

## CHAPTER 3

# THE STUDY AREA

### Locational Aspects

As noted in Chapter 1, the present study pertains to the 72 ambient air quality recording stations located in 28 cities spread through the length and width of India. Shimla ( $31^{\circ} 09' N 77^{\circ} 15' E$ ) and Cochin ( $9^{\circ} 58' N 76^{\circ} 19' E$ ) are respectively the northernmost and southernmost cities included in the analysis. Ahmedabad ( $23^{\circ} 04' N 72^{\circ} 38' E$ ) and Howrah ( $22^{\circ} 33' N 88^{\circ} 20' E$ ) on the other hand are westernmost and easternmost cities of India included in this study (Figure 3). India, also known as Bharat, embraces the major part of the South Asian realm. It is bounded by the young folded mountain chain of Himalaya in its north and is enclosed by the Indian Ocean and its two main arms - the Arabian Sea and the Bay of Bengal - on the south, southwest, and southeast. The origin of the word 'India' goes back to the old Greek literature and it means the land of 'Indoi' the people living near the Indus (Lambert, 1960 (quoted by Singh, 1995)). The name 'Bharat' on the other hand, bears the testimony of geographical and historical significance. The concept of Bharat was developed after the name of Bharat, a sovereign king of the Vedic period who visualised the fundamental unity of the country. (Singh, 1995).

The Republic of India, with a land frontier of 15,200 km and a coastline of 5,700 km, is a geographical unit exhibiting contrasting geomorphic, meteorologic/climatologic and cultural features. It extends from  $8^{\circ} 4' 28''$  north to  $37^{\circ} 7' 53''$  north latitude and from  $68^{\circ} 7' 53''$  east to  $97^{\circ} 24' 47''$  east longitude (Kund, 1989). The north-south extent is 3200 km and in east-west direction it extends over a distance of 3000 km. Geographical planimetric area of the country is 32,67,500 square km. In terms of size, it ranks seventh amongst the countries of the world. India is a country of great diversities exhibiting manifold physical, cultural and economic contrasts. It enfolds within its bounds the loftiest and youngest mountain chain (the Himalaya). This mountain chain has been built

up by the youngest mountain-building episode in the geological history of the earth called the Himalayan orogeny (Marh. 1986). The subdued relief in the Peninsula, in contrast, shows one of the oldest and most stable geological structure of the earth called the Deccan Shield ( a part of the Gondwanaland). Hemmed in between the two, lies the Indo-Gangetic Plain, one of the greatest alluvial plains of the world. Although climatically a typical monsoonal realm, with all its rhythmic characteristics, the country exhibits a wide range of climatic variations from the dry continental conditions in the interior northern parts to the humid littorals, in the southern coastal areas.

### **Physical Geographic Set-up**

#### **Geomorphology**

Geologically, in the country are represented a great variety of geological assemblages varying in age from Pre-Cambrian to the Recent (Wadia, 1964; Krishnan, 1953). The Peninsular shield (the Deccan), which has been a part of the Gondwanaland, has been tectonically the most stable part. This land mass separated from Gondwanaland some 200 million years ago in the Mesozoic Era and drifted northward through the Tethys Sea. This resulted in progressive closure of Tethys Sea and uplift of the sediment as the Deccan shield came closer to the Eurasian Plate located in the north. This culminated in the uplift of Himalaya (Marh. 1986). The interplay among geologic, tectonic and erosional forces has created in India a great variety of geomorphic landscapes. India is divided into following major (macro) geomorphic divisions (Figure 4):-

1. High mountain barrier formed by the Himalaya in the north and eastern highlands known as Purvanchal in the east;
2. The plains of North India, the Indo-Gangetic-Brahmaputra plain;
3. The plateau of Peninsular India, the Deccan Plateau stretching south of the plains of North India; and
4. The coastal plains fringing the plateau of Peninsular India to the east and west.

Ramamoorthy Gopalakrishnan (1996) divided India into seven physiographic divisions, 20 sub-divisions, and 58 provinces. The seven, major physiographic divisions are:

1. Northern Mountains or Himalaya
2. Great Plains
3. Central Highlands
4. Peninsular Plateaus
5. East Coastal Plains
6. West Coastal Plains
7. Island of Arabian Sea and Bay of Bengal

Northern Mountains comprise the young folded Himalaya mountains in the north and mountain ranges in the north east. The Himalayas are the world's highest mountain system which extends approximately for 2500 km obliquely from west-north-west to east south-east. The width of these ranges varies between 250 and 300 km. (Dewan.1988).

Four transverse divisions of the Himalaya have been identified (Burrard and Heron. 1934; Wadia.1961; Gansser,1964; Spate and Learmonth.1967; Jhingran,1981):

1. Punjab Himalaya: from Indus to Satluj rivers;
2. Kumaon Himalaya: from Satluj to Kali rivers;
3. Nepal Himalaya: from Kali to Tista rivers; and
4. Assam Himalaya: from Tista to Brahmaputra rivers.

Across the width of the Himalaya have been identified five longitudinal zones (Spate and Learmonth,1967). These are:

1. The outer zone of the Siwalik Hills and Duns or longitudinal valleys behind them;
2. The lesser or lower Himalaya which includes a great number of minor ranges at 1830-3050 m;
3. The zone of spurs from main ranges, presenting the general aspect of a very deeply dissected planation surface at about 4570 m;
4. The Great Himalaya or Higher Himalaya with many peaks over 6095 m; and
5. The Indus-Tsangpo furrow at about 3660-4270 m.

In general, the entire Punjab Himalayan region tends to be aridic and aridity increases from south to north. Only the windward slopes at the southern edge are wet. The Lesser Himalaya and Siwaliks Hills have a mean annual rainfall from 1000 mm to 2100 mm. The greater Himalayas experience rainfall between 500 to 1000 mm. Beyond that rainfall is less and that too is in the form of snow.

The Kumaon, Nepal and Assam Himalaya are wetter than the Punjab Himalaya. The topography and altitude play a major role in influencing precipitation. The abundance

of low north-south valleys in the Assam Himalaya take the monsoons right up to the foot of the Great Himalaya. The Himalaya receive considerable snow in the higher parts. Many high ranges remain permanently under snow. The total snow/ice cover of the Himalaya is around 16,000 sq. km (Dewan.1988).

The Great Northern Plains cover about 700,000 square kilometre area in the basins of the Indus, the Ganga and the Brahmaputra. Geologically, this plain occupies the area once covered by the Tethys Sea. It is one of the largest and most densely populated alluvial plains of the world.

The advancing edge of the Peninsular shield is represented by the Central highlands which is a wide belt of hilly country bordered on the west by the Aravalli and by Vindhyan ranges and Narmada valley on the south. This division separates great northern plains from peninsular plateaus. Guru Shikar (1722m) in the Aravalli range on the Abu Hills is the highest peak in this region.

Peninsular Plateau covering an area of 1.6 million square kilometre extends due south up to the coastal plains. Peninsular geomorphic landscape consists of several cycles of igneous activity, denudation and rejuvenation (Singh, 1967 (Quoted in R.L. Singh 1995)). The western and eastern edges of the Peninsular plateau are marked by the high Western Ghats (Sahyadris) and the subdued Eastern Ghats. The overall slope of the peninsular plateau is from west to east. The west is wet due to summer monsoons whereas east remains dry except during winter monsoon season.

The broad East Coastal Plains cover about 1,02,882 km<sup>2</sup> of area extending over the states of Orissa, Andhra Pradesh and Tamilnadu. The East Coastal Plains are generally formed by alluvial fillings of the littoral zone comprising some of the largest deltas made by the peninsular rivers.

The narrow West Coastal Plains lie between Sahyadris and the Arabian Sea. The region is 1400 km long and 10-80 km wide and covers an area of 64,284 km<sup>2</sup>. The region is a distinct strip of lowland, interspersed by hills, rising up to 150 m above sea level. It comprises one or more of the following elements of the landscape: sandy beach, coastal sand dunes, alluvial tracts along rivers or lagoons, laterite platforms, and residual hills (Singh, 1995).

The islands of Arabian sea and the Bay of Bengal differ significantly in origin and physical characteristics. The Arabian Sea islands are in the form of an archipelago with an average elevation of 3-5m. They cover about 108.78 km<sup>2</sup> area. These islands, called Lakshdweep, are coral islands. The Bay of Bengal islands extend up to 590 km with a maximum elevation of 750m. The total area of these islands is about 8,32,685 km<sup>2</sup>. These islands called Andaman and Nicobar Islands are of volcanic origin.

### **Drainage**

The Indian drainage may broadly be divided into the Bay of Bengal drainage and the Arabian Sea drainage (Figure 5). The water divide lies approximately along the Western Ghats or Sahyadri, Amarkantak, Aravallis and Satluj-Yamuna divide in the Himalaya. The rivers of the Peninsular uplands are characterised by broad and shallow valleys with low gradients presenting almost graded profiles. Most of the country is drained into the Bay of Bengal. The Peninsular drainage pattern is radial. These rivers are dependent on monsoons and are more or less dry in summer (Wadia, 1961).

The extra-peninsular rivers ( the Himalayan rivers) are snow fed. They never dry up. Most of the rivers originate in the Himalaya or in the trans-Himalayan Tibetan highlands and traverse the Himalayan terrain before entering the vast Indo-Ganga plains. They meander through these plains before finally emptying into the Bay of Bengal or the Arabian Sea.

## Climate

Locational and physiographic factors have greatly influenced the climatic characteristics of India. Though its considerable portion belongs to the sub-tropical zone, the country as a whole shows the characteristics of tropical monsoon climate. This is because of the Himalaya which functions as an effective meteorological barrier (Spate and Learmouth, 1967). The annual march of seasons in India is greatly affected by the regime of the monsoons. The cool, dry season or the period of the retreating monsoons in fall and winter (October to February/March) is usually a period of anticyclonic conditions dominating northern two thirds of the country. The southeastern parts of the Peninsula have their seasons of rains in this part of year. The southern one third, particularly the western margins have warmer and frequently fine weather conditions. This season is dominated by locally subsiding air. It is during this season that meteorologic conditions favourable for greater pollution concentration, e.g. temperature inversion, air subsidence, etc. are most commonly found.

The hot season extends from April to about mid-June. The temperature in the northern half of the country rises through April and May and at times till the first half of June. This period is also marked by decreasing atmospheric pressure. Local winds are prominent. In the coastal areas they are in the form of sea breezes and land breezes whereas in the interior areas they are as mountain and valley breezes. With the increasing range of temperature, the warmest area shifts from the south and central Deccan to the northwestern part of the country. The thermal equator, due to the intensity of heat gets located in the northern part of the country along 25° - 30° latitudes. The initial conditions at the beginning of the hot season is frequently anticyclonic in character both at the surface as well as aloft.

By late June and early July, more than two-third of the country comes under the grip of south west monsoons. The monsoon rains start suddenly. This is referred to as the burst of monsoons. The burst of the monsoons, according to the modern meteorological studies is associated with the sudden shift of the upper tropospheric air

streams, called jet streams, from a location south of Himalaya to a location north of it. The westerly subtropical jet stream gets replaced by easterly equatorial jet stream (Das, 1968).

The retreat of monsoons is gradual. Stormy conditions in the early part of September and October are normally associated with the upper tropospheric troughs. Late summer and Autumn periods are frequented by tropical cyclones in the Arabian sea and the Bay of Bengal. They frequently cause terrible storms and result in large-scale damage.

The length of seasons varies from year to year and from place to place. This is due to the changes in the time of the onset and the duration of the monsoons. Broadly speaking, the climate in India varies from the sub-freezing ( $-45^{\circ}\text{C}$  in Leh in winters) to year-round tropical climate of the Madras coast to the aridity of the Thar desert (Chopra, 1984).

### Vegetation

As per the Champion's scheme modified by Puri the following five major groups of India's natural vegetation have been identified (Puri, 1960):

1. Moist Tropical Forests;
2. Dry Tropical Forests;
3. Montane Sub-Tropical Forests;
4. Montane Temperate Forests; and
5. Alpine Forests.

In the Himalayan region the main species is chir pine (*Pinus longifolia*), but other conifers like deodar (*Cedrus deodara*), blue pine (*Pinus wallichiana*), spruce (*Picea morinda*), silver fir (*Abies webbiana*), silver birch (*Betula utilis*), and juniper (*Juniperus species*) in the high altitudinal zones, and broad-leaved temperate trees in low altitudinal zones. The Indus Plain, which is dry and hot, supports scanty natural vegetation. The region of the Ganga Plain has forests of widely different types. The islands of the Andamans in the Indian Ocean abound in evergreen, semi-evergreen and mangrove beech

forests (Chopra, 1984). The western and the eastern coastal regions have tropical moist deciduous, littoral and thorny thickets (Singh, 1995).

The natural vegetation of India displays a great variety, but a long period of human exploitation of forests for the purpose of fuel wood, timber, and other forest produce and expansion of agricultural and urban land into the forest area have left the forests in a depleted state and the forest area has shrunk considerably. The problem of deforestation has been recognised since long as is vindicated by the studies of deforestation and resultant erosion in the hilly areas of Punjab and other states by Hamilton (1935), Glover (1946) and Gorrie (1948) in the first half of the present century. The long period of forest exploitation has left the forest area greatly shrunk. In the late 1960s it was estimated that the total area under forests in India was 695,000 hectares which made about 22% of the geographical area of the country. More recently the forest area of the country has been estimated using satellite remote sensing data. These data have been periodically published in the State of Forest Reports brought out by the Forest Survey of India. For the period 1981-83 on the basis of LANDSAT-MSS data it was estimated that 19.49 % of the geographical area of the country was under forests. Comparable figures for the periods 1985-87, 1987-89, and 1989-91 respectively have been 19.43, 19.45, and 19.45 % on the basis of LANDSAT-TM data. For the period 1991-93, on the basis of IRS-1B LISS-II data, the forest area has been estimated to be 19.43 % of the total geographical area. Roughly a value of 19.5 % can be accepted. It needs be emphasised that there is considerable variation from state to state and that there have been considerable amounts of change in different states. This is shown in Table 27.

### **Human Aspects**

#### **Population**

India ranks second in population and seventh in land area among the countries of the world. It has 15% of the world's population residing in about 2.4% of the world's area. The present population of India is 96,05,69,826 (The Tribune office) while the

**Table 27**  
**Per Cent Forest Cover and Forest Cover Change**  
**in Indian States and Union Territories**

State / Union Territory	Per cent forest cover (1997)	Per cent Change (1995-97)
Andhara Pradesh	15.7	-8.66
Arunachal Pradesh	81.9	-0.03
Assam	30.4	-0.98
Bihar	15.3	-0.14
Delhi	1.7	NIL
Goa	33.8	+0.40
Gujarat	6.4	+2.09
Haryana	1.4	+0.17
Himachal Pradesh	22.5	+0.56
Jammu & Kashmir	9.2	+0.03
Karnataka	16.9	+0.06
Kerala	26.6	-0.02
Madhaya Pradesh	29.6	-2.94
Maharastra	15.0	+5.25
Manipur	78.0	-0.80
Meghalaya	69.8	-0.36
Mizoram	89.1	+1.07
Nagaland	85.8	-0.49
Orissa	30.1	-0.35
Punjab	2.8	+3.35
Rajasthan	3.9	+0.55
Sikkim	14.1	+0:06
Tamil Nadu	13.1	+0.13
Tripura	52.9	+0.14
Uttar Pradesh	11.5	+0.02
West Bengal	9.4	+0.88
Andaman & Nikobar Islands	92.3	-0.03
Chandigarh	6.1	NIL
Dadra & Nagar Haveli	41.5	NIL
Daman & Diu	2.7	NIL
Lakshdweep	NIL	---
Pondicherry	NIL	---

Source: *State of Forest Report, 1997*, Forest Survey of India.

population was 23.8 crore in 1901 (Chandna, 1994) thus recording an increase of about 391 % in the present century.

As the sources of air pollutants lie in the activities of human population, both domestic and industrial, there is bound to be some relationship between the concentration of population and that of the pollutants. It is therefore, relevant to discuss the distribution of population in general and that of urban population in particular in the study area.

About 74.27% of the total population of India live in villages. A very high concentration of people is found in the Ganga plains, the Punjab-Haryana plains and coastal plains. More than half of the population of India lives in these areas. The remaining parts contain 76.8% of the area of the country over which rest 50% population is distributed (Singh, 1988). Low densities (0-150 persons per sq. km) generally occur in all states/union territories; medium densities (151-300 persons per sq. km) in eight states/union territories; high medium densities (301-600 persons per sq. km) are present in six states; high densities (601-1200 persons per sq. km) occur in 3 states/union territories; and very high densities (above 1200 persons per sq. km) are found in 4 union territories only (Census of India, 1991). Table 28 shows the state-wise area, population and population density. Population growth of India from 1901 to 1991 is shown in Figure 6.

The ratio of urban population to the total population of India has increased very slowly through the present century. The increase is from 11% in 1901 to 18% in 1961. In 1991 the per cent of urban population to total population was 25.73%. There are 23 cities with a population of over one million.

According to the 1991 Census, about 217.2 million people in India lived in 3,609 urban centres of varying size. It may be pointed out that at the beginning of the present century only 25.8 million people in India lived in urban centres. It became 25.9 million in 1911 registering an increase of only 0.35 %. From 25.9 million in 1911, the urban

**Table 28**  
**State-wise Population Density of India**  
**1991**

States/Union Territories	Area in Sq. pm	Population	General Population Density (Persons/sq. km)
West Bengal	88,752	67,982,732	766
Kerala	38,863	29,032,828	747
Bihar	173,877	86,338,853	497
Uttar Pradesh	294,411	139,031,130	471
Tamil Nadu	130,058	55,638,318	428
Punjab	50,362	20,190,795	401
Haryana	44,212	16,317,715	369
Goa	3,702	1,168,622	316
Assam	78,438	22,294,562	284
Tripura	10,486	2,744,827	262
Maharashtra	307,713	78,748,215	256
Andhra Pradesh	275,045	66,354,559	241
Karnataka	191,791	44,806,468	234
Gujarat	196,024	41,174,343	210
Orissa	155,707	31,512,070	202
Madhya Pradesh	443,446	66,135,862	149
Rajasthan	342,239	43,880,640	128
Himachal Pradesh	55,673	51,111,079	92
Manipur	22,372	1,826,714	82
Meghalaya	22,492	1,760,626	78
Jammu & Kashmir	222,236	7,718,700	76
Nagaland	16,579	1,215,573	73
Sikkim	7,096	405,505	57
Mizoram	21,081	686,217	33
Arunachal Pradesh	83,743	858,392	10
Delhi	1,483	9,370,457	6319
Chandigarh	114	640,725	5620
Lakshadweep	32	51,681	1615
Pandicherry	492	807,045	1605
Damman & Diu	112	101,439	906
Dadra & Nagar Haveli	491	138,401	282
Andaman & Nicobar Islands	8,249	279,111	34

Source: *Census of India*, 1991 and Chandna 1994

population became 78.9 million in 1961, an increase of 205 %. From the base of 1961 the increase in urban population was 175 per cent in 1991. Table 29 and Figure 7 show the total urban population of India from 1901 to 1991, percentage increase during preceding decades, and per cent increase in comparison to 1901 (Chandna, 1994).

### **Industrial Development**

India has large reserves of natural resources in the form of minerals, power potentials (hydro, thermal, nuclear etc.), agriculture, and above all the human resources. These resources are utilised for industrial development. Spate and Learmonth (1967) recognised the following five phases of Indian industrial development:-

- (1) 1854-1914: railway network was established, emphasis was on textiles;
- (2) 1914-1921: recognition of India's potential significance and insignificance of British military economics, political unrest culminating in the attainment of fiscal autonomy;
- (3) 1921-1939: experiments with protection, rise of iron and steel and sugar industry, considerable but uneven progress;
- (4) 1939-1950: involvement in the World War II, the struggle for independence, the first uncertain years of a new nation; and
- (5) 1950 to date: the era of planning, considerable industrial development, the bad effects are becoming apparent.

India has registered tremendous industrial progress since the Independence in about the middle of the present century. Trends for the recent years are shown in Table 30. The table shows the annual growth rates of major sectors of industry in India for the period 1981 to 1989 (Industrial development reports, 1981-1989). It is clear from the data in this table that the annual growth rate of the mining sector has decreased in the period concerned from 17.7 % to 7.9 %. On the other hand, manufacturing industry, which has the largest share in the industrial sector, has registered an increase in the annual growth rate. The rate of increase of electric power generation increased by 2 per cent points from 1981-82 to 1984-85, decreased in 1987-88, and marginally increased in 1988-89. The annual growth rate of the industrial sector as a whole has decreased up to 1987-88 and slightly increased in 1988-89. The annual per cent growth rates of the Indian industrial sector since 1988-89 are shown in Figure 8. This shows that from a growth rate

**Table 29**  
**India: Growth of Urban Population 1901-91**

<b>Year</b>	<b>Urban Population in thousands</b>	<b>% age increase during preceding decades</b>	<b>% age increase in comparison to 1901</b>
1901	25,867	--	--
1911	25,958	0.35	0.35
1921	28,091	8.22	8.59
1931	33,468	19.14	29.38
1941	44,168	31.97	70.75
1951	62,444	41.38	141.40
1961	78,937	26.41	205.16
1971	109,114	38.23	321.82
1981	159,727	46.02	517.48
1991	217,177	36.19	739.59

Source: Chandna, 1994

**Table 30**  
**India: Annual Growth Rates of Major Sectors of Industry**

<b>Year</b>	<b>Mining</b>	<b>Manufacturing</b>	<b>Electricity</b>	<b>General</b>
	<b>11.40</b>	<b>77.11</b>	<b>11.43</b>	<b>100.00</b>
1981-82	17.7	7.9	10.2	9.3
1984-85	8.8	8.0	12.0	8.6
1987-88	3.8	7.9	7.6	7.3
1988-89	7.9	8.9	9.6	8.8

Source: *Industrial Development Reports*, 1981-1989

of 8.8 % in 1988-89 it decreased to zero in 1991-92 and has steadily increased to 12.2 % in 1995-96. The overall turnover of Indian industry between 1988-89 and 1994-95 in rupees is shown in Figure 9. This shows that the industrial output increased from 4537 crores of rupees in 1988-89 to 6931 crores in 1994-95 registering an increase of about 152.8 %.