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A SOCIO-ECONOMIC ANALYSIS OF THE IMPACT OF INDUSTRIAL POLLUTION IN THE PERIPHERAL VILLAGES OF NALCO, ANGUL SECTOR OF ORISSA

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Abstract:

The production of aluminum has increased globally as a consequence of increased industrialization in many developing countries and emerging economies. as well as greater demand for aluminum products. It has significant industrial and economic importance for Orissa, as this is the one of the metals for which the state has abundant raw material. Having national and local importance the metal has been produced increasingly creating a lot of environmental concern creating worth addressal at the local, regional and national level. The present study is an effort to address such issues at the local and regional level and make policy suggestions at the national level. Divided into five parts the present paper tries to understand the effect of outdoor pollution in the rural peripheral regions of Angul Aluminum smelter plant and captive power plant. Based on a cross sectional survey data collected through primary survey from 169 households within the 15 km radius of two plants the study tries to find the impact of exposure on possible health effects of peripheral population.The primary and secondary data indicated prevalence of health issues in nearby area to the plant specific to the industry in comparison to distant and control village. The outcome of the study is significant for planning of management of air pollution and its effect on local and peripheral population.

Index terms: Angul-Talcher area,socio-economic study, health survey, industrial pollution

I. Introduction:

The industrial sector is one of the most dynamic sectors of the economy and plays an essential role in economic development and the alleviation of poverty. Thus every state has been trying hard to achieve economic growth with the help of industry and industrial growth. One-third of the population of the world lived in poverty in 1981, whereas the share was 18 per cent in 2001 (Chen and Ravallion,2004). The decline is largely due to rapid economic growth in population rich countries like China and India. ((Kniivilä, 2007). Evidence from 51 countries during 1980-2004 indicates that the development of the rural economy and development of small town might be more poverty reducing than employment generation in industries in larger cities (Christiaensen&Todo, 2014) ;(Christiaensen et al. 2013; and Christiaensen and Todo 2013). The location of industrial facilities has an impact on overall poverty reduction and inequality, as enterprises are often concentrated in urban areas because of ready access to skilled labour force, better infrastructure, larger markets and technological spillovers (Lanjouw and Lanjouw, 2001).Realizing the importance of industrial and manufacturing sector Odisha also invested resources in development of industry though slow in comparison to other states of India. Endowed with rich mineral resources such as Iron ore, coal, Bauxite and Chromites, Odisha has a comparative advantage which has attracted the attention of many mining and metallurgical companies. After nationalization of coal in 1975 and the national policy on energy sector,

many power plants were set up, which led to the growth of Talcher-Angul industrial belt. Taking advantage of abundant labour stock and mineral resources the district has registered the distinction of being top industrially developed districts of the state with five major public sector undertakings and three major private sector industries. The industrial growth in the state has mostly taken place in the areas where raw materials, water and power are available. The manufacturing industry is one of the vibrant sectors of the state economy and contributes significantly to the industrial output. Industrial growth of Odisha though slow yet registered a consistent increasing figure between 2020 -2023(fig. 1) showing signs of recovery from the slump of COVID period DE&S (2023).

Environmental pollution reduces welfare indirectly by imposing economic and social cost and lessening availability of amenities or directly by affecting human health, and contaminating drinking water (Stiglitz&Dasgupta, 1982). Industries, in general, consume 37 per cent of the world's energy and emit 50 per cent of world's CO2, 90 per cent of world's SO2 and nearly all of its toxic chemicals (Singh et al., 2013). Various types of dust are emitted into the atmosphere by the industrial, mining and related activities and it is observed that plants around large dust sources are susceptible to chronic decrease in photosynthesis and consequently in growth (Hirano et al., 2013). The pollutants emitted from industries have been grouped as criteria pollutants on the basis of their contributing share in damage of ecosystem. The World Health Organization (WHO) states that 2.4 million people die each year from causes directly attributable to air pollution, with 0.9 million of these deaths attributable to outdoor air pollution (WHO, 2002). (Mishra et al., 2014) estimated the damage to human health and agricultural productivity loss from pollution induced by coal-mining activities in Odisha. The Odisha disease burden profile, 1990-2016 estimated the risk factor associated with air pollution at 8.2% making it the second largest contributor to DALYs (Chaulya ,2003) Like most of the industrial centers the Angul region of Orissa which has been an abode of many PSUs has seen a drastic change in its topography and climatic condition owing to rampant industrial expansion (Singh et.al 2011). The study found land use pattern of Angul-Talcher to have undergone several changes over the years due to Surface and sub-surface mining and industrial activities.

Good health with mental well-being is termed both a resource and means for stimulating economic development (BrundtlandReport, 2024). The WHO (2005) argues that 'quality of health' is related not only to freedom from diseases but also associated with a healthy and hygienic environment. Epidemiological evidence suggests that outdoor air pollution is a contributing cause to morbidity and mortality (EPA, 2000). But most of the air pollution studies have been conducted in the developed countries whereas epidemiological data on the health effects of air pollutants are not abundant for most of the developing countries, where a major proportion of the population lives in environmentally poor conditions (Bates et al., 1992); (Subramanian et al., 2016). The present paper is an initiative to investigate the association of different components of industry related air pollution and occurrence of diseases in the peripheral area based on cross sectional study conducted in the Nalco Angul sector of Odisha.

The main objective of the study

- Is to find possible health effects of air pollution in the peripheral area
- To identify and measure direct and indirect cost of health effect of air pollution.

The paper is divided into six sections. The second section has a brief review of literature exploring the contribution and gap of earlier research. Section III explains the methodology data collection technique and details of sample population that depicts the probable association between human health and outdoor air pollution. Section IV explains the Analysis of data and Section V presents conclusion and future courses of action.

II. Review of literature

Traditionally, opportunity costs of human health was interpreted solely on account of the individual's physical well-being without considering the environmental and social backgrounds around him (Rapport &Mergler, 2004).With a departure from traditional thinking health is viewed as a precious asset in which an investment reduces morbidity and prolonged life increases time available to produce money earning and commodities (Grossman, M.,1974).Air pollution is a matter of serious concern in megacities where the pollution levels often exceed the permissible limits due to its associated health risks for city residents (Chattopadhyay et al., 2010); (Leirião et al., 2022). The metropolitan cities of India are exposed to unhealthy and unhygienic conditions due to air pollution (Dutta et al., 2021). The deterioration of air quality has been further aggravated by emission of toxic pollutants such as particulate matter, greenhouse gases like SOx, NOx, and O3 (Rumana et al., 2014). Increase in population, urbanization, and industrialization has

depleted air quality and hence adversely affects human health (Rumana et. al., 2014); (Xiong et al., 2020);(Wang et al., 2020) found an increased risk for Alzheimer's disease in their meta-analysis of individuals chronically exposed to aluminum in drinking water.Urban air pollution from gaseous pollutants is a growing environmental and public health problem in many cities of the world (Bauer et al., 2020);(Kim et al., 2015). Carbon monoxide (CO), Nitrogen dioxide (NO2), Sulphur dioxide (SO2), and Ozone (O3) are gaseous pollutants that have been internationally recognized as environmental priority air pollutants since they can constitute a threat to human health and the environment (Mustaficetal., 2012). Adverse lung diseases and genetic abnormalities in exposed lung tissues were reported for children exposed to polluted air in Kolkata (Lahiri et al., 2019).Reduction in lung function in children with a history of persistent asthma resulting from exposure to modest ambient concentrations of NO2, NO, PM10, and SO2 has been reported in South Africa (Naidoo et al., 2014). In addition, O3, NO2 and SO2 can induce harmful effects such as increased bronchial reactivity (Happo et al., 2010) pulmonary and systemic inflammation (Ko et al., 2016); (Hui et al., 2012) and protracted inflammatory and thrombotic responses in vulnerable individuals (Chen et al., 2017). The increasing and unplanned urbanization coupled with industrialization and population growth are posing threat to human health by increasing air pollution levels leading to number of health issues (Dutta et al., 2021). There are some studies on the health impact of air pollution in the cement industry (Bogahawatte&HerathBandara, 2011) and iron mining (Pattanayak et al., 2011), and of the occupational hazards (i.e., direct impact) of coal mining (Sarkar et al. 2004).

Based on above references an attempt has been made in this paper to study economic impact of industry specific pollutant and its effect on peripheral atmosphere with special reference to humans. Most of the literature studies were either related to air pollution specific to coal mining area or traffic pollution concentrated in urban and industrial centers. Industry specific air pollution targeting the peripheral rural area was found to be scarce.The literatures mostly conducted epidemiological and ecological research in the mining area to establish linkage between outdoor air emission specific to Talcher thermal area and diseases found in vegetation, animal and human. The risk assessment is either related to water pollution, vegetation loss or economic cost around mining region.Understanding this gap the present study tries to bridge the research gap by examining the association between the air pollution level and negative health outcome of peripheral village of Angul smelter plant and CPP of Nalco. Unlike many studies which were based on the urban conglomerate and mining, the present study chose specifically rural area circling the two industries of NALCO for assessing impact of industrial pollution on health.

With the projected growth of GDP of India and increased importance of various national and state projects demand for aluminum is going to rise so does the production (Fig.1). Aluminum industry is hazardous to both the workers and the community. The pulmonary hazards are significantly higher in workers who are continuously exposed to gases and pollutants. Moreover, the free radicals of silica and polycyclic aromatic hydrocarbons may have a direct relationship with the recorded changes in diaphragmatic and pulmonary functions and may be precancerous (Shaaban et al., 2016). Due to production of Aluminum, there is emission of fluoride which is detrimental to health (Pradhan et al 2020). Data available from OSPCB shows that all locations in cities where monitoring is done are either highly or critically polluted with respect to PM10 and the situation has deteriorated since 2007(Table: 2.1).

Traditionally, exposure assessment is focused on ambient air pollution levels, which can be easily obtained by establishing several fixed monitoring sites in the region of interest (Han &Naeher, 2006). It is well established fact that monitored ambient air quality value reveals concentration of outdoor pollutants and risk of potential health though indirectly (Baklanov et al., 2007). Usually the concentrations of pollutants vary among monitoring sites and over the months, but due to limited access to data we could not develop a spatial model for emission and population exposure. Instead this study adopts application of the annual average level of ambient concentration of PM10 to the rural areas of NALCO periphery. It is difficult to differentiate between indoor sources of air pollution and outdoor sources of air pollution because of the fact that the later often gets elevated by use of biofuels in cooking inside a house raising the level of PM10 well above from the ambient level. Apart from this indoor sources also contribute to overall exposure (EPA 1996). Because of this fact in the present study we have emphasized on the estimation and application of outdoor air pollution in the study area. Industry specific pollutant approach has been followed with respect to selection of air pollutant for health effect analysis. Instead of a pollutant by pollutant approach which requires an air pollution modeling and which lies beyond the purview of this paper, pollution level of criteria pollutants which are major source of emission from the industries under study particularly PM10 have been selected for being within limit of prescribed standard by CPCB (Table 2.2).

With aluminum production increasing (Fig. 2) though marginally it is quite evident that ambient air pollution as monitored by CPCB monitored data of PM10 is going to increase. Based on this pretext we try to address certain unanswered questions (1) To what extent does the Industrial setup has contributed to the health related issues of the peripheral area. (2) does the socio economic factors of the neighboring community reflect the impact of industrial pollution.

III. Research methodology

A number of studies have investigated the contribution of particles and gaseous forms of air pollution to both acute and chronic related health effects. There is also compelling evidence that morbidity from particulate and gaseous air pollution is found more often among particularly susceptible populations (Utell et al., 2002)(Burnett et al.,1997 a, b); (Anderson et al., 2003; Sunyer et al., 2003;Jedrychowski.W ,1998& Burnett et al., 1995).Based on cross-sectional study they analyzed the effect of outdoor air pollution on respiratory effect after confounding for allergies. The basic approach to estimate the effects of air pollution on acute mortality and morbidity is to use a dose response function which empirically explains variations in number of cases of illness or death observed in population based on changes in the ambient concentration of the air pollutants and other known explanatory factors. (ESMAP, World Bank, 2003).

In the line of epidemiological literatures, the present study has used both descriptive and analytical framework for analyzing prevalence of possible linkage between air pollution and health effect. In any health impact analysis the study of affected population is quintessential for assessing the degree of effect. In order to do the same the present paper is based on repeated cross sectional survey conducted in the peripheral villages of NALCO Angul sector during period of (2004-2006).

Data collection technique:

The study is based on both primary and secondary data. The primary survey conducted to gather socio-demographic and health profile of the peripheral had been conducted in four stages. In the first stage out of five blocks coming under the buffer zone of the study area and centering the two plants of NALCO two blocks have been chosen on the basis of their concentration and coverage based on the environmental impact assessment study made by Nalco for the two plants in the year (2003-04) (Fig. 3).In the second stage selection the villages coming under other directions have been discarded for either being closer to industrial setups like FCI and TTPS or urban centers related to these industries and district capital town Angul. Thus for the purpose of study the villages in the south east and east direction covering a radius of 10kms have been selected for being predominantly rural. However, it is to be noted that the choice of 10 kilometer area is not arbitrary based on the environmental impact assessment study made by Nalco for the two plants in the year (2003-04). In the third step the Villages have been selected on the basis of their distance from plants of NALCO. For this purpose, the entire peripheral area have been stratified into three groups on the basis of their aerial distance from the industrial site. Four villages from strata one(0-5kms), two from strata-2(5-10kms) and one from strata 3(>10 km) have been selected. Selections of these villages have been done cautiously, so that they won't overlap with the peripheral area of other industrial clusters prevalent in the same area like FCI & TTP. In the selection of villages, prevalent wind direction which is north-west to south-east during summer and south-east to north and north-east in winter has been taken into consideration. A control village, selected from the south-west direction, situated at an aerial distance of 15 km from the plant site.

Data collection Instrument:

Primary data have been collected through a cross-sectional field survey conducted in the year 2005-2006 from 169 households in seven sampling villages. A questionnaire prepared on the basis of a pilot survey conducted in the year 2005 was canvassed to the households in the vicinity of NALCO adjoining areas. Main survey was conducted in July 2005 and completed in January 2006.The primary data were collected by administering questionnaire through a face to face interview with the head or any other member of the household. During survey collection of information with respect to health endpoints caution has been made to include the affected person itself. Total member of 169 households consists 957 persons with average household size of 6. Percentage share of male and female in these household are respectively 58% and 42% on an average (Table no 3.5). Selection of male respondents has been done purposively due to the well-established fact that men are more exposed to pollution since they have less family and child rearing

responsibilities outside work. Through the questionnaire, information relating to socio-economic characteristics, demographic profile, and health impact and awareness level of the households were obtained (Table 3.2).

The secondary data pertaining to this study also includes the information relating to ambient air quality level measured by State Pollution Control Board (SPCB), Odisha. The mean daily concentration of Suspended Particulate Matter (SPM) and Respirable Suspended Particulate Matter (RSPM) at the NALCO Township monitoring station for the year 2005-2006 (Table.3.4) was taken as the referred secondary data for analysis. Annual average (24-hour range) data on pollution concentration for SO2, NOx and SPM was collected from the pollution monitoring stations controlled by SPCB as part of national Ambient Air Quality monitoring program. Even though exposure is a reasonable measure of risks to health, different people exposed similarly may receive different doses of the same pollutant and may experience dissimilar health effects (Table 3.1). To account for aggravated reaction of sensitive people, the exposure level of various population groups should be assessed, especially the vulnerable ones, such as children and elderly. The study thus included time activity pattern and micro environmental concentration for different population groups. The sample population which includes six different groups like adult male, adult female, old male, oldfemale, boy child and girl child gave information regarding individual exposure and family exposure in the vicinity Equation (1) (Kathuria and Khan ,2007).

$$HHEIxij = Xj\ (Nam*Tam+Naf*Taf+Nom*Tom+Nof*Tof+NC*TC)/(24*hh\ size) \quad (1)$$

Where,

Xij = Household exposure index of ith household in jth environment

In the present case a total of 168 households have been considered into account.

j= is the pollution monitoring station.

Xj= is the monitored value of SPM in the jth monitoring station

IV. Analysis of Data:

Distribution of working population on the basis of occupation as given in (fig.4) which suggests that agriculture has a greater share in total working population constituting 31.41percent and Nalco service has the lowest percentage share of (1.68%).The Health survey found disparities as per the health expenditure in peripheral villages of ASP and CPP and control village (Table 4.1). Average household size of the sample population is 5.92 and education was found to be 6.2. The contribution of family size and education has a relation with exposure as it increases average exposure and initiative to abate exposure to outdoor pollution. Distribution of population on the basis of age required to calculate individual exposure registers increase in percentage share of 15-55 age groups at 56% (Table 3.5). Data on income and expenditure reveals highest average income of Bonda followed by Bantala. Lowest income is that of Inkarbandha. The share of health expenditure is highest in Gadarkhai (11.8%) against 2.82% in Bantala which is the control sample. Share of average health expenditure to total expenditure is an indication of economic implication of health problems (Table 4.1).

Exposure to air pollution at the individual level may substantially differ from ambient level depending upon the no of microenvironments in which an individual move during an entire day (Parikh &Hadker, 2003). Though study of micro environment and calculation of individual exposure has been adopted in many epidemiological studies which are mainly involved in calculating the effect of indoor air pollution, an attempt with respect to outdoor air pollution has been made in few (Srivastava A ,2010; Murthy et al.,2003;(Kathuria& Khan, 2007). In reference to the methodology followed in these available literatures the present study tries to find out household exposure level to outdoor air pollution instead of total individual exposure. This method has been adopted purposively due to the fact the present study is an estimation of effect of industrial pollution on household exposure level and health. Since characterization and division of indoor air pollution from outdoor sources requires modeling which remain outside the purview of this analysis only ambient air pollution have been taken for calculation of air pollution exposure. In order to find how people are exposed to air pollution an ideal index of exposure should be sensitive to the distance of the exposed person from the source and time spent by the exposed person under the exposure (Kathuria 2007). The present study assumes that in and around a region each individual is exposed equally, but average household exposure varies depending upon the number of household members and age distribution. Parikh et.al. (1995) have maintained that the people living in the vicinity of Industrial area are supposed to expose

to highest or average concentration, whereas people living in distant places can be assumed to have been exposed to at least the lowest monitored value of criteria pollutants. Based on these above ideas in the present study we have assumed that the nearby areas to the Industrial site are exposed to average mean concentration and the distant and control areas are being exposed to at least lowest concentration of the average ambient monitored value .The average household exposure of the sample village was found to be at 19.67µm (Table 4.3).With Average annual outdoor pollution increasing the household exposure is going to increase further (Table 4.2).

In the absence of any published information relating to disease of our concern in the peripheral areas data collection have been done on the basis of symptoms, time period of medicine taken for different disease and frequency of such disease based on one year recall period. It was noticed during the study period that people often avoid going to doctors or medical practitioners in less severe and manageable cases of health problems. Due to restricted time and expertise data on same could not be covered. Many health effects which have overlapping entities are grouped under one heading. Environmental conditions and components of socio-economic structure play a very important role in deciding the work participation rate. Apart from being situated in close vicinity area of Nalco Smelter plant the sample village population has greater share of children. Reporting of health endpoints in the form of symptoms of diseases have been done from either head of the household or any other representative person of the family along with an examination of available prescription or medicine taken for the disease. In case of children who are absent during the time of survey mother's response have been taken as a proxy for absentees in addition to above mentioned procedure. Such procedures had been followed considering the MRC guidance (Parikh et al.,2001) that only directs responses that can be analyzed in case of respiratory diseases. Since the prevalent study is only a health survey, we have included the symptoms of disease as the disease itself based on certain disease related verification. The health survey found prevalence of 15 diseases with varying intensity in different villages. Diseases mentioned by respondents to have prevalent in the area are malaria, gastric ulcer, skin disease, bone disease, fever, eye irritation etc Fig.5. The diseases with overlapping symptoms are grouped under one heading. Thus fever, cough, cold throat infection etc are grouped under Air Respiratory tract infection. The highest percentage of sample population are found to be affected by bone disease which include swelling, brittle bone, pain in joint, restriction of movement etc after ARI.

V. Conclusion and future course of action:

The socio economic and demographic study conducted revealed that share of male to total sample population is greater in all the villages though each village vary from the other in relation to percentage share. Income of Bonda is highest among all the villages and income of Gadarkhai is lowest. Expenditure pattern of sample households represent that while Nanguliabeda has got second greater share in annual average health expenditure, the share of Gadarkhai is highest in case of health expenditure. The share of control village in Annual health expenditure is lowest which indicates a probable relation of distance from Industrial setup with exposure. This suggests a further analysis of reason and constituent of such expenditure in the context of present study. During the study period population of the peripheral area particularly, area in the vicinity of aluminum smelter plant and captive power plant had reported of occurrence of special kind of disease which have not been found in other two strata or distant area from the industrial site. This special kind of disease is related to eye irritation, redness of eye and eye itching. Occurrence of the incidence and prevalence of this disease have been highest in Gadarkhai and absent in Purkia and Inkarbandha. The socio economic assessment through questionnaire found prevalence of problems related to bone ranging from acute to severe in the age group of 15-55 more which can be related to health impact of air pollution since this group were found to be in highest proportionin sample andthis is the group which are more active in outdoor environment. Considering this fact, though these diseases had been earlier included in eye disease a separate needed to be carried out to The disease though on account of medical checkup cannot be reported as fluorosis, such symptom is prevalent in each adult in age group of 15-55. Severe pain in joints, back ache, pain in knee joint, problem in movement and change of posture during sleep are some of the common problems which the respondents have accused of having been suffering from. With the increased share of PM10 pollution (RSPM) increasing every year there is a need to extrapolate the effect of increased pollution on the microenvironment and so on health of people.

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Figures and tables

1.1Major industries of Angul District

Table 1.1: Major Industries of Angul District

Public Sector

Sl. No.	Name Of The Unit	Location	Production
1	Mahanadi Coal Field Ltd. (MCL)	Talcher	Coal
2	National Aluminium Company (NALCO)	Nalco Nagar, Angul	Aluminium
3	National Thermal Power Corporation (NTPC)	Kaniha	Thermal Power
4	Talcher Thermal Power Station (TTPS)	Talcher Thermal	Thermal Power
5	Heavy Water Project	Vikrampur, Talcher	Heavy Water
Private Sector			
Sl. No.	Name Of The Unit	Location	Production
1	Shree Metalics Ltd	Makundapur	Sponge Iron
2	Jindal Steel & Power Ltd.	Nisha, Angul	Steel
3	Jindal India Thermal Power Ltd.	Pathamunda, Kaniha, Angul	Thermal power

Source: District Industries, Government of Odisha, 2023
https://angul.odisha.gov.in/

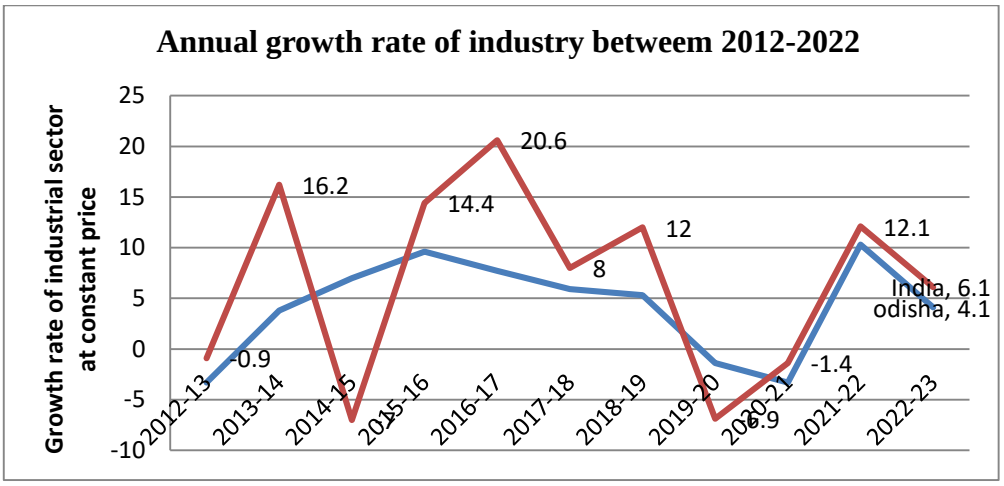

Fig.1 Growth rate of industrial sector as percentage of GDP at constant price

Source: Directorate of economics and Statistics, GoO, MOSPI,GOI

2.1: PM10 status in monitoring locations in each city based on CPCB classification of air quality

Table 2.1:classification of air quality

Year	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
RO office	H	C	C	C	C	C	C	C	C	C	C
NALCO	H	H	H	H	H	C	C	C	C	C	C

Source: Based on air-quality data provided by OSPCB.
Note: C is critical; H is high

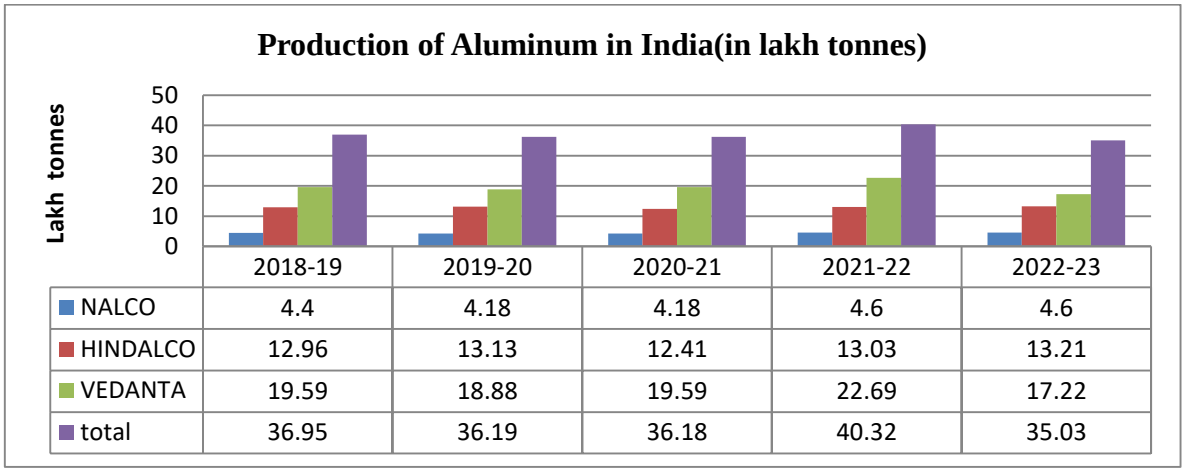

Fig .2: Year and plant wise production of Aluminum
Source: Ministry of Mines, GOI, 2023

2.2: Ambient air Quality Monitoring Data of Angul from 2013-2021

Table 2.2: Monitored data from 2013-2021

YEAR	SO2(50)			NO2(40)			PM10(60)		
	MIN	MAX	AVERAGE	MIN	MAX	AVERAGE	MIN	MAX	AVERAGE
2013	4	13	8	12	20	16	39	216	106
2014	4	13	9	12	31	22	46	191	116
2015	8	14	10	17	29	23	50	159	104
2016	6	14	9	17	28	22	47	198	100
2017	7	13	9	21	30	26	56	182	96
2018	5	15	10	20	20	25	63	163	103
2019	8	15	10	22	34	26	34	223	92
2020	6	25	9	16	28	24	46	158	91
2021	1		10			27			96

Source: NAAQMS 2012-13, Central pollution Control Board, Manual Monitoring data, NAMP, CPCB (2013-2021)

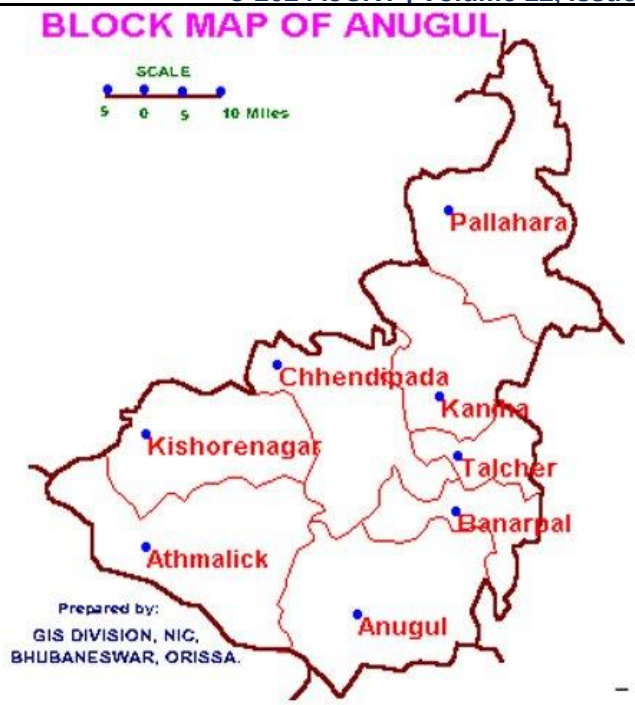

Fig. 3: Block map of Angul

3.1:Effect of pollutants and resultant effects on living organism

Table 3.1: Effect of air pollutants

Sl no	Pollutant	Major sources	Impact on Human health	Other effects
1	Particulate Matter	Combustion of fossil fuels, Material handling, processing, Automobiles, Construction of road and buildings.	Particle size less than 10^m will affect the respiratory tracts and lungs, leads to asthma, bronchitis and pneumonia.	Affect the photosynthetic process of plants.
2	Sulphur Dioxide (SO2	Volcanic eruptions, Combustion of fossil fuel containing sulphur e.g., Coal, Natural gas, Petrol, Diesel, Manufacturing of sulphuric acid	Eye and nasal irritation, (i) bronchitis, asthma, pulmonary emphysema, visibility impairment	Bleaching of leaves, Necrosis, Interferences in the photosynthetic process (ii) Corrosive effect on material (iii) Cause of Acid rain
3	Oxides of Nitrogen (NOx)	Automobile exhaust, Industrial process like Power plant and Nitric plants, lightning & forest fires.	Eye and nasal irritation, Headache, Chest tightness and discomfort, Lung irritation, increase susceptibility to respiratory infections	Suppressed growth, leaf bleaching, epinasty, leaf abscess, Acid Rain, precursor of ozone observed in atmosphere
4	Carbon Moioxide (CO)	Automobile exhaust, combustion process, Organic Combustion	Reduce the ability of hemoglobin to carry oxygen, affect the central nervous system and responsible for heart attack and high mortality	

5	Ozone (O3)	Natural process in tratosphere of the atmosphere and reaction between NOx and VOC.	Irritation of the upper respiratory tract and can cause impaired breathing and reduced athletic performance.	(i) Fleck on upper surface, suppressed growth, Necrosis and bleaching of leaf, reduction in yield of crops, (ii) Adverse effect on materials especially plastic and rubbers.

Source: Compiled from Ambient Air Quality status, Odisha (2006-2014), state pollution control board, 2015.

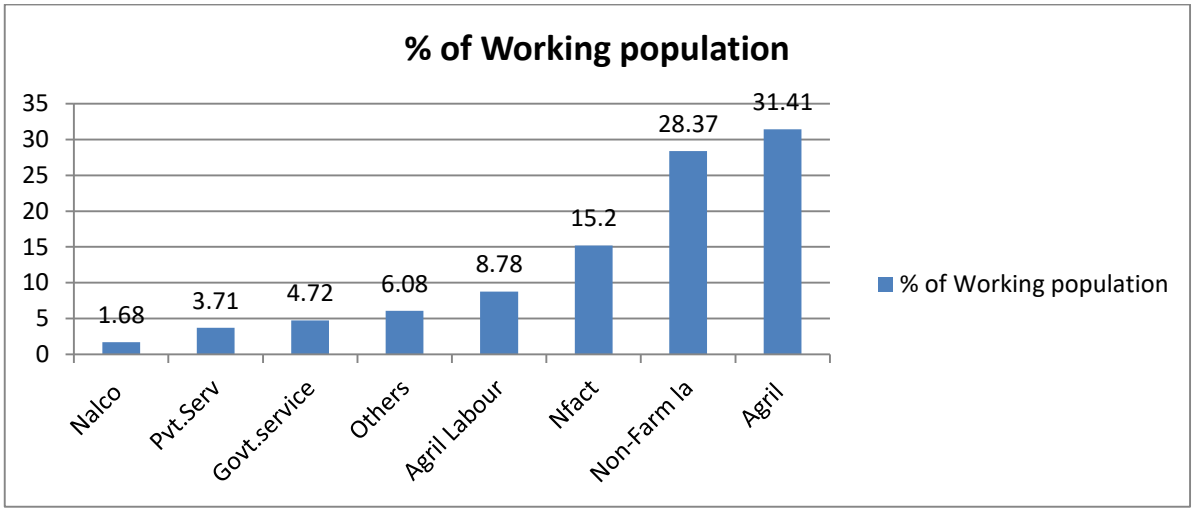

Fig. 4: Occupation wise distribution of working population

Source: Compilation from Primary Survey conducted in 2004-2005

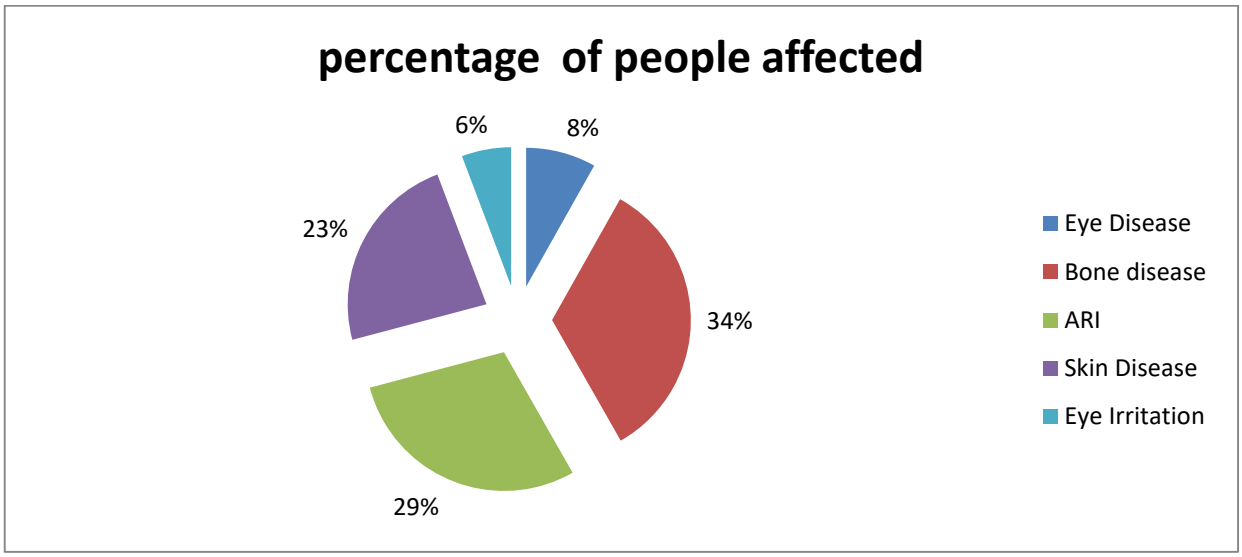

Fig .5: Percentage of people affected by different diseases

Source: Compilation from Primary Survey conducted in 2004-2005

3.2: Example of variables used in health survey

Table 3.2: Decision Variables

Effect of Aluminum Smelter plant and Captive power plant	Defining variable for household exposure and health impact Assessment	Questions asked
Health Survey	Adult outdoor Exposure and workplace information	Work place location working hour along with nature Age of respondent

	Children outdoor exposure	Daily spending time outside school and home and age of child
	Health effect with frequency with recall period of 6 month to one year recall period substantiated by prescription , medicine and information of local medicine shop and health workers	To capture health effect *URTI Eye Disease Skin Disease Issues related to bone and joint pain are taken into consideration. Health endpoints are linked to household air pollution
	Health cost	Income lost due to illness and its treatment (both direct and Indirect)
	Annual income	Income and expenditure on various sources

Source: Author's own compilation from primary Survey

Table 4.1: Income and Expenditure pattern of sample villages

Village	**Avg.Income**	Avg.totalexp	**AvgExp on Health**	% of Health exp.
Inkarbandha	30383.33	25186.66	1526.66	6.06
Balaramprasad	36524	26548	1340	5.04
Bantala	44171.74	28454.78261	804.34	2.82
Bonda	45513.75	26033.82	1758.75	6.755634
Gadarkhai	30437.14	23500	2785.714286	11.85
Nanguliabedha	40776.19	29730.47	2342.85	7.88
Purukia	36550.35	23170.58	1188.23	5.128

Table 4.2: NALCO Township, NALCO Nagar

YEAR	No. of Obs. (24 hrs.)	SPM	RSPM	SO2	NOx	-
2006	105	132 (26-261)	70 (15-167)	4.3 (BDL-6.8)	21 (BDL-24	-
2007	97	132(3 7 -2 4 1)	64 (24 -114)	5 (B D L -7 .1)	18.5 (BDL-23.6)	-
2008	66	172(82-237)	89 (38-143	8.0 (BDL-12.2)	18.2 (11.1-22.5)	-
2009	88	165 (64-229)	80 (32-112)	8.0 (4.5-11.2)	17.3 (11.8-21.6)	-
2010	100	147(65-261)	75 (27-119)	7.6 (5.7-12.2)	19.3 (16-26.4)	-
2011	69	176 (111-260)	89 (58-146)	6.8 (BDL-9.1)	18.8 (13.2-23.0)	-
2012	103	186 (76-293)	91 (36-142)	6.4 (BDL-9.3)	18.5 (13.6-24.4)	-
2013	103	217 (80-448)	108 (38-214)	8.1 (4.3-12.6)	20.3 (14.4-25.9)	-
2014	104	238 (104-376)	115 (45-191)	9.3 (4.0-13.4)	21.8 (11.6-30.6)	-
2015	105	-	104(50-159)	10(8-14)	23(17-29)	-
Prescribed standard(R)	24 hrly/Annual Ave	200/140	100/60	80/60	80/60	As per 1998 standard
	24	-	100/60	80/50	80/40	As per

	hrly/Annual Ave					2009 standard

Source: Authors compilation of NAMP data 2006-2016, CPCB,Angul,Odisha.
*figure in parentheses are maximum and minimum reported value

Table 4.3: Descriptive statistics of Independent variables of health and socio economic survey

Variable	Description	observation	Mean*/percentage
PM10*	Average Annual PM10(HH_ exposure)	105	(19.67)70
Edu_inyrs	Education in yrs of schooling(for literate)	957	6.4
HH_size	Household size	957	5.92
Percentage of male	Male as proportion to sample population	957	57.37
Percentage of female	Male as proportion to sample population	957	42.63
Total population by Age	Distribution of population by age	957	
<15		333	34.796
15-55		545	56.948
>55		79	8.254

Source: Compilation from Primary Survey conducted in 2004-2005
*Figure in the parenthesis is the household exposure data compiled with monitored data