PART - I

CONCEPT AND STRATEGY

CHAPTER - 2

GEO-ENVIRONMENTAL SYSTEMS: FACTORS, RESOURCES AND RISKS

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CONCEPT

The term geo-environment has been used here to indicate the dynamic process operating due to interaction of the primary earth spheres like lithosphere, toposphere and atmosphere. The system produces a variety of earth resources and also certain hazards. The various factors of the primary spheres have been dealt with here, include lithostratigraphy, structure and tectonics, geomorphic forms and processes and the climate and hydrometeorologic aspects. For the study area the factors have resulted into an interesting and intricate geo-environmental system. The relevant factors include the geology of late Tertiary and Quaternary periods, geomorphology of the Gujarat alluvial plain and semi-arid climatic condition. These factors and parameters of the geo-environmental system have given rise to an array of rich natural resources coupled with the inevitable risks. The resource base for the study include land and soils, groundwater and surface water, energy resource like fossil fuels and some surficial resources like aggregates and clays. The system also poses some risks like droughts, floods, erosion, deposition etc. The overall terrain conditions and high potential resources related to land, water and energy with relatively low intensity of hazards have provided reasonably good

geological environmental conditions for growth and development of human induced activities.

Due to higher capacity of the environments and resources, the human activities have expanded at a very high pace. The recent process of high rate urbanization and industrialization has been accommodated by the present geo-environmental system. However, it has already shown the clear signs and indications of its over loading and adverse environmental impacts like groundwater mining and quality deterioration, problems of industrial effluents and sewage disposal, seasonal inundation and water logging, degradation of soil productivity in downstream areas, accelerated effects of storm floods, and increasing aridity. It has been observed that the anthropogenic activities have not very much taken into consideration the actual relationship between the geo-environmental system of the region and the developmental planning. The study indicates that it is now high time that future planning be done in tune with the system dynamics and existing and on going works be reviewed accordingly.

The study area provides a very good example of the geo-environmental system, which is characterized by a set of favourable factors, rather rich resources and an interesting interaction of high intensity human activity. In order to fully understand and attempt the diagnostic and distinctive terrain features of the system, the author has attempted to identify the various factors and parameters as under:

(A) **Geo-environmental attributes :**

(I) Geological setting : Lithology, structure, tectonics

(II) Climatic conditions : Major factors and parameters with special reference to hydrometeorology

(III) Geomorphology : Regional landscape and detailed study of various land form features

(B) **Natural Resources and Risks:**

(I) Water regime: Groundwater and surface water

(II) Soil resources and land use pattern

(III) Energy resources: Fossil fuels like oil, gas and lignite; construction materials: Aggregates and clays

(C) **Anthropogenic activities:**

(I) Human-nature interaction

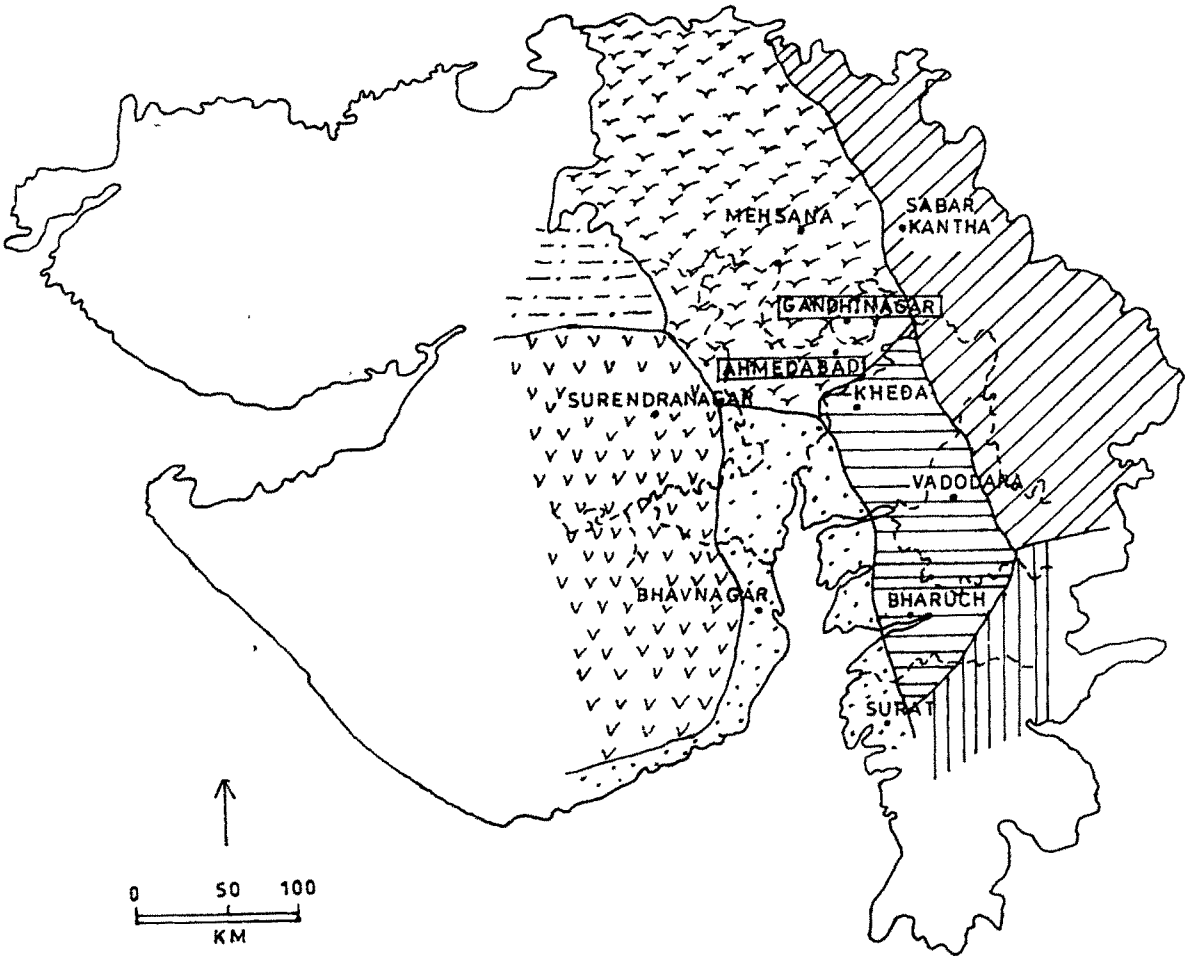
(II) Urbanization and industrialization

(III) Infrastructure and waste disposal

GEO-ENVIRONMENTAL ATTRIBUTES

Three important attributes have been considered, which are related to lithosphere, atmosphere and toposphere. The three attributes collectively form a system of mutual interaction and also sometimes internally within each attribute. Patel (1998) has broadly classified eight eco-regions of the Gujarat state. Accordingly, the present area falls within the Central Alluvial Plain. The location and adjoining other regions are shown in Fig.2.1. The details for each major attribute that is described here provide a basic understanding and the role played by it in the dynamic functioning and producing the natural resources as well as threats. These are described under the broad title of geological setting, climatic conditions and geomorphology. The available resources are both nonrenewable and renewable. Of course all natural resources under geological cycle are renewable and generated as an on going process of the geo-environmental attributes. The soils and energy resources have got a very long duration regenerative cycle i.e. of geological time scale and hence considered here as nonrenewable resources. While the surface water (runoff) and groundwater (recharge) are the distinct parts of hydrological cycle and have a very short term renewability. Such resources are therefore considered as renewable resources. A part of the groundwater stored within the deeper confined aquifers may not be regarded as renewable resource. Some surficial resources like the sand/gravel aggregates and brick-clays are in this respect could be regarded as quasi-nonrenewable. The system has also been

FIG: 2.1 REGIONAL GEOENVIRONMENTAL MAP



SYMBOL	*GEOENVIRONMENTAL UNIT*	*ELEVATION RANGE (m)*	*CLIMATE*	*GEOLOGICAL AGE*
	ROCKY OUTCROPS (CRYSTALLINE)	200-1000	SEMI-ARID	PRE-CAMBRIAN
	ROCKY OUT CROPS (SEDI., AND TRAP)	100-1000	SUB-HUMID TO HUMID	TERTIARY TO MESOZOIC
	ALLUVIAL PLAIN (FLUVIAL. AEOLIAN)	50-200	SEMI-ARID TO ARID	QUATERNARY
	ALLUVIAL PLAIN (FLUVIAL)	20-150	SEMI-ARID	QUATERNARY TO TERTIARY
	SALT ENCRUSTED RANN SEDIMENTS	5-15	ARID	HOLOCENE
	ROCKY TABLE LAND	50-700	SEMI-ARID	QUATERNARY DECCAN TRAP
	MUD FLATS. ESTUARIES.	5-15	SUB-HUMID TO SEMI-ARID	HOLOCENE

rendered with obvious associated risks. These mainly include that related with climate and geomorphology like drought, flood, erosion, deposition etc.

GEOLOGICAL SETTING

The geological framework of the region generally considered being a static type of attribute. It provides the basic substance matter for the system. It has evolved over the period of geological time. It mainly comprises of the factors like the lithology, structure and tectonics. In the case of study area, geology of the late Tertiary and Quaternary periods mainly contribute to this important attribute. During the period, sedimentation has attended the maximum depth of about 2000 m, of which the top 400 m was deposited during the Quaternary. The Tertiary was predominantly of marine sediments deposited in a tectonically active basin, a part of the Cambay graben. They have produced rich energy resources of oil, gas, and lignite. The Quaternaries have a mix environment of deposition like marine, fluvial and aeolian. These have formed good aquifers for fresh water storage at depth and fertile sandy loam type soils on the top. The Quaternaries have been characterized by complex palaeoenvironmental conditions of climatic changes, eustatic sea level fluctuation and neotectonic activities. Geology of the late Quaternary have great relevance to the present day physiographic features, hydrogeomorphic conditions and surficial natural resources like natural aggregates and brick-clays.

CLIMATIC CONDITIONS

Atmospheric factors continuously interact with the top layers of the lithosphere and in turn this mutual interaction gives rise to toposphere (land) and the hydrosphere. Biosphere is also a resultant product of the two major attributes of the geo-environment. But biosphere treatment has not been included in the present study. Since, it forms the subject matter for the ecological study, and therefore it has been considered beyond the scope of this study. The toposheric aspects have been separately considered as an independent attribute and dealt independently. The climatic attributes for the present area rather play a predominant role. The surficial geological attributes like the top alluvial cover is the most vulnerable and readily responsible to the harsh climatic factors.

The climate of the area is of semiarid nature. The various parameters like temperature, humidity, rainfall, wind etc, show generally a quite wide range of variation. The aridity index is 20% to 30% and moisture index is (–53), indicating a very large range of moisture deficiency. Daily mean temperature is 20° C while the extremes recorded are 48° C (May 1916) and 2° C (Feb 1920). Average annual evapotranspiration is 1966 mm. Average annual rainfall is 765 mm with extreme recorded are 1998 mm (1927) and 120 mm (1899) and heavier 415 mm/d (July1927). The total numbers of average rainy days are 37 in a year. Average wind speed is 7 km/h with maximum of 18 km/h (June/July) and minimum of 2.5 km/h (Dec).

The special weather phenomena like hail, thunder, fog, dust storm, squall are occasionally recorded.

The higher aridity index is a rather adverse climatic feature creating an oppressive conditions but the rainfall pattern locally and that in the upper reaches of the Sabarmati basin are quite favourable for a reasonably higher rate of groundwater recharge and surface water runoff yield. Though, the average rainfall is low, the geomorphic and geological conditions being most favourable the water regime has given rise to good resource potential on ground and underground. At the same time potential higher intensity storm rainfall (700 mm/d) in the area and upper catchment of Sabarmati with Dharoi dam reservoir is a potential threat of flood and land erosion.

GEOMORPHOLOGY

The geomorphic attribute in the geo-environmental system can be regarded of secondary origin. It is resulted due to the continuous interaction of the lithosphere and atmosphere. But this attribute is of vital importance in the dynamics of the system. It undergoes continuous changes of landform evolution and generation of natural resources like land, soil, water, surficial deposits etc. It facilitates the habitation and infrastructural developmental activities of human kind. Unlike the other two attributes of geology and climate, human kind has got some control over this. Some landform manipulation is possible with the diverse geomorphic factor such that the mankind could optimize better advantage of resource harnessing.

At the same time protection from the hazardous impact of the system could also be mitigated through appropriate treatment of the geomorphic feature.

Geomorphologically, the study area forms a part of the central Gujarat Alluvial Plains. It falls within the bound of the lower Sabarmati basin. It presents a general landscape of a flat terrain. Its average elevation above mean sea level is 65 m. It has a general southwesterly slope and average gradient of 1:700. On the regional scale though the terrain shows ground characters of a flat alluvial plane, at local scale, the terrain shows an interesting development of a variety of landform features. It is mainly due to the centrally flowing river Sabarmati dividing the area into two parts. The river section and banks show escarpments (15-25 m) development of ravines along the riverbank. The top loessic horizons of the planes have greatly facilitated the development of such ravines. Khari and Chandrabhaga are two major tributaries of Sabarmati also locally break the flat monotony of the plane. The Sabarmati shows development of meandering course and formation of depositional terraces. The otherwise plane topography shows on local scale minor undulations in the form of mounds and depressions. The mounds generally represent the ancient sand dunes, now occur as fossilized features. The depressions generally represent inter dunal low lands or at times represent the relict watercourse of palaeochannels.

Development of good fertile soils of sandy loam type is the result of a typical condition of top loessic cover with climatic attributes aided by the prevailing

biogenic activities. The general flatness of the terrain is also a favourable feature for planning major infrastructural facilities. The loess covered land along the watercourses readily causes the gully erosion and formation of ravines. These also cause high rate erosion and loss of fertile land and at times cause instability to the foundation of major buildings.

NATURAL RESOURCES

The given attributes of the present geo-environmental system have produced a very rich potential of natural resource base. The Tertiary and Quaternary formations have each provided with their characteristic non-renewable and renewable resources. While the climatic attributes on regional scale contribute to the high rate of renewable resource of water on ground and underground. The geomorphic setup as conditioned by the subsurface geology and prevailing climate has provided good potential of land and soil resources. It is interesting to observe that as compared to the rich availability of resource, the relative natural risks are considerably of lower order. The risks to mention are drought, flood, land erosion and silting.

WATER RESOURCES

The area has been endowed with a high potential of groundwater and surface water reserves. The groundwater aquifer system extends to the depth of about 400 m of which the top 100 m unconfined aquifers get recharged regularly. The deeper confined system provides a huge reserve in the form of quasi-nonrenewable

resources. At an estimated rate (GWRDC, 1993) of average annual recharge of 15% of rainfall, the total renewable groundwater potential for the area of 2000 sq km is 230 MCM/yr. Over and above this, the static resource within the study area of 2000 sq km, considering 100 m of confined aquifer thickness and 10% of specific yield, the storage works out as 20,000 MCM. This is a very large storage.

The Sabarmati drains about 20,000 sq km catchment up to the study area and brings 50% dependable runoff of 3000 MCM/yr (TEC, 1995). This is quite a large potential for the area.

SOIL RESOURCE

Entisol and Inceptisol types of soils have been developed in the area. As per NBSS (1994), these are characterized by very gently sloping, very deep, well drained, slightly alkaline, fine loamy with low to medium AWC. They have a high fertility, supporting a variety of crops.

ENERGY RESOURCES

The Tertiary formations have provided with good reserves of natural oil and gas resources within depth range of 1500 m to 2500 m. The area falls within Navagam basin of Ahmedabad-Mehsana block. Over and above within the depth range of 1000 m to 1500 m there are several horizons of thick lignite seams. These form a very good potential of coal bed methane through the process of internal gasification.

CONSTRUCTION MATERIALS

Riverbed sand and gravel provide a very good construction material in the form of natural aggregate. The upper catchments of Sabarmati and Khari have Precambrian crystalline rocks. The decay and disintegration of these rocks have produced high quality sand and gravel and every year a large quantity of aggregate is brought in the area. Similarly a good quality brick manufacturing clay deposits are also available almost all over the area. In fact the silty clay loam forms this resource.

The plane topography as available, though forms a good agricultural land but at the same time it also provides an alternative use when required for better developmental infrastructural facility creation works. The roads, building and other workings are provided safely at lesser cost.

ENVIRONMENTAL RISKS

The geo-environmental system along with providing a natural resource base poses problems of hazards that form potential risks. The human-nature interaction for the purpose of resource exploitation, many a times complicates the geo-system dynamics and increases the risk potential. The study area as has been observed is endowed with rich natural resources providing good opportunities for overall development. It has relatively lesser proportion of natural risk potential. This includes frequent droughts, occasional floods associated with high rate land erosion and sedimentation, changes of river course, formation of ravines and gully

erosion etc. From the seismotectonic stability point of view, the risk to the area is of very low order. Structurally the area forms a part of Ahmedabad-Mehsana block of the Cambay graben. However, the area being included in the seismic zone-III (IS: 1974) of the Indian subcontinent and hence it has got low seismic risk (fig. 2.2).

In the process of fast pace developmental tempo and local and surrounding resources exploitation, the area has been subjected to several human induced risks like groundwater mining and quality deterioration, environmental health problem of unplanned disposal of industrial affluent and urban sewage, blocking natural drainage leading to water logging and inundation in some parts (Plate 2.1). Land and water degradation in the irrigation command of Vasna-Fatewadi project of canal irrigation with contaminated water is evident from Plate 2.2. Construction of Dharoi dam has rendered the Sabarmati river course almost dry during normal and lean monsoon years causing increase in the aridity index for the area. During heavy monsoon years on the occasions of cloudbursts in upper Sabarmati catchment, sudden opening of dam gates on safety counts brings about unprecedented floods in the area threatening great deal of property and life loss. In extreme case of dam break flood, the area runs a very high order risk of disastrous flood hazards. The area falling in the rich zone of fossil fuel, there are occasional cases of oil well fires in the out skirts. All these warrants for a systematic hazard survey, risk analysis and mitigation planning for such a densely populated area.

FIG. 2.2: SEISMICITY MAP OF GUJARAT.

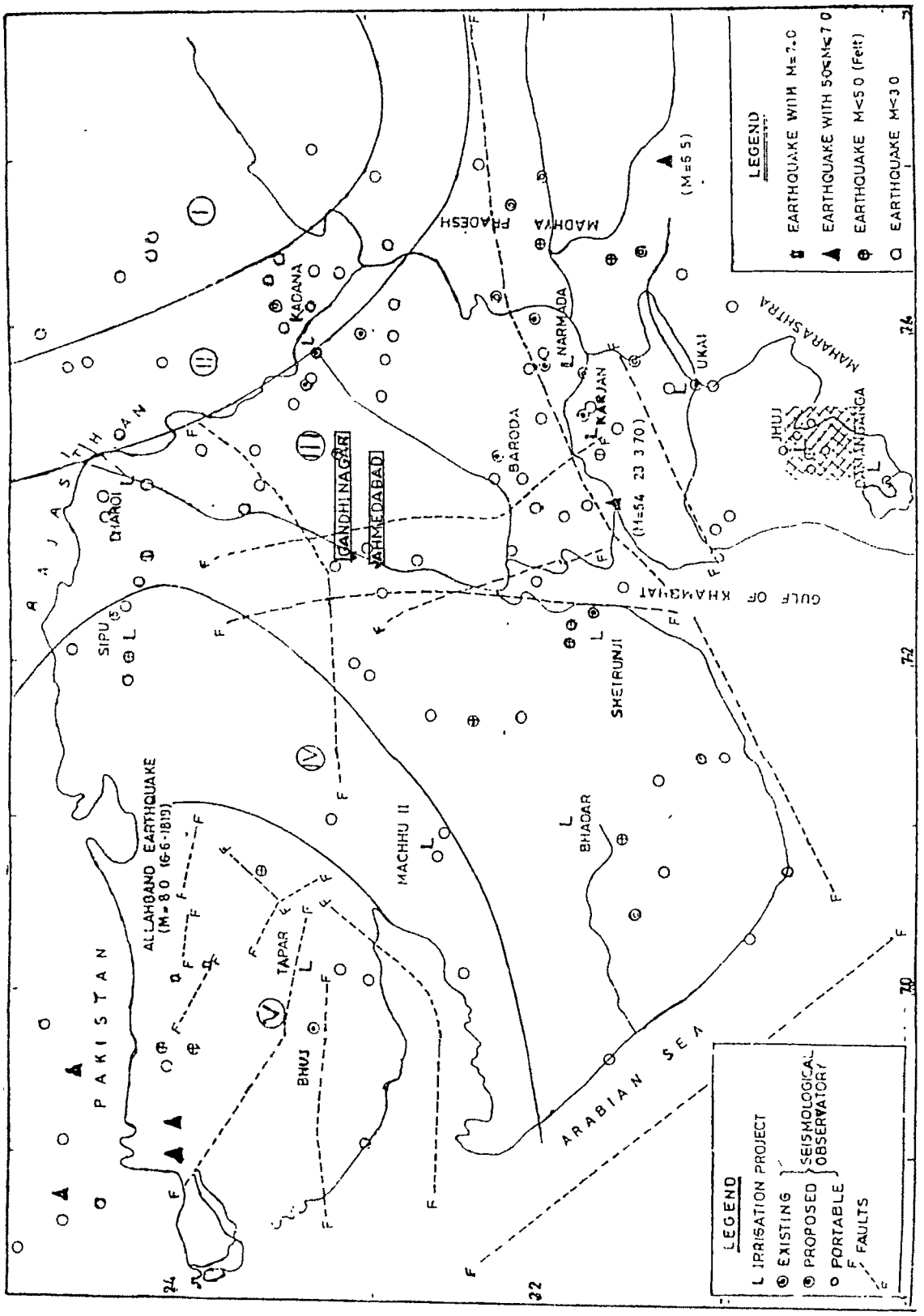


Plate 2.1: Water Logging in Drive-in Area of Ahmedabad.

Plate 2.2: Irrigation by Lifting Contaminated Water from Fatehwadi Canal, South of Ahmedabad City.

absence of small scale local harvesting practice, hardly 10 MCM (25%) is being stored for local usage. In fact there is arrangement to obtain about 300 MCM/yr (at 800 mld rate) from Dharoi dam, 160 km upstream on Sabarmati. This indicates about the mismanagement of the water resources.

INFRASTRUCTURE AND WASTE DISPOSAL

The roads, buildings and other installations, excluding water supply, cause great stress on the land and soil resources. This adversely affects the natural rate of recharge, air pollution etc. the liquid waste produced out of the total fresh water consumption of nearly 900 MCM/yr poses greater problem of proper disposal. The industrial toxic effluent in the Khari-cut canal has severely affected the downstream irrigated command area by way of local water quality deterioration, land degradation and environmental health. The solid waste disposal and related health hazards is also a matter of serious concern (Plate 2.3).

Industrialization with accompanying unplanned disposal of toxic waste, indiscriminate applications of pesticides in agricultural practice and overdraft of the groundwater are the most common and vital hazards to the local and surrounding environments. It is not to say that the development activities need to be completely stopped. But it is most essential that the human activities have to take into account the various facets of the prevailing natural geo-environmental components of the area and work out a sustainable strategy such that a happy balance exists between the development and the environment.

Plate 2.3: Open Waste Disposal in Urban Area, Vastrapur, Ahmedabad.

It has been observed in the present case that the local environmental degradation on several fronts has already gone in the dark zones and the signs are clear that it is now high time to restore the system by appropriate corrective measures.

GEO-ENVIRONMENTAL OVERVIEW OF THE STUDY AREA

The geo-environmental study carried out in the area is very interesting and intriguing. It presents a classic example of two entirely opposite cases. The first is the case of Ahmedabad city which is more than 600 years old. The city has grown in all the directions since then. Till the independence it was confined within the city walls built by Ahmed Shah Badshah. But after the independence the city saw a sharp growth in population and also in the number of industries. Textile industries, which were flourished during this time, put Ahmedabad in the world map and the city was known as Manchester of India. Auxiliary industries also developed which required more manpower. Many people from the surrounding areas and also from the far off places made Ahmedabad their home and this was the beginning of the process of urbanization. In the later years the growth of textile industries declined. But at the same time other industries such as pharmaceutical, chemical, engineering etc, grew very rapidly. The process of urbanization has speeded up since last three decades. The Ahmedabad Municipal Corporation limit was extended. But the growth of the city was not well planned and the basic emanites became very much sought after. As a result the natural resources like land, water and air have been worst affected. Deforestation, conversion of

agricultural land in to constructed areas, depletion of quality and quantity of water resources, soil degradation etc. are some of the adverse effects of this unplanned, haphazard growth. This has also led to air pollution in the city area. The second case is that of Gandhinagar. This city was planned on the base of the famous city of Chandigarh, capital of Punjab and Haryana. All the natural geo-environmental attributes have been care fully considered in the planning of Gandhinagar. This city was built in the year 1969 and started functioning as capital of the state in 1970. Population of Gandhinagar was 24000 in 1971, which increased to 64000 in 1981 and was 1.5 lakhs in 1991. At present the population is around 2.5 lakhs. It covers an area of 573 sq km out of which 350 sq km is planned area. This planned area is for a population of 4 lakh people. The city has been divided in to 30 sectors. Plantation has been carried out in a very large scale, which has helped in maintaining the natural environment and curbed the gully erosion along the riverbank. In 1994, about 2,50,000 plants were planted over an area of 166 ha bringing down the temperature and increase the rainfall. The per capita forest area in Gujarat is 0.05 ha which is less than half of the all India average of 0.13 hectors and far below the world average of 1.04 ha. This has caused frequent occurrences of droughts and floods. Both the cities of Ahmedabad and Gandhinagar are very near to each other. They are at the point of merging to becoming twin cities like Hyderabad and Sikandarabad. Thus both of these cities present a classic case of negative and positive effects of environmental friendly planning.