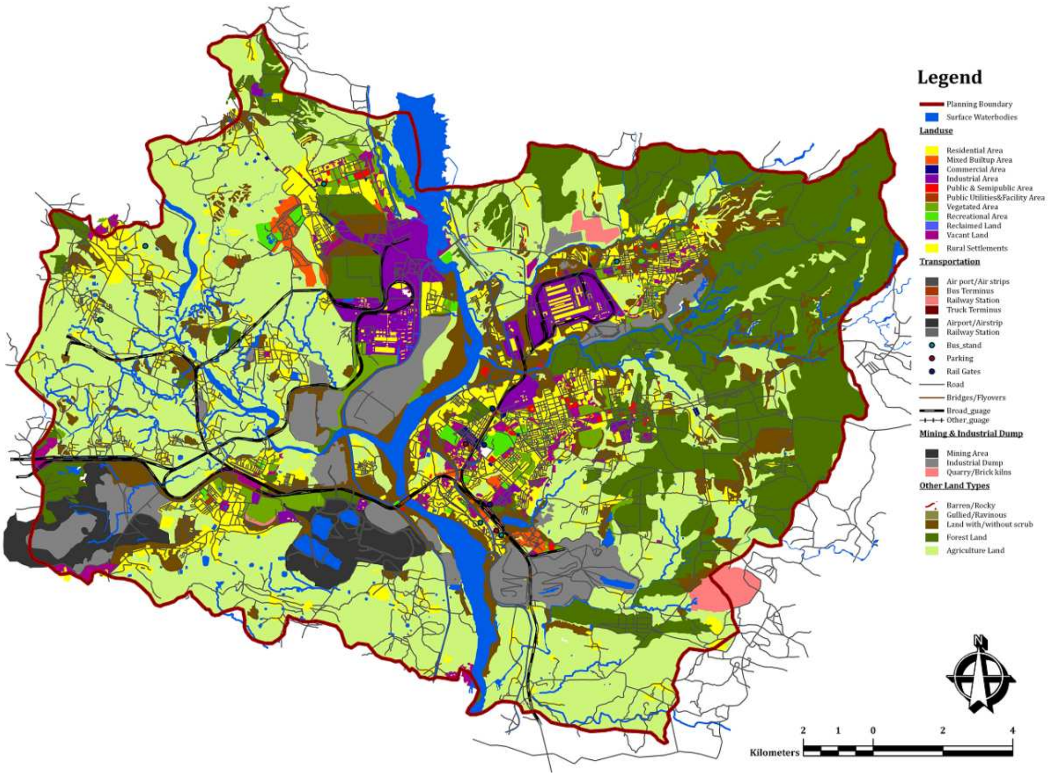


Figure 2
KPA Land use (2011)

## 4. Analysis and results

The ambient pollution and meteorology characteristics confirm the critical status of air pollution in KPA. However, the limited number of air pollution monitoring stations in the planning area is not adequate for identifying areas suitable for spatial planning of future land use where sensitive land uses such as residences has to be located away from proximate air pollution sources to reduce the exposure of the population (CEPA, CARB 2005, Perrotta 2011). In the present research, survey data on diseases commonly linked with air pollution is used as an alternative to measuring the ambient air quality at multiple locations and to understand the severity of the problem at the same time.

A cross-sectional household survey was conducted in the Korba planning area (KPA) by visiting individual dwellings in which residents were questioned to identify the major persistent diseases amongst other aspects. The dwellings were selected through random stratified sampling considering ward population and population density. The final survey had a sample size of 516 households (2513 people) out of which 122 households (637 people) reported of diseases during the previous year. The self-perceived morbidity survey included questions related to the type of disease, hospital/medical center visit frequency and duration of ailment during the previous year. The different types of diseases were broadly categorized into ten groups out of which the first nine namely; eye, skin, throat, respiratory, cough, discomfort, headache, lung and child respiratory problem could be linked with air pollution based on existing studies (WHO 2000; ATS 2000; Singh/Pal/Tiwari 2007) and doctors' opinion in Korba, while the last category , "others" included all other diseases . Acute and chronic cases were not identified separately.

In addition to the survey, data on incidence of different types of diseases and annual number of medical visits were collected from the hospitals and through interview of the doctors practicing in the area. The health care facilities in Korba comprises of 1 government district hospital (100 beds), 9 private hospitals(80-40 beds each), 10 private nursing homes, 5 testing labs, 1 health center and 27 private clinics with people mainly depending on the private health care facilities. Table 3 shows the incidence of main diseases as recorded in the government district hospital during the period 2005 to 2010 which showed increasing number of asthma and tuberculosis cases recorded during the last few years. Other common diseases reported in the area are bronchitis, chronic obstructive pulmonary diseases, conjunctivitis, dryness of eye, skin diseases, osteoporosis, ulcer and cancer.

Table 3 Disease data recorded in the Korba district hospital

| **Main Diseases** | **2005** | | **2006** | | **2007** | | **2008** | | **2009** | | **2010** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cases | Death | Cases | Death | Cases | Death | Cases | Death | Cases | Death | Cases | Death |
| Gastroenteritis | 1680 | 0 | 89 | 0 | 75 | 0 | 120 | 0 | 55 | 0 | 96 | 0 |
| Diarrhea/Dysentery | 14177 | 0 | 10861 | 0 | 8011 | 3 | 2568 | 0 | 9095 | 10 | 2103 | 1 |
| Aids | 304 | 11 | 324 | 20 | 987 | 19 | 1506 | 15 | 1483 | 43 | 1698 | 16 |
| Asthma | NA | NA | 125 | 0 | 114 | 0 | 139 | 0 | 161 | 0 | 145 | 0 |
| Tuberculosis | NA | NA | NA | NA | NA | NA | 841 | 0 | 952 | 0 | 1208 | 0 |

## 4.1 Household survey findings

A total of 166 cases of incidence of diseases were reported by 122 households out of which 96 cases were due to the first nine categories. The data thus obtained was classified according to gender, age and length of stay of the affected population in Korba for the first nine categories. The results showed that the male population (60%) was more affected compared to females (40%). People staying for a longer period in Korba and people above the age of eighteen (working age population and senior citizens) were also found to be more affected. Respiratory diseases and cough were found to be most common followed by eye irritation, headaches, skin and throat problems. Figure 3 shows the incidence of diseases per thousand population in some of the wards in KPA where the levels were found to be relatively high.

Respiratory diseases were found to be very high in ward number 1,3,4,11,24,32,35,36, 47 and 56, child respiratory problems in ward 3, 4 and 11, cough in 1, 4,11,32,44 and 47 etc. The spatial analysis showed that morbidity rate for certain wards were much higher than the national average (Ghosh/Arokiasamy 2009) with high incidence of air pollution related diseases in wards 1, 3, 4, 6,7, 11, 24, 32, 35, 36, 44, 47 and 56 as shown in Figure 4. These wards were then checked for their proximity to different thermal power plants and ash dykes in conjunction with the prevailing wind direction. The results of this analysis indicated the severity of the problems of air pollution at different distances and directions from the existing identified sources as shown in Table 4. Ward 53 which is located far away and at the windward side of all the air pollution sources shows low incidence of air pollution related diseases except for eye problems which may be due to its close proximity to the coal mine and the use of coal as the cooking fuel in the area. Ward 1 and 4 is located in the busy central area of Korba city where emission from transportation in addition to the emission from ash dykes and thermal power plants may be responsible for the high incidence of air pollution related diseases. Ward 11, 24, 32, 44 and 47 were also found to be located at the leeward side and in close proximity (within 3 to 5 km (Sharma/ Pervez 2005)) of either thermal power plants or ash dykes which makes these areas highly susceptible to SPM and RSPM concentration (Sharma/ Pervez 2005) and thus justifying the use of population health data as an alternative to ambient air quality data for identifying areas vulnerable to air pollution.

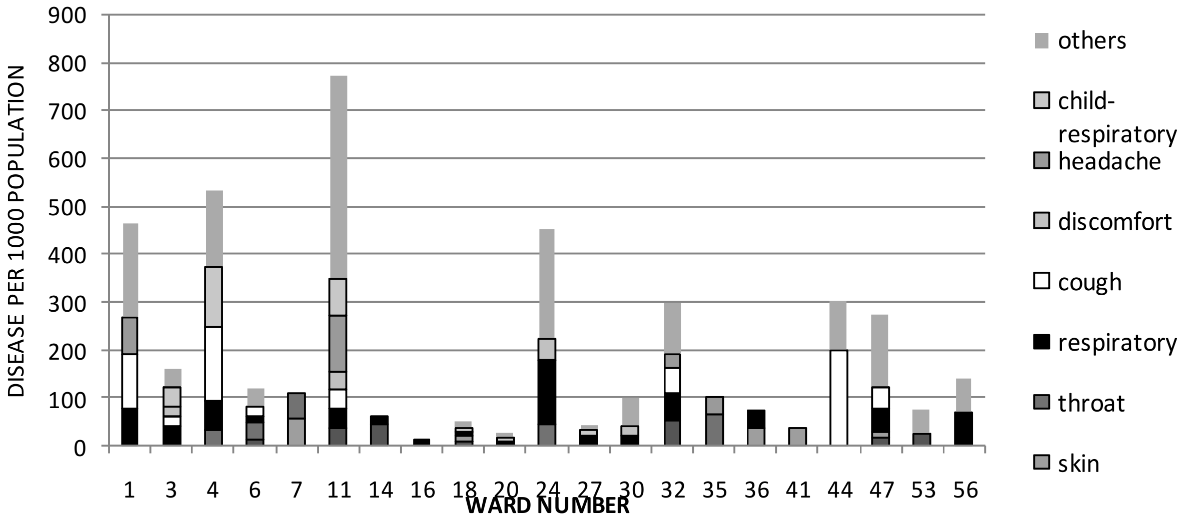


Figure 3
Ward wise incidence of diseases per 1000 population

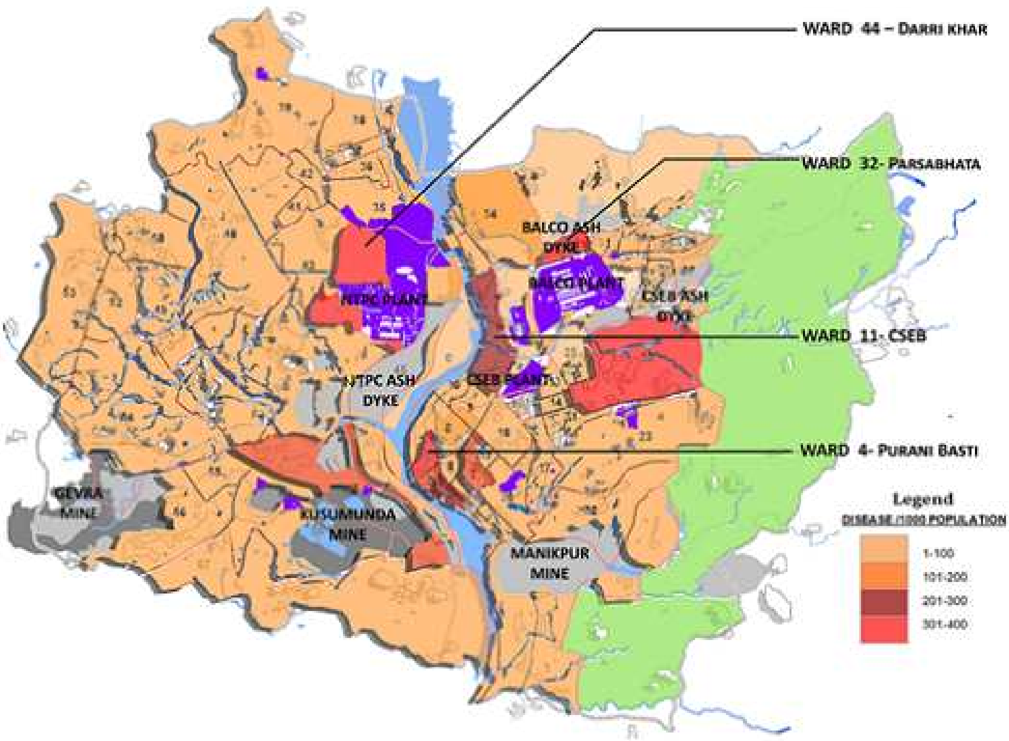


Figure 4
Ward wise incidence of air pollution related diseases per 1000 population

Table 4 Spatial proximity of selected wards to air pollution sources

| Ward Number | 01 | 04 | 11 | 24 | 32 | 44 | 47 | 53 |
|---|---|---|---|---|---|---|---|---|
| Ward name | Ramsagar | Purani basti | CSEB | Kosabadi | Parsabhata | Darrikhar | Vikas nagar | Mogara |
| Density (Pop/sq. km) | 21444 | 18225 | 1672 | 615 | 4855 | 870 | 585 | 590 |
| **CSEB (km)** | 3.5 (W) | 3.8 (W) | 1.0 (W) | 2.9 (L) | 3.5 (W) | 4.6 (W) | 5.8 (W) | 12.8 (W) |
| **BALCO (km)** | 6.6 (W) | 7.2 (W) | 4.5 (W) | 2.4 (L) | 1.2 (W) | 4.0 (W) | 8.2 (W) | 14.4 (W) |
| **NTPC (km)** | 4.2 (L) | 5.4 (L) | 3.3 (L) | 6.9 (L) | 5.2 (W) | 0 (L) | 4.7 (L) | 8.9 (W) |
| **Ash Dyke-CSEB (km)** | 7.6 (W) | 7.6 (W) | 5.2 (W) | 1.4 (L) | 3.4 (W) | 8.2 (W) | 9.8 (W) | 16.6 (W) |
| **Ash Dyke-BALCO (km)** | 7.4 (W) | 7.9 (W) | 4.2 (W) | 4.3 (L) | 1.0 (L) | 5.6 (W) | 9.2 (W) | 14.1 (W) |
| **Ash Dyke-NTPC (km)** | 2.8 (L) | 3.85 (L) | 2.1 (L) | 6.1 (L) | 5.0 (W) | 2.2 (W) | 3.9 (L) | 9.8 (W) |

Note: L – Leeward side of source, W- Windward side of source

## 5. Strategies and recommendations

Finally, different strategies and recommendations are proposed to reduce the emission of air pollutants and to select the locations for future land uses to reduce the exposure of the population to ambient air pollution in KPA. Some of the recommendations to reduce emission of air pollutants were to retrofit the existing thermal power plants with ESPs (Electrostatic precipitators) with a rating of 50 µg/m3 for SPM in the flue gas, use of high concentration slurry disposal system (HCSD) for fly ash disposal and to improve upon the percentage of utilization of fly ash thus reducing the land requirement for fly ash dykes and abandoned fly ash dyke reclamation through conversion to horticulture gardens thus reducing the dispersion of fly ash etc.

Spatial planning of future land use and residential area allocation was also undertaken for the KPA with the view to reduce exposure of the population to high levels of ambient air pollution along with other objectives. First, based on the analysis on ward wise incidence of air pollution related diseases in conjunction with the prevailing wind direction and proximity to different air pollution sources, scores were assigned to individual wards on a range of 1 to 10 to prepare an index to show the suitability of the ward for future allocation of residential land use. Wards with high incidence of air pollution related diseases were assigned the least score. Similarly, other indices were prepared based on the existing situation in KPA considering water pollution, land value, solid waste management system, population density, housing condition, sanitation and transportation accessibility for the different wards. Finally, a land suitability matrix was prepared through combining all these indices by assigning weights for each criteria/index and then adding the weighted scores. Weights were determined based on expert judgment. The land suitability matrix thus prepared was used for residential area allocation in the future land use plan.

## 6. Conclusion

The present research shows the use of human health data on diseases commonly linked with air pollution as a guide for framing guidelines for future land use planning and particularly residential area allocation in KPA which could also be repeated in other areas vulnerable to high ambient air pollution. There is also a need for further research on identifying the contribution of each pollution source towards the ambient air quality at different locations. The study can also be further improved by increasing the sample size of the household survey and by analyzing the acute and chronic cases separately.

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