Chapter – 1

Introduction

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1.1 INTRODUCTION

Industrialisation is considered as one of the principal processes responsible for regional and economic development of a region. This process of change leads to the improvement of human well being, development of infrastructural facilities and technological advancement. Industrialisation where on one hand accelerates the process of development but at the same time, it may result in depletion of resources and environmental degradation which would adversely affect the human health. Industrial activities like manufacturing of fertilizers, chemical products and oil refinery generate hazardous waste and dispose in the nearby areas resulting in the contamination of water, soil and air and adversely affecting the surrounding environment. A number of studies have shown a high concentration of different parameters like *lead, mercury, total dissolved solids, fluoride, sodium, potassium, calcium* and *nitrite* in the water and soil in and around the industrial sites. Continuous consumption of water with higher concentration (above desirable limit) of these elements can cause human health problems which may range from mild to severe. According to Salem et al. (2000) the chronic diseases like renal failure, liver cirrhosis and hair loss at Cairo were related to injudicious disposal of industrial waste and consumption of contaminated drinking water. Similarly, Rose et al. (2001) stated that skin rashes, headache, fever, heart diseases, respiratory problems, diahhorea, eye problems at United States were also associated with drinking contaminated water. Cases of neurobehavioral problems, short term memory dysfunction and visual motor coordination deficit effects were noted in young children residing near petrochemical industrial estate in Rayong Province, Thailand (Aungudornpukdee, 2009). A study undertaken by Kanchan in 2007 at Ankleshwar GIDC, Bharuch, Gujarat stated higher prevalence rate of different diseases like asthma, malaria, respiratory, skin and eye irritation, nausea, vomiting and body ache.

When untreated, the hazardous waste disposed by the industries can be toxic and detrimental to both environment and human health. This waste pollutes the soil and when mixed with water it percolates and pollutes the surface and sub-surface water. Improper waste management in the industrial regions posses a great challenge to the people living adjacent to the dumpsites because of polluted environment (Vrijheid, 2000). Thus, waste disposal from the industries leads to destruction of ecosystem, environmental degradation and enhances the risk of deteriorating health of the people.

1.2 HISTORY OF INDUSTRIALISATION

The process of industrialisation is a very old phenomenon in the district. It took place since the regime of Shri Maharaja Sayajirao Gaekwad III. In 1894, the Maharaja had appointed an Industrial Commission for planning the development of industries in various parts of Vadodara (Jha, 2012). Later, a special cell was formed for fast growth and development of the industries. In 1908, Bank of Baroda was incorporated to give the financial support to the industries. The Kalabhavan Technical Institute was established in 1890 and it provided training to the people for generating a skill industrial worker. Alembic Chemicals was set up in 1907, Sayaji Iron Works in 1914 and Dinesh Mills Limited in 1935. After the independence, the district experienced a change in the industrial scenario. Many new industries were set up and the district diversified its industrial base substantially. During 1960-70, Gujarat State

Fertilizer and Chemical Limited (GSFC), Indian Oil Corporation (IOC), Refinery and Indian Petrochemical Limited (IPCL), Asia Brown Boveri, Sussan Textile, Tensil Steel, Oil and Natural Gas Corporation (ONGC), industries were set up near Vadodara city (Jha, 2012). Along with the large and medium scale industries, small scale industries emerged and the older industries too continued to expand. In 1962, the state Government had established Gujarat Industrial Development Corporation (GIDC). It provided developed industrial plots, water drainage, street light, gas, telecom, pipelines, ready built up sheds to industries, material, market, technology, common services, linkages etc. It promoted sector specific estates for chemicals, engineering, apparels, electronics and brass parts etc. In major estates social and commercial infrastructure like housing, schools, banks, post office, dispensaries etc. are also provided. GIDC also makes the sites/land available for solid waste disposal. In Vadodara district, GIDC was developed at *Nandesari* and Makarpura. The Government also developed infrastructure facilities required for industries such as power, roads, ports, water supply and technical educational institutions. The government had also introduced incentives schemes from time to time to promote industries. All such incentives helped Vadodara to emerge as the industrialized district.

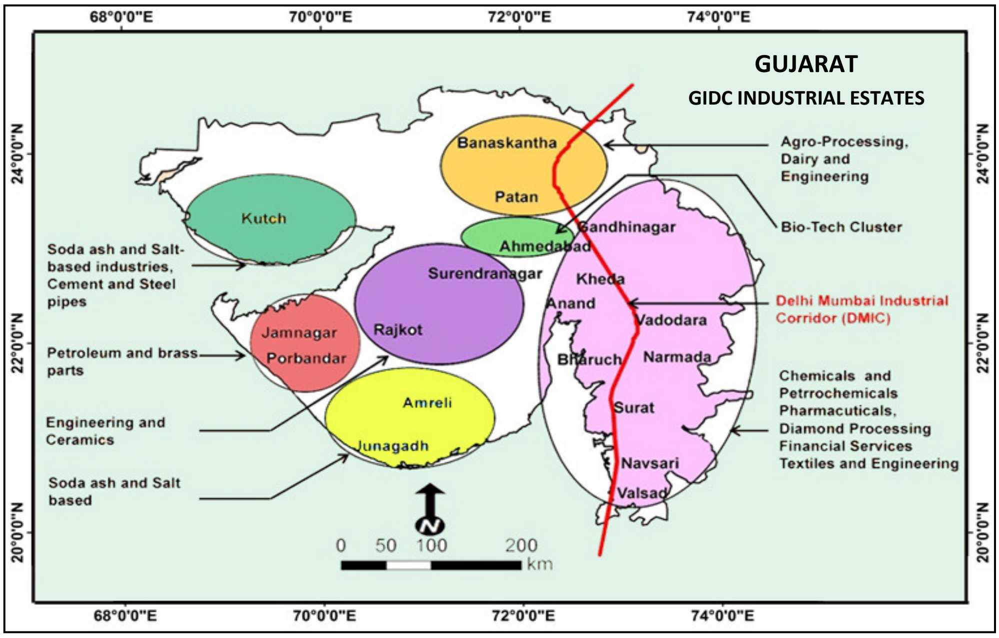

Fig.1.1: GIDC Industrial Estates and Cluster in Gujarat
Source: gidc.gujarat.gov.in Dated: Jan 2017

1.3 STATEMENT OF THE PROBLEM

Gujarat is one of the most industrialized states in India. The industrial progress has led to its economic as well as regional development but when the waste discharged from the industries are not disposed judiciously then it might turn into a source of contamination.The industrial estates of Gujarat State Fertilizer and Chemical Limited (GSFC), Indian Petrochemical Corporation Limited (IPCL), Gujarat Alkalies and Chemical Limited (GACL) and many chemical industries of Gujarat Industrial Development Corporation (GIDC) at *Nandesari* are located along the National Highway 08 in Vadodara Taluka. GSFC is situated near *Chhani* village. The company has set up a number of plants producing fertilizers, chemicals, petrochemicals and agricultural products. IPCL is located at *Koyli* (Vadodara). It produces liquefied petroleum gas, jet fuel, marine fuels and petrochemical and crude oil. *Nandesari* industrial estate is another hub where large numbers of chemical and petrochemical industries are established and it stretches along the River Mini. These small and medium units in the estate comprise of chemicals, pharmaceuticals, dyes, pesticides, plastics etc. Apart from the small and medium units, industrial giants such as IPCL and GSFC discharge the industrial waste in the nearby areas. The effluent channels which flow across the study area, discharge the material into the Mini river which finally joins river Mahi. The disposal of industrial waste and effluents from the industries

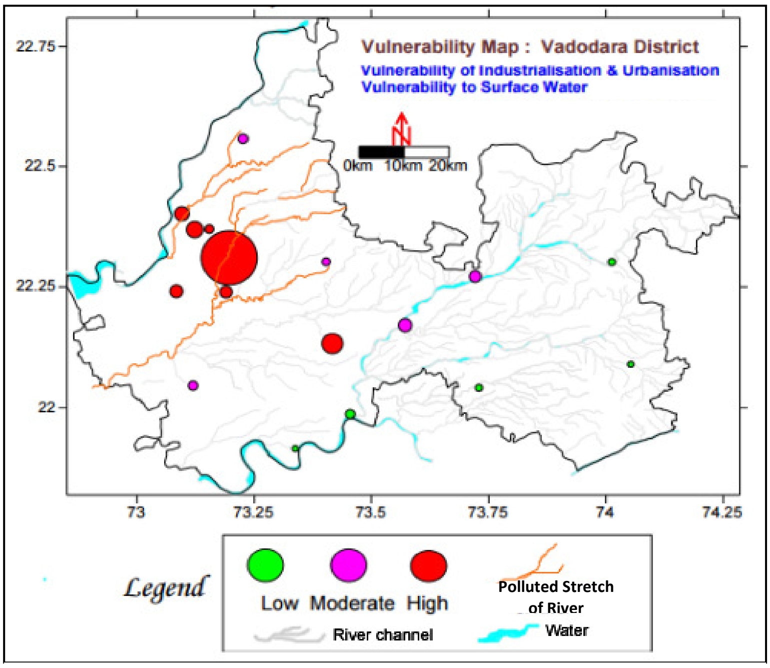

Fig.1.2: Industrialisation and Urbanisation in Vadodara District
Source: Report by Central Ground Water Board, Ministry of Water Resources, Govt. of India, 2010

might pollute the soil and water. Initially, surface water becomes unfit for drinking and gradually the quality of underground water also gets deteriorated. The particles emitted from the industries also settle on the top layer of soil and pollutes it. Sub-surface water is an important source of drinking water in many parts of the country and here also in Vadodara district it remains to be the main source. When consumed untreated, this contaminated water adversely affects human health. The neighbourhood places of industrial areas have a high incidence of skin ailments, respiratory, gastritis and ulcer, diarrhea, cholera and cancer (Govindarajalu, 2003; Ebenstein, 2012 and Mohsin, 2013). The eventual objective of industrialisation is to attain a better quality of life for everyone. A degraded environment means a direct threat to the quality of life and therefore poses a challenge to industrialisation. Industrialisation is essential, hence there has to be greater awareness about the need for protecting the environment, effective planning and the ability to strike a fine balance between industrialisation and environmental protection.

Therefore, the present work focuses on twenty-two (22) places (covering villages/urban outgrowth/census town) and studied the water and soil quality and disposal of industrial waste. Human health in industrial neighbourhood has also been analysed.

1.4 LITERATURE REVIEW

1.4.1 Water Quality in Industrial Area

Water is an important resource which is essential for activities like drinking, agriculture, industries and for domestic purposes. Unfortunately, inspite of it being such an important resource, its indiscriminate overexploitation results into its restricted availability and deterioration of quality. (Kanchan and Ghosh, 2012; Villaescusa and Bollinger, 2008 and Harvey et al., 2005). Natural factors like leaching of minerals, chemical reactions of various organic and inorganic elements, weathering and erosion etc. affects the surface and sub-surface water characteristics (Ghosh and Kanchan, 2014).The injudicious discharge of industrial affluent and excessive use of fertilizer and pesticides in agricultural fields were the main sources of man-made contaminants (Fawell and Nieuwenhuijsen, 2003).

The problem of surface water near the industrial estate has been discussed by scholars in various ways. Phiri et al. (2005) studied the impact of industrial effluents on water quality of rivers in Malawi, Africa. It was noted that the effluent receiving points were acidic with high level of *total dissolved solids (TDS), electrical conductivity (EC)* and *chloride*. Paridaens and Vanmarcke (2001) mainly focused on the contamination of *radium* due to *phosphate* industry on the banks of the river Laak in Belgium. The results revealed that the concentrations of *radium* do occur along the river banks upto 10 m on both sides of the river. The impact of industrialisation and urbanisation on surface water quality was discussed by Teng et al. (2011) in Panzhihua Mining Town in China. It was observed that the effluents bearing *COD (chemical oxygen demand)* and *BOD (biological oxygen demand)* were released into the river water which caused degradation of the surface water quality. Chang (2008) analysed the water parameters like *temperature, pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), suspended sediment (SS), total phosphorus (TP),* and *total nitrogen (TN)* in river water of Han River basin, South Korea. The Mann-Kendall's test was used for determination of trends for each of the parameter. Gyawali et al. (2012) studied the effects of industrial waste disposal on the surface water quality of U-Tapao River, Thailand. It was found that the river water was polluted with *electrical conductivity* and *suspended solids* due to effluent and waste from the industries. Rajaram and Das (2008) reviewed the water pollution by industrial effluents in India. Lokhande (2011) studied on physico-chemical parameters of waste water effluents from Taloja industrial area of Mumbai, India. The effluent samples collected from textile industries shows extremely high *TDS*, *chloride*, *COD* and *BOD* resulted in pollution of nearby Kasardi River. The high level of heavy metals like *Fe, Cu, Cr, Cd* and *Ni* in effluents discharge from Gove industrial area were noticed by Singare et al. (2011) in Maharashtra, India.

The study of seasonal change in surface water quality is an essential aspect to assess the temporal variations due to natural or anthropogenic activities (Ouyanga, 2006). Dan'Azumi and Bichi (2010) examined the effect of heavy metals discharge from industrial effluents on Challawa River in Kano, Nigeria during different season. It was observed that the level of *Cr, Cu, Pb*, and *Zn* into the river, for both the wet and dry season has exceeded the maximum permissible limit. Similar study was undertaken by Kar et al. (2008) in river Ganga, West Bengal and results showed that the maximum *iron* concentration was observed in summer, *manganese* in monsoon but *cadmium* and *cromium* during the winter season. The seasonal variations in physico-chemical parameters of Tapi estuary in Hazira industrial area, Gujarat was studied by Gadhia et al. (2012) and concluded that the water quality of estuary has been affected with *BOD* and *COD* due to industrial and domestic effluents. Rahman et al. (2012) worked on similar line in Turag river, Bhatulia, Bangladesh. Kumar and Bahadur (2009) analysed physico-chemical properties of river Kosi at Rampur (India) by determining various water quality parameters, for winter, summer and rainy season. It was concluded, that the highest values in winter may be attributed to an increase of industrial discharge from sugar industry.

Groundwater is the major source of drinking water in both urban and rural areas (Gupte et al., 2009). It is also the most important source of water supply for irrigation and industrial purposes (Saravanakumar and Kumar, 2011). Increasing population and its necessities have lead to the deterioration of surface and sub-surface water (Pranavam, 2011). Large scale industrial growth has caused serious concern regarding the susceptibility of ground water contamination due to waste materials (Shaji et al., 2009). Waste materials near the factories which are subject to reaction with rain water percolate and reach the aquifer and degrade the ground water quality. Heavy metals are persistant in nature and therefore get accumulated in water, soil and plants (Shaji et al., 2009). Dietary intake of many heavy metals through consumption of plants and drinking water has long term detrimental effect on human health (Sharma and Agarwal, 2005; Farooqui et al., 2007; Sabal and Khan, 2008). The concentration of heavy metals in ground water was examined at different industrial areas. Bikkad and Mirgane (2009) and Hassan et al. (2012) worked on the ground water quality in industrial areas of Aurangabad district, Maharashtra. High level of *EC, TDS, Th, Ca* and *COD* in water were noticed in this belt. Raja and Venkatesan (2010) also observed that water qualities near textile industries are highly polluted at Punnam Area of Karur District, Tamilnadu, India. The high level of *BOD* and *TDS* in groundwater near the discharge was noticed by Olayinka and Alo (2004) in Lagos, Nigeria and Saravanakumar and Kumar (2011) at Ambattur industrial area, Tamil Nadu, India. Ramesh et al. (2012) worked on ground water quality in designated Peenya industrial area and estate, Bangalore, India. The contaminants like hardness, nitrates, chromium and lead in bore wells were exceeding the limit in the drinking water. The sub-surface water was analysed by Ano and Okwunodulu (2008) in Abia state, Nigeria and Rameeza et al. (2012) in industrial zone of Visakhapatnam. Both the studies concluded that the wastes generated by industrial activities polluted the groundwater. Severe groundwater pollution was noted by Mondal et al. (2005) near the tannery industries in and around Dindigul, Tamilnadu due to extensive use of salt in the leather industries and discharge of untreated industrial effluents. Similar study was done by Shaji et al. (2009) at Chavara industrial area, Quilon, Kerala, Ravisankar (2014) at Vijayawada, Andhra Pradesh, Sharma (2012) at industrial area of Bathinda, Punjab and Tank and Chippa (2013) at Halena Block in Bharatpur, India. All the studies depicted that the groundwater in the industrial area was highly contaminated with different parameters.

Khanna et al. (2013) analysed the seasonal variations in different physico-chemical characteristics of ground water quality in and around Integrated Industrial Estate (IIE) Haridwar, India. The study found that the ground water quality exceeded permissible standard with maximum total alkalinity in summer and maximum nitrate levels in winter. Hassan (2012) also work on seasonal variations of ground water in the industrial area of Aurangabad (Maharashtra) and concluded that the deterioration of water due to increase in improper release of industrial effluents and human activities. Fluctuations in spatial and temporal variations in level of ground water parameters were noted by Ahmadi and Sedghamiz (2007). Basavaraddi et al. (2012) observed a high level *TDS* during post-monsoon in and around Tiptur Town, Tumkur district, Karnataka, India.

To assess the water quality many scholars have applied statistical techniques like correlation, t-test, multivariate analysis and factor analysis. Kumar et al. (2013) studied the seasonal variation in lake water quality of Byadagi Taluka. Correlation between *EC, TDS* and *total hardness* were calculated and principal component analysis evinced that all the parameters equally and significantly contribute to variation in groundwater quality. Principal component analysis was also used by Das et al. (2010) and Ouyanga et al. (2006). To study the seasonal variability of water t-test was applied by Kanchan and Chandabadani (2015). Simeonov et al. (2003) studied the surface water quality in Northern Greece by using multivariate statistical method. This method was also adopted by other researchers to study the surface and sub-surface water quality (Singh et al., 2004; Noori et al., 2009; Singh et al., 2005; Guler, 2006; Akbal et al., 2010; Castrignano et al., 2008; Filik Iscen et al. 2007 and Bu et al. 2010). Srinivas and Kushtagi (2012) studied seasonal variation in groundwater quality in Bidar urban and its industrial area in Karnataka by applying factor analysis. The study revealed that *thorium, calcium* and *magnesium* were the most significant elements which control the water quality.

1.4.2 Soil Quality in Industrial Area

In many industrial regions soil pollution has become a serious problem. This problem is especially noted in regions with high population density, where land is extensively used and as a result pollution cannot be simply set aside (Fent, 2004 and Van Straalen, 2002). Soils are considered as the ultimate sink for heavy metals released into the environment (Dang et al., 2002; Chlopecka et al.,1996; Obiajunwa, et al.; 2002). Usually, the distributions of heavy metals are influenced by climate, nature of parent materials, texture, mineralogy, and classification of soil (Krishna and Govil, 2007). Significant increase in the level of metal in the soil was observed in highly industrialised region where concentration was higher than the other non-industrial areas. This fact has been observed by many authors (Krishna and Govil, 2007; Aprile and Bouvy, 2008; Sonawanea et al., 2010). Parizanganeha et al. (2010) analysed the heavy metal pollution of topsoil in the surrounding area of Zinc Industrial Complex in Zanjan. It was concluded that the emissions transported by air, sewage water and industrial effluents lead to the increased of heavy metal concentrations. The influence of industrial effluents on soil was also noted at around Gajraula Industrial Area, Uttar Pradesh (Tyagi et al., 2014). Eana and Sridhar (2004) found that the soil near Chemical Fertilizer Industry at Port Harcourt, Nigeria was contaminated with urea, phosphate and zinc. The hazardous wastes from petrochemicals, refineries, and fertilizer pollute the soil with heavy metals at Manali industrial area in Chennai (Krishna and Govil, 2008) and Balanagar industrial area, Hyderabad (Machender et al., 2011). Iordache et al. (2014) found that the sediment of upstream section in the Olt River near the Industrial Platform of Ramnicu Valcea had high concentrations of *nickel, copper, zinc* and *lead* while level of *nickel, mercury* and *lead* have been noted in the downstream section. The sediments near dumped site in Konabari industrial area, Bangladesh were investigated by Islam et al. (2012). The results indicated that heavy metals concentrations were higher on the industrial effluents site.

Pekey (2006) analysed heavy metals (*Fe, Al, Cu, Mg, Zn, Cd, Cr, Co, Ni* and *Pb*) in surface sediment fraction <63μm of the Ismit Bay, Turkey and observed that, the northern coast was heavily contaminated by industrial and domestic wastes. A study on geochemistry of elements in sediments in north-western Spain depicted that, particle size as well as industrial, urban and rural waste dumping sites played a significant role in metal concentration of the sediment (Rubio et al., 2000). The influence of dye industrial effluent on physico chemical properties of soil was examined by Ahmad et al. (2012) at Bhairavgarh, Ujjain MP, India. The study concluded that the continuous application of effluent deteriorated the soil (0-25cm of depth) quality. Prasad et al. (2006) studied the core sediment in Achankovil river basin India and rise in the concentration of heavy metal was noted with an increase in depth. The distribution of heavy metals like *Cu, Pb, Ni* and *Cd* in the surface sediments of Dongping Lake in China was analysed by Zhu et al. (2006) and found that the absorption of substances increased with the decrease in grain size. The inverse relationship existed between the sediment particle size and element content in the soil (Singh et al., 1999; Lakhan et al., 2001; Adiyiah 2014).

Different statistical techniques were applied for soil analysis. Jayashree and Sarma (2012) determined the heavy metal contamination in soil at East Guwahati industrial zone. The study revealed that the top soils in the area were polluted with heavy metals and correlation was used to find out the relationship between variables. Tsai et al. (2003) noticed a positive correlation between particle size and concentration of metals in Ell-ren River Sediment in Taiwan. Correlation among physico-chemical properties of the sediment of the creeks were analysed by Kumar and Edward (2007) and Varsani et al. (2013) in Manakudy estuary, Surat, India. Mustapha and Lawal (2014) performed the comparative study of heavy metal pollution (*Cu, Zn, Cr, Pb, Ni, Co* and *Cd*) of sediments between Odo-Owa and Yemoji Streams, SW Nigeria. The result of t-test showed a significant variation among metals level in Odo-Owa and Yemoji downstream area. Factor analysis was performed by Liu et al. (2010) and Gulten (2011) to analyse soil pollution by heavy metals. Simeonov et al. (2005), Candeias et al. (2010) and Zhao et al. (2014) used multivariate statistical methods for assessment of soil pollution by heavy metal.

1.4.3 Industrial Waste Disposal and Human Health

The industrial activities like manufacturing of fertilizers, chemical products and oil refinery, dispose waste water and generate hazardous waste resulting in the contamination of air, soil and groundwater and affecting the surrounding environment (Khopkar, 2004; Prajapati and Singhai, 2012 and Bichi et al., 1999). Large numbers of studies have been carried out by scholars in different countries in their various industrial regions and health hazards were observed due to injudicious industrial waste disposal (Ruston, 2003; Bhagure and Mirgane, 2011; Adeola, 1994 and Fierens, 2007). Hamer (2003) examined the solid waste treatment and the effect of its disposal on environment and public health and he stated that dumping of solid and liquid waste enhances the problem of pollution. Vrijheid (2000) discussed the health effects of people living near the landfill sites of hazardous waste and cautioned ill effects of living in their neighbourhood. Increase in risk of adverse health effects like low birth weight, birth defects, certain types of cancers and fatigue, sleepiness and headaches have been reported near individual landfill sites. Porta et al. (2009) reviewed the various epidemiological studies on health effects associated with solid waste disposal and concluded that skin, respiratory and gastrointestinal problems were rampant around the industrial area. The incidence rates of cancers and birth defects were also high in this part. According to Salem et al. (2000) the chronic diseases like renal failure, liver cirrhosis and hair loss were observed due to injudicious disposal of industrial waste and drinking contaminated water in Cairo industrial area, while Su G. S. (2005) analysed water borne illness resulting from contaminated drinking water near dumpsite in Payatas, Phillipines. Kudyakov et al. (2004) examined the morbidity of respiratory disease of people residing near to hazardous waste sites. Dolk et al. (1998) and Fielder et al. (2000) studied the risk of congenital anomalies near hazardous waste landfill sites. Similarly, Elliott et al. (2001) observed the excess risks of congenital anomalies and low and very low birth weight in people living near landfill sites in Great Britain. Cases of neurobehavioral problems, short term memory dysfunction and visual motor coordination deficit effects were noted in young children residing near petrochemical industrial estate in Rayong Province, Thailand by Aungudornpukdee (2009). Abdul (2010) noted that the resident whose houses were less than 200 metres from the dumpsites were victims of malaria, chest pain, cholera and diarrhoea at Mangwaneni dumpsite in Manzini, Swaziland.

The exponential rise in industrialisation in the past few decades has brought the necessity to develop environmentally sustainable and efficient waste management systems. Misra and Pandey (2005) talked about the hazardous waste, impact on health and environment for development of better waste management strategies in future in India. The impact of waste management on health was discussed by Forastiere et al.

(2011). Identification of suitable industrial waste disposal sites (IWDS) is important in order to ensure minimum damage to the various environmental sub-components as well as to reduce the effect on human health. The sitting of suitable new landfill can be performed by using Multi-Criteria Decision Analysis and overlay analysis using a geographic information system (Sumathi, 2007). Jensen and Christensen (1986) work on selection of solid and hazardous waste disposal site was using GIS in the south eastern United States. Developing and implementing for planning landfill sites in UK was discussed by Baban & Flannagan (2010). Bilgehan et al. (2009) studied on the selection of municipal solid waste landfill site for Konya, Turkey using GIS and multi criteria evaluation. Eight input map layers were used and a final map was generated which identified regions showing the suitability for the location of the landfill site. Zamoranoa et al. (2007) evaluated municipal landfill site in Granada, Southern Spain with GIS. Landfill site suitability is assessed based on surface water, groundwater, atmosphere, soil and human health. The results show that suitable locations for the disposal waste were successfully identified.

1.4.4 Industrialisation and Human Health

The process of industrialisation leads to overall development of a region but it also adversely affects the environment and human health. Number of studies have been undertaken to study the impact of industrialisation on human health (Berry and Bove, 1997; Ruston, 2003; Krishna and Govil, 2004; Srinivasa and Govil, 2008 and Bhagure and Mirgane, 2011). Various types of diseases and problems were observed near the industrial areas. Tsai et al. (2003) noted the higher incidence of delivery of preterm-birth infants among the women living in the industrial area (petrochemical, petroleum, steel, and shipbuilding industries) in Taiwan. The health effects like respiratory, blocked nose and eye problems of children living near the cement work in East Lancashire, UK was discussed by Ginns and Gatrell (1996). The diseases like asthma and chronic bronchitis, respiratory troubles, teeth and gum problems, eye and ear diseases frequent attack the people living near the industrial regions due air pollution caused by industries (Sarkar, 2004; Khan and Ghouri 2011; Maantay, 2007;

Sichletidis et al., 2005 and Wichmann et al., 2008). The presence of *arsenic, bismuth* and *thallium* in human hair was found among those who were residing near mining area and employed in factories (Liu et al., 2011 and Ciszewskia et al., 1997). Ebenstein (2012) observed the incidence of cancers due to water pollution as a consequence of industrialization in China. The other diseases like diarrhoea, cholera, skin allergy, respiratory infections, general allergy, gastritis and ulcers are also related water quality (Mohsin et al., 2013 and Govindarajalu, 2003). Strong correlation existed between natural fluoride level in water and the prevalence of dental fluorosis (Indermitte et al., 2009). Although there was good evidence that the presences of fluoride in water resulted in substantial reduction of dental carries (Adekunle et al., 2004 and Alvarez et al., 2009) exposure to high fluoride in drinking water caused dental and sketelal fluorosis (Gopalakrishnan et al., 1999; Zhu et al., 2005 and Ramires et al., 2006).

Comorbidity is the co-occurrence of multiple disorders (mental or physical) in the same person (Goodell, 2011). It is associated with worse health outcomes and more difficult for clinical management (Valderas et al., 2009). The influence of socio-economic status in occurrence of comorbidity was observed by Marrie et al. (2008). Mental comorbidity was observed by Johansen et al. (2011). Similar study was done by Essau et al. (2000) and Jarrett and Ollendick (2008). Zhang et al. (2009) noted the repeat admission of older adults to hospital for adverse drug reactions due to prevalence of multiple diseases.

Bi variable analysis was done by Wnkleby et al. (1992) to study the socio-economic factors and pattern of diseases. McKay and Blumberg (2001) applied this method to find the relationship between the consumption of tea and human health and suggest that tea plays an important role in the pathogenesis of cancer and heart disease. Multivariate analyses were performed for analysis the prevalence of cardiovascular disease risk factors among Nigerian adult population by Oguoma et al. (2015) and Fereidoun et al. (2007) evaluated the effect of long term exposure to particulate pollution on lung function using t-test. Hierarchical regression was applied for the analysis of problem of diseases and the role of socio-economic condition by Li et al. (2016), Arnold et al. 2004 and Jackson (2007).

1.5 OBJECTIVES

The objectives of the study are as follows:

1) To examine the spatio- temporal pattern of the water and soil condition.
2) To identify the industrial waste disposal sites and establish the probable relationship with water quality.
3) To examine the suitable sites for disposal of industrial waste.
4) To study the health condition of the people living in the industrial neighbourhood.

1.6 HYPOTHESIS

1. Null Hypothesis (H_0): There is no seasonal variation in the level of physical and chemical parameters in water and soil.

   Alternative hypothesis (H_1): There is seasonal variation in the level of physical and chemical parameters in water and soil.

2. Null Hypothesis (H_0): There is no relationship between human health condition and sub-surface water characteristics.

   Alternative hypothesis (H_1): Positive relationship exists between the quality of drinking of sub-surface water and the prevalence of diseases.

1.7 STUDY AREA

Vadodara district is one of the most developed districts of *Gujarat* State. The name Vadodara is derived from Vadaparta means 'area where banyan trees (Vad) exist in large number'. In the historical past Vadodara town was called as 'Chandanvati" which later on changed to 'Viravati'. Subsequently, Vadapatra and finally Vadodara name was formed (Gupte, 2010).

1.7.1 Location and Geographical Extent

Vadodara district, geographically extends between 21°49'19" and 22°48'37" north latitude and 72°51'05"and 74°16'55"east longitude covering an area of

7546sq.km. (District Census Handbook, Vadodara, 2011). It occupies the central part of mainland of Gujarat and is surrounded by Panchmahals, Kheda and Dahod districts in north, Narmada district in the south and Bharuch district in the south and south-west. The state boundary between Gujarat and Madhya Pradesh is in the east. In the

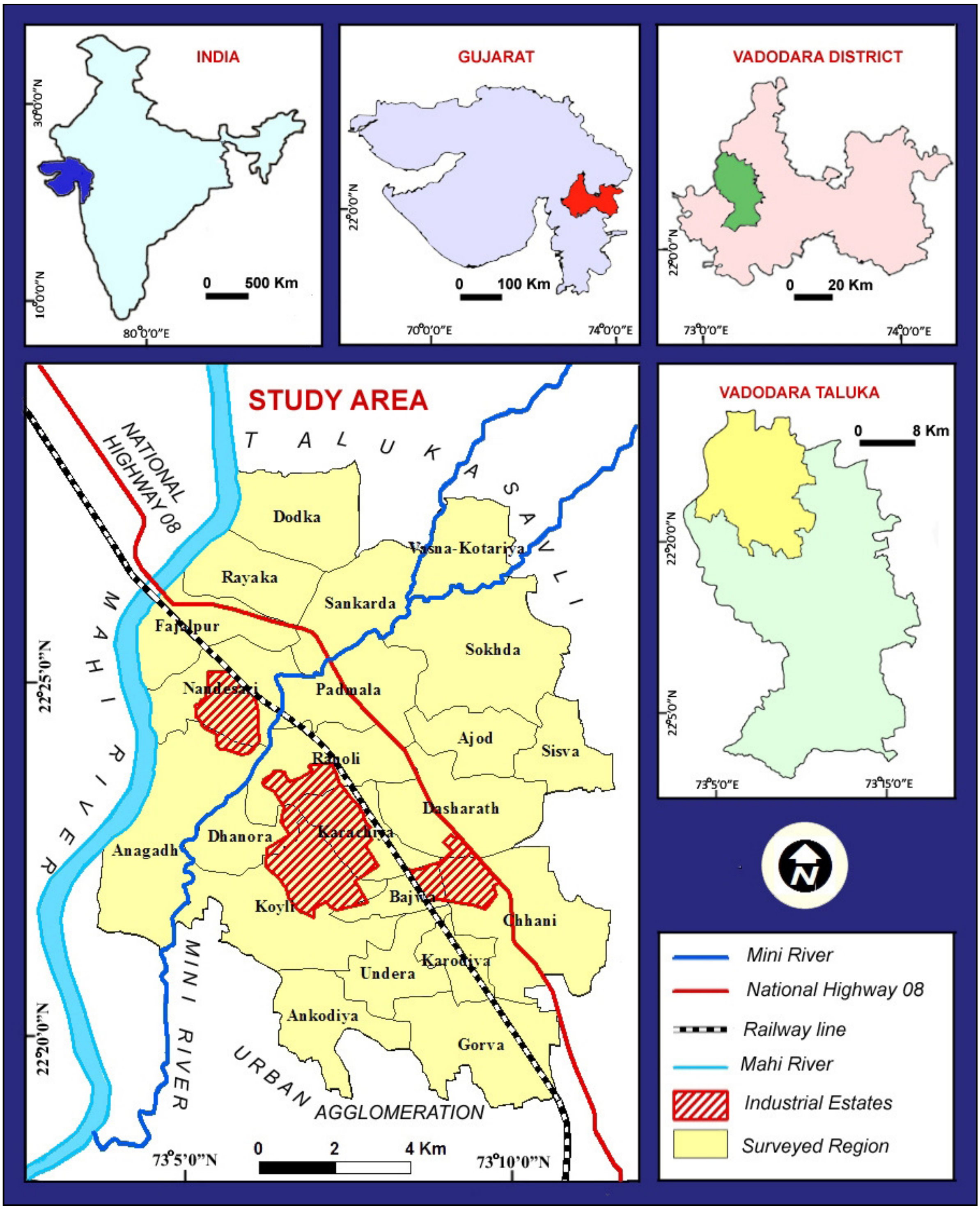

Fig.1.3: Location Map of the Study Area

south east, it shares the national boundary with the Maharastra state. In the north-western part it is bounded by Anand district. Currently, the district is divided into twelve talukas namely Savli, Vadodara, Vaghodia, Jetpur Pavi, Chhota Udaipur, Kavant, Nasvadi, Sankheda, Dabhoi, Padra, Karjan and Sinor. The district headquarter is located in Vadodara taluka and is well connected to other parts of the state and country. The present study focuses upon a selected segment of the northern part of Vadodara taluka which is an industrialized belt of Vadodara district, Gujarat, India. Geographically, the region extends between 22°19'2.332"N to 22°28'12.305"N latitude and 73°3'34.974"E to 73°11'29.23"E longitude covering an area of 149.51 sq.km. (Fig.1.3). In the north, this area is bounded by Savli taluka of Vadodara district. While Vadodara Urban Agglomeration is towards the south. In the west, the area extends upto Mahi river. The study area includes twenty two (22) places, of which twelve (12) namely *Ajod, Anagadh, Ankodiya, Dhanora, Dodka, Fazalpur, Padmala, Rayaka, Sankarda, Sisva, Sokhda* and *Vasna-Kotariya* are villages. The five (05) places (*Bajwa, Karachiya, Undera, Nandesari* and *Ranoli*) are census town and other five (05) places (*Chhani, Gorva, Dasharath, Karodiya* and *Koyli*) are urban outgrowth. There are nine Primary Health Centres (PHC) in Vadodara taluka of which five are located in the study area at *Bajwa, Ranoli, Koyali, Sokhda* and *Sankarda*.

1.7.2 Physiography

Vadodara district is a part of Gujarat Plain and is sub-divided into seven sub-micro regions-

i) Khambhat Silt - occupies the western part of Padra taluka and is the smallest region located in the mid western side of the district. The eastern part is relatively higher where the maximum elevation 22 metres above M.S.L. is noted. The minimum height (10 meters) is found in the western part of the region.

ii) Mahi Plain - extends over the north-western part of the district and covers parts of Vadodara and Padra talukas and major part of Savli taluka. The maximum height (100 metres above M.S.L.) of this region is observed in the north eastern part while the minimum elevation (30 metres) is recorded in the western portion.

The study area belongs to the Mahi plain. The highest elevation of this part was recorded in the southern portion (60 metres above M.S.L) while the minimum height was observed near the Mini River.

iii) Vadodara Plain - occupies the central part of the district and spreads over Savli, Padra, Dabhoi, Vadodara, Karjan, Sankheda, Sinor and Vaghodia talukas. In this plain, the elevation ranges from 27 metres to 88 metres above M.S.L.

iv) Orsang-Heran Plain - extends in the mid-eastern part of the district and extends over Sankheda, Dabhoi, Nasvadi, Chhota Udaipur, Tilakwada and Jetpur Pavi talukas.

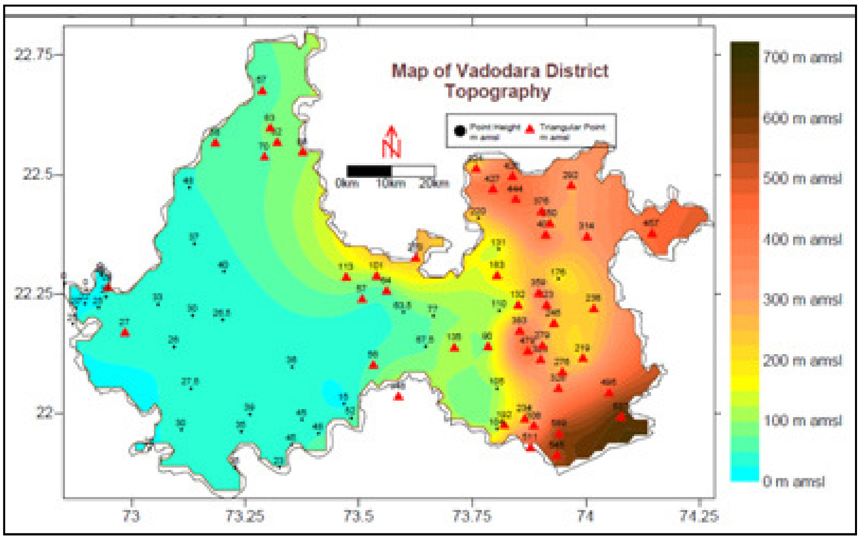

Fig.1.4: Topographical Map of Vadodara District
Source: Report by Central Ground Water Board, Ministry of Water Resources, Govt. of India, 2010.

v) Narmada Gorge - lies in the south-eastern part of the district and covers some parts of Nasvadi and Chhota Udaipur talukas. The terrain of the region is undulating with an altitude varing between 300 metres to 520 metres above M.S.L.

vi) Lower Narmada Valley - extends over Karjan, Dabhoi, Sinor and lies in the southern part of the district. The maximum height of 45 metres above M.S.L. is recorded in the eastern part while in the western portion the elevation is upto 20 metres only.

vii) Vindhyan Hills - falls in the eastern part of the district and extends over Nasvadi and Chhota Udaipur talukas. The contour line of 300 meters passes through the northern part of the region.

1.7.3 Geology

Geologically, the Khambhat Silt, Mahi Plain, Vadodara Plain and Orsang-Heran Plain are mainly composed of alluvium, blown sand, Deccan trap and erinpura granite. While Narmada Gorge consist of Deccan trap, Intra-Trappean, Bagh and Lameta Beds. The geological structure of Lower Narmada Valley and Vindhyan Hills region pertains to alluvium, blown sand, Deccan trap, Intra-Trappean, Bagh and Lameta Beds and Gneiss.

1.7.4 Drainage

The major rivers of the district are Mahi and Narmada. Mahi river flows along the north-western boundary which originates from Vindhya hills near Gomanpur village of Madhya Pradesh. It passes through Vadodara, Savli, and Padra talukas and makes them fertile.

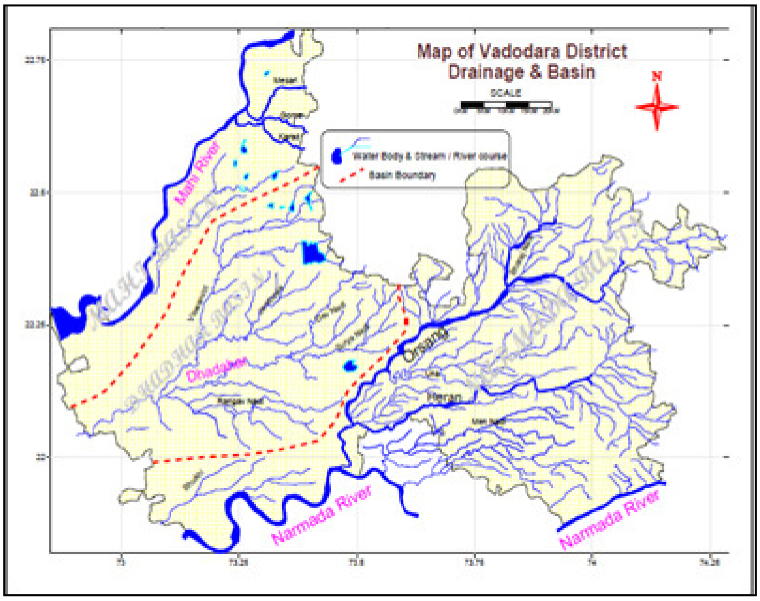

Fig.1.5: Drainage and Basin Map of Vadodara District
Source: Report by Central Ground Water Board, Ministry of Water Resources, Govt. of India, 2010

Narmada river originates from Amarkantak of Madhya Pradesh and flows along the southern flank of the district. It flows towards Karjan taluka and meets the Bay of Khambhat near Hansol village of Bharuch district. Dhadhar with its numerous tributaries are noticed in south central part of the district. The district may be divided into three river basins, namely Mahi, Narmada and Dhadhar basin. Goma, Karad, Mini and Mesari are the tributaries of Mahi River flowing in the north-western part of the district. Jambuva, Dhadhar, Viswamitre and Surya are part of the Dhadhar Basin which flow through central parts of the district and empty into the Gulf of Khambat. The southern and the eastern part of the district are drained by the

Narmada River. Unch, Orsang, Heran, Karjan, Dev, Bhukhi and Aswan are the tributaries of the Narmada river flowing in the district.

The study area i.e the northern part of the Vadodara City comes under the Mahi basin. The Mini River is the tributary of Mahi river flowing in the study area. It flows from north to south-west in the eastern side of the Mahi river.

1.7.5 Soil

The soils of Vadodara district can be broadly classified into three types.

i) Black Soils: Black soil is formed from basaltic rock, granite and gneiss. The colour of the soil varies from dark to light grey and from dark brown to very dark grayish brown. The soils are sandy clay loam to gravel, silty loam to clayey with clayey type of texture. Black soil is further sub-divided into three group (a) shallow (b) medium and (c) deep.

(a) Shallow black soils occur in eastern hilly terrain and in south western part of the district. The depth of soil varies from few cm to 30 cm with no distinct horizon.

(b) Medium black soils are observed in central part of the district. The depth of soils ranges from 30 to 60 cm. It has distinct layers of mature soils and partially decomposed and unconsolidated muram rocks.

(c) Deep black soils (Regurs) are the typical black soils. It is formed from trap rocks and is transported soils, found in south western part of the district. Their depth varies from 60 cm to as high as a few meters. These soils are more fertile than the shallow and medium black soils.

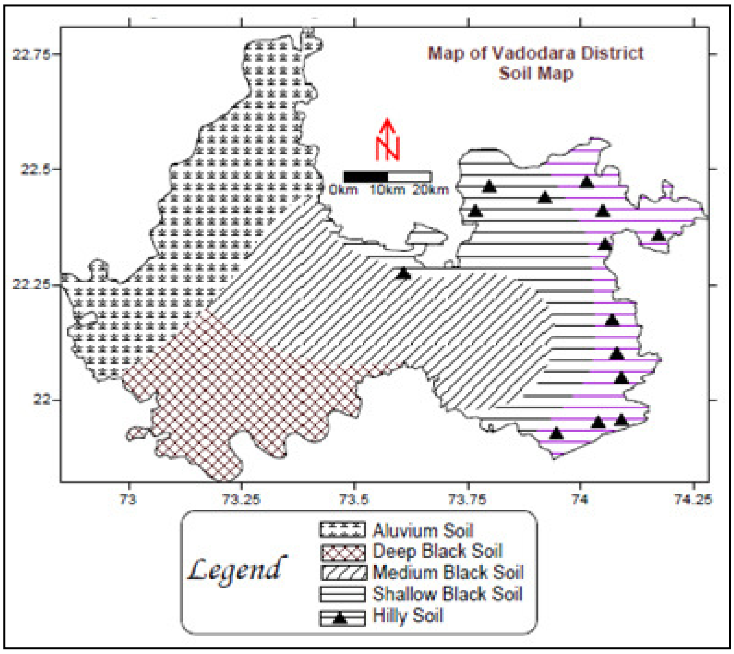

Fig.1.6: Soil Map of Vadodara District

(Source: Report by Central Ground Water Board, Ministry of Water Resources, Govt. of India, 2010)

ii) Alluvial Soils: These types of soils are mainly formed due to fluvial processes. They have coarse sandy to clayey beds with varied thickness. In north-western part of the district including Vaododara taluka sandy loam to sandy clay loam type of soils are noted. Alluvium soils are divided into three types such as (a) Goradu or Gorat (b) Bhatta soils and (c) Besar. The Goradu soils are alluvial soils of older origin while Bhatta soils are of recent origin deposited along the banks of river. Besar soils are silty loam to clay loam in texture and reddish brown in colour. They are deep, well-drained and more fertile soils.

iii) Hilly Soils: These soils are found in hilly terrain of eastern part of the district. The soil profile is not well developed due to steep slope and continuous erosion. They are shallow in depth, composed of muram and rock fragments with poor in fertility.

1.7.6 Climate

The climate of the district is hot and dry in the non rainy seasons. The year may be divided into four seasons. The cold season from December to February, is followed by the hot season (March to May). The south-west monsoon season starts from June and end in the month of September. The post-monsoon season prevails from the month October to November.

i) Rainfall: The district receives much of its rainfall from the south-west monsoon from June to September. The maximum intensity of rainfall occurred in the month of July and August. From the year 1985 to 20, the average annual rainfall of the district was 892 mm. Sometimes heavy torrential rains cause flood to the district. (Whole Gujarat Rainfall Report, 2015). Sometimes heavy torrential rains cause floods in the district. The rainfall in the district increases from west towards the east.

ii) Temperature*:* The temperature generally increases during the period from March to May. In the year 2016, mean monthly temperature varies between 21°C and 35°C (timeanddate.com https://www.timeanddate.com/information/copyright.html). Generally, May is the hottest month with 47°C highest recorded temperature. From the beginning of November, temperature gradually drops and January becomes the coldest month. The maximum (32°C) and minimum (10°C) temperature of January is found to be lower than that of other months. Cold waves sometimes affect the district which is largely associated with western disturbances which move across north India during the cold season.

iii) Winds: Winds are generally light and moderate during the summer. They become stronger in the south-west monsoon season. In the month of October, winds blow from west towards the north-east. While in November and December winds mainly blow from north-east to south-west. In January and February, they are from west to north-east.

1.7.7 Demography

According to the 2011 census, the total population of Vadodara District was 4,157,568 persons with 51.71% male and 48.28% females. The total area of the district was 7,550 sq.km. and the density of population was 552 persons per sq.km. The population of the district grew by 14.16% between the years 2001 to 2011. Sex ratio in the district was 934 females per thousand males. Out of total population nearly 50.51% of rural population is spread in 1537 villages while 49.59 % of urban population is localised in towns and urban agglomerations. The density of population was 552 persons per sq.km. The urban literacy rate of the district was 91.49% while 70.71% of the rural population was literate. As per census 2011, Vadodara taluka is one of the most urbanized taluka of the state.

1.7.8 Economic Resources

i) Land and Land use Pattern: Out of total land in the district 40.54 % of the land is under irrigation. 29.75% un-irrigated and 8.32% is forest area. (District Census Handbook, Vadodara, 2011). Barren and un-cultivable land comprised of 6.97% of the total area. 4.35% is the area under non-agriculture uses and permanent pastures and other grazing lands constituted 4.41% of area. Other land use pattern covered lesser area of the district that i.e. land under miscellaneous tree crops (0.56%), cultivable waste land (1.95%), fallow lands other than current fallows (1.85%) and current fallows (1.31%).

iv) Agriculture: Food crops & non food crops are grown in the district. Main food crops consist of food grains such as jowar, wheat, paddy, bajra, maize etc., and pulses. Other food crops are sugarcane, fruits & vegetables. Non food crops consist of cotton, castor, oil ground nut, fodder, tobacco etc. It was observed that a majority of the cropped area was used under production of cereals in the 2010-11. The average yield per hectare for the crop of wheat, bajra, maize, cereals, food grains, oilseeds, jowar, gram, rapes & mustard and cotton have increased significantly in 2010-11(District Census Handbook, Vadodara, 2011).

v) Industry: Vadodara district is one of the most industrially developed areas of Gujarat state. It has many strategic industries, such as petrochemical complex, oil refinery, fertilizers and heavy water project etc., located in and around Vadodara Taluka. Metal products, non-metallic mineral product, rubber and plastic, pharmaceuticals, engineering and machinery parts etc. are other important industries. Besides these, there are many industrial notified areas in district which are established and managed by Gujarat Industrial Development Corporation Ltd. (GIDC Ltd).

In the northern part of Vadodara taluka various large and small scale industries are located. Gujarat Industrial Development Corporation (GIDC) situated at *Nandesari* is a major industrial estate of the area which spread over 2.06 sq. km. stretching along the River rini, a tributary of river Mahi. There are about 250 small and medium units in the estate which largely produce chemicals, pharmaceuticals, dyes, pesticides, plastics etc. Gujarat State Fertilzer and Chemical Limited (GSFC) is another important large scale industry and is spread over 3.21 sq. km. situated in the southern part of the study area. It had set up a number of plants producing fertilizers, chemicals and petrochemicals, agricultural and biotechnological products. *Channi* and *Bajwa* adjoin this industry. Indian Petrochemical Limited (IPCL) (now owned by Reliance Industries) situated near *Karachiya* and *Koyli* produces benzene, carbon fibre, caustic soda, chlorine etc. Gujarat Alkalies and Chemical Limited (GACL) produce potash, caustic soda, chloroform, compressed hydrogen gas, hydrochloric acid, liquid chlorine, sodium cyanide, potassium carbonate etc. *Undera* village is near GACL.

Gujarat Refinery is the largest refinery of Indian Oil Corporation Limited (IOCL) near *Koyli*. It generates liquidified petroleum gas, petrol, gas oil, jet and marine fuel, petrochemical and crude oil. Many ancillary industries are also found in the region which supports the aforementioned major industries.

1.7.9 Water Facility

Vadodara district has huge potential of surface water resources mainly because of the two major river that is the Narmada and the Mahi. Besides these rivers other smaller river like Viswamitri, Heran, Dadhar, Orsang also flow in the district. Water of the Narmada river has been harnessed by Sardar Sarovar Dam and consequently large part of the district now forms a part of Narmada Canal Command Area. The various sources of surface water irrigation are tanks, canal and rivers which are harnessed by various lift and flow irrigation projects. Ground water is used for drinking as well as for irrigation. The extraction of groundwater is largely done by hand pumps, tube wells and dug wells. There are number ponds and lake in the district but dependency on the groundwater and river water is notably high.

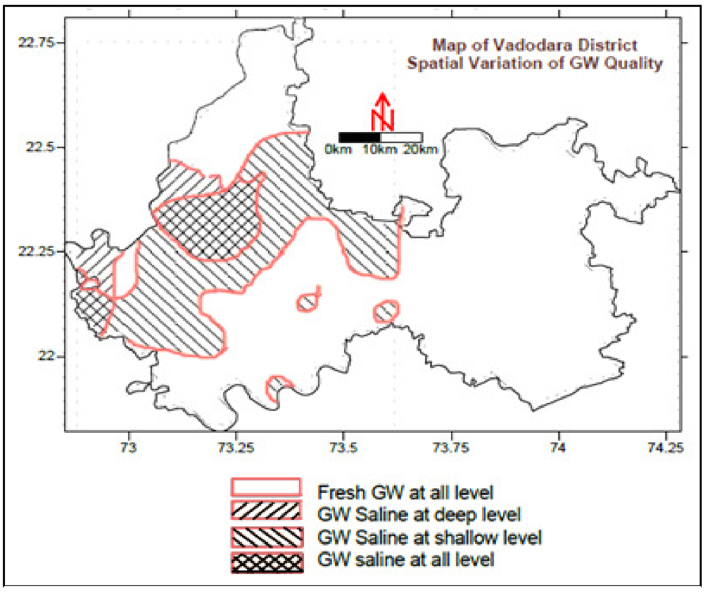

Fig.1.7: Variation of Ground Water Quality
Source: Report by Central Ground Water Board, Ministry of Water Resources, Govt. of India, 2010

A large part of urban area of Vadodara taluka and its surrounding industrial units meet water requirement from Mahi river.

1.7.10 Transport and Connectivity

Vadodara taluka is on the major rail and road arteries joining Mumbai to Delhi.

i) Air: The Airport at Vadodara city is located in its north-eastern part. It has air connectivity with many major cities of the country.

ii) Railway: Railway station of Vadodara belongs to the Western Railway zone of Railways. It is a major junction of the Western Railway main line. Passengers can travel to almost all the parts of India from Vadodara Junction, which had direct connection with all four directions. Among the major railway stations three railway stations, namely *Bajwa, Ranoli* and *Nandesari* are noted in the study area.

iii) Road: Vadodara taluka is well connected by national and state highways. National Highway 08, connecting Delhi to Mumbai, passes through the study area. Various large and small scale industries have come up along this national highway which leads to overall development of the region. The taluka is also connected with Ahmedabad through Indian National Expressway 1.

1.8 DATABASE AND METHODOLOGY

1.8.1 Water Sample

To study the water condition, surface and sub-surface water samples were collected from the twenty-two (22) places taking three (03) water samples from each of them. Twenty- three (23) samples were of surface water (pond or lake), thirty-eight (38) sub-surface and five treated river water (TRW). Thus, sixty-six (66) water samples were collected for one season. To understand the seasonal variation, the water samples were collected for the pre and post-monsoon seasons for the year 2011, 2012 and 2013. Thus, in a year, 132 (46 surface, 76 sub-surface and 10 TRW) water samples were collected. Totally in 3 years, 396 (138 surface, 228 sub-surface and 30 TRW) water samples have been collected for the consecutive three years.

Separate analysis was carried out for twenty (20) surface water samples for monsoon, post-monsoon and pre-monsoon seasons for the year 2013 and 2014. Thus, a total of 60 samples were analysed.

1.8.2 Soil Sample

Three (03) top soil samples were collected from each of the twenty-two (22) places making a total of sixty-six (66) soil samples. Of the 66 samples, care had been taken that one soil sample was collected from the site near to the place from where the water sample was taken. The remaining two sites were choosen randomly with the administrative boundary of the said places. Over a span of one year, 66 x 2=132 soil samples were collected for analysis. The study was based on 396 soil samples which were collected consecutively for three years (2011, 2012 and 2013).

For depth-wise study of the soil characteristics, five (05) sub-soil samples were collected from upstream to downstream along the river Mini which is a tributary of river Mahi.

1.8.3 Tools and Technique

Garmin E-trex Vista HCx handheld GPS was used for marking the sample location of water and soil as well as for marking the identified waste disposal sites.

Random sampling technique was applied for the selection of water and soil sample sites. The water samples were collected in 250 ml capped polyethylene bottles and were later acidified with hydrochloric acid for laboratory analysis. Till the chemical analysis started the samples were refrigerated and kept below freezing point.

Before the collection of the top soil, the surface area was cleared and soil samples were collected from a depth of approximately 1 feet. 500 gram zipped polytheline bags were used for keeping the soil samples.

During the selection of the sampling locations of sub-soil sample, equal distance between the samples was taken into consideration. PVC (Polyvinyl Chloride) pipes with 3 inch diameter were used for the sample collection. Initially, the surface area was cleared and the pipe was held vertically. At the top of the pipe, a thick piece of wood was kept and continuous hammering was done on it so that the pipe can penetrate into the sub-surface. After collection of the sample, the pipe was cut longitudinally along with the sub-soil sample by using stainless steel saw. Later, it was sub-sampled by using stainless steel saw latitudinally at 1 inch interval. Each of the portions of the sub-samples was retained in the zipped polytheline bag. From a sampling location 09 sub-sample were collected.

1.8.4 Chemical Analysis

For all the chemical analysis, Analytical Reagent grade or Lab Reagent grade (Merk, SDFCL, Sulab, Loban, National Chemicals) chemicals were used. All the

METHODOLOGY

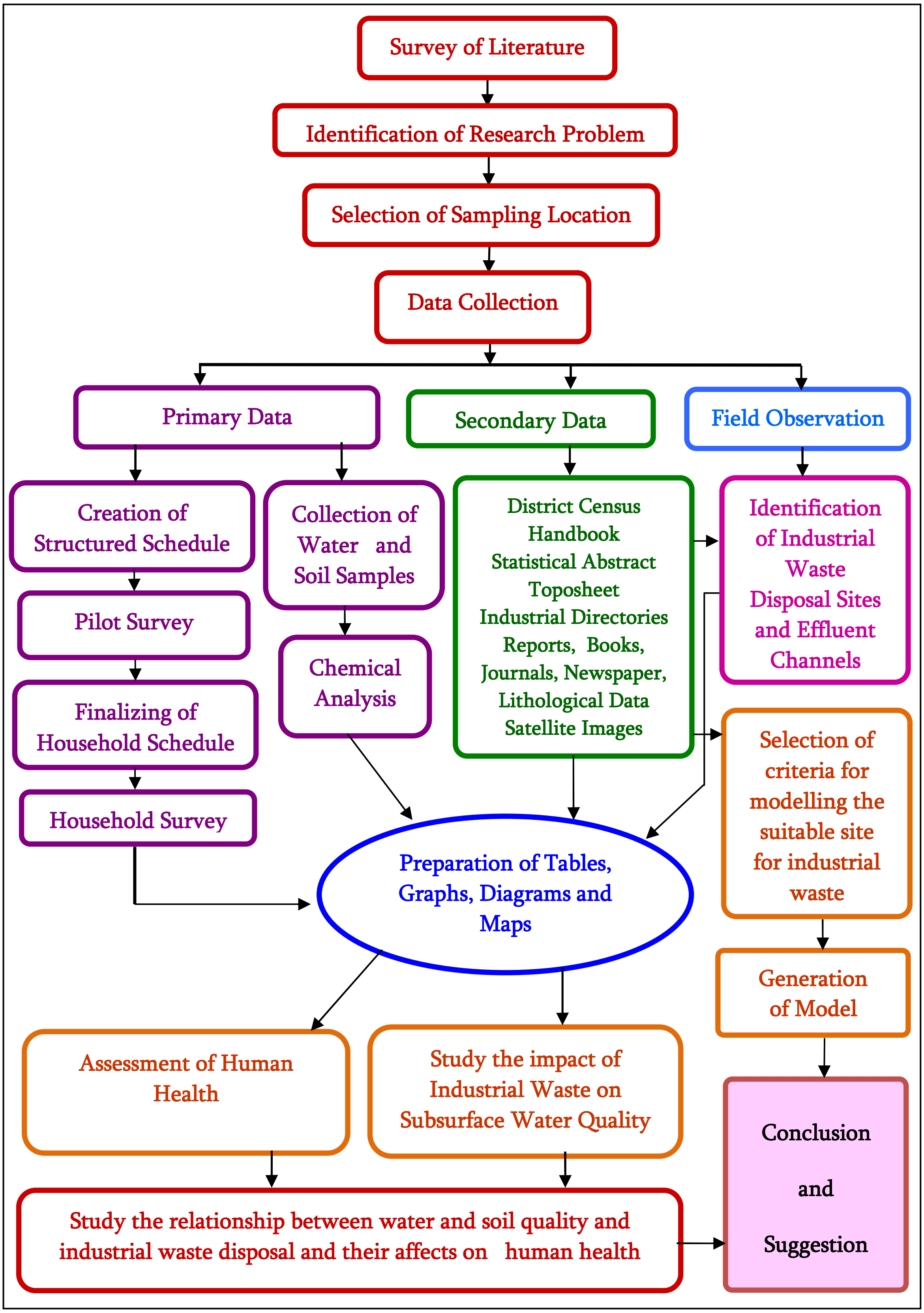

Fig.1.8: Flow Diagram of Methodology

glasswares were of Durasil, Borosil and Borosilicate make and were thoroughly sterilized by Hydrochloric acid, rinsed with distilled water and dried before analysis.

The level of geochemical parameters were measured in the field as well as in the laboratory. The total dissolved solids (*TDS*) and the *pH* was measured in the field itself. The *TDS* metre (Henna Dist. 4, HI 98304) was used for *TDS* while *pH* was measured by *pH* indicating paper (Merk Made).

The level of iron in water and soil samples was determined by using Elico Double Beam UV-VIS spectrophotometer model SL-210 through 1, 10 phenanthroline method (Jeffery et al. 1989). While *nitrite* was determined by using Cadmium Reduction Method (APHA, 1991). All these experiments were carried out in the Laboratory of the Department of Geography, Faculty of Science, The Maharaja Sayajirao University of Baroda. The concentration of *magnesium, potassium, calcium, lead, mercury and fluoride* were analysed at Met Chem Laboratory, Chintamani, Pashuram Nagar Society, 10 Sayajigunj, Vadodara, Gujarat. For cross checking, some of the samples were analysed at Environmental Engineering Laboratory, Civil Engineering Department, Faculty of Technology and Engineering, The Maharaja Sayajirao University of Baroda. Standard wet sieving method (Kilmer and Alexander, 1949) through pipett was adopted for the analysis of the grain size of subsoil sediment.

The data were tabulated, analysed and finally graphs were prepared in Microsoft Excel, SPSS V. 20 and Origins 8.5. Arc GIS 10 software was used for preparation of maps. The sampling location in GPS was tripped to the computer by using Mapsource software.

1.8.5 Identification of Waste Disposal Sites

Industrial waste disposal (IWDS) sites were identified through field observation and satellite image for February 2007, 2011 and 2015. Initially, the IWDS were identified in the satellite image (Google earth image and satellite image IRS-P6, sensor-L4 MN, Date of pass 31 Jan. 2011). The latitude and longitude of the marked IWDS were noted and subsequently it was verified through field visit with the help of map and hand held GPS.

1.8.6 Household Data

To comprehend the health condition of people residing near the industrial area household survey was carried out through random sampling method. The survey was done in twenty-two (22) places, of these twelve (12) were villages (*Ajod, Anagadh, Ankodiya, , Dodka, Dhanora, Fajalpur, Padmala, Rayaka, Sankarda, Sisva, Sokhda and Vasna-Kotariya)*, five (05) Census Towns (CT) that is *Bajwa, Karachiya, Nandesari, Undera* and *Ranoli* and five (05) were outgrowth (OG) of urban Vadodara city (*Chhani, Dashrath, Gorva, Karodiya* and *Koyli)*. Almost 1.8 lakh (1,87,076) people resided in the area of 141.51 sq.km. (District Census Handbook, Vadodara, 2011). Few villages like *Anagadh, Dasharath, Ranoli ,Undera and Sokhda* have a population greater than 10000 persons in >2500 household while least population was noted in Rayaka with roughly 1900 people in nearly 350 households. Considering the variation in the number of household total houses to be surveyed is fixed to be around 200 from each village which amounts to 10% of the households and 10.50% (19645 people) of the total population. The information related to health and diseases like respiratory, skin, intestinal and abdominal, eye and ear, hair, skeletal and dullness, dental and nervous system problems were procured through the survey.

1.8.7 Secondary Data

In addition to the primary data, secondary data was also collected from:

Smt. Hansa Mehta Library, The Maharaja Sayajirao University of Baroda, Gujarat. Online journals were referred through:- Science Direct (www.sciencedirect.com), Springer Online (www.springer.com); Google Scholar (http://scholar.google.co.in/schhp?hl=en), Wiley Online Library (onlinelibrary.wiley.com); Oxford Journals (www.oxfordjournals.org); American Chemical Society Publications (http://pubs.acs.org/), Directories Open Access Journals (www.doaj.org), Taylor and Francis (www.tandf.co.uk/journals),

All of the above said websites were accessed and articles were downloaded from the portal of The Maharaja Sayajirao University of Baroda through INFLIBNET.

Maps of industrial estate were collected from the Office of the Petrochemical Complex situated at Sayagigunj, Vadodara, Gujarat. Cadastral Maps of 22 places were taken from taken Urban Development Authority, Vadodara, Gujarat.

District Census Handbook, Vadodara Gujarat 2011 and Toposheet (Toposheet No 46 F/3 with R.F. 1:50000) were taken from the Department of Geography, Faculty of Science, The Maharaja Sayajirao University of Baroda.

Rainfall data for different years were downloaded from the website of Indian Metrological Department. (http://www.imd.gov.in/pages/city_weather_main.php)

For identification of waste disposal site Google earth images for different time period were downloaded. (Google earth- Image Landsat / Copernicus. Image© 2013 Digital Globe, Imagery Date: 2/21/2007, Google earth- Image© 2015 Digital Globe, Imagery Date: 2/27/2011, Google earth- Image© 2015 Digital Globe, Imagery Date:2/20/2015)

Satellite image IRS-P6, satellite image, sensor-L4 MN, Date of pass 31 Jan. 2011

Information of current issue near the chemical and petro-chemical industrial area of Vadodara taluka, Gujarat were also collected from news paper of Times of India.

1.9 LIMITATIONS OF THE STUDY:

The limitations of the study are:

1. The present study is limited to the northern part of the Vadodara taluka, Vadodara district, Gujarat.
2. Only some selected physico-chemical parameters were incorporated in the study.

1.10 STRUCTURE OF THE THESIS:

The structure of the thesis is as follows:

Chapter 1- Introduction

The first chapter deals with the research problem, history of industrialisation, literature review, research objective, hypothesis, study area, data base, methodology and limitation of the study.

Chapter 2 - Spatial and Seasonal Pattern of Geochemical Properties of Water

This chapter focuses upon the seasonal changes in the concentration of geochemical parameters (*TDS, pH, EC, iron and nitrite*) of water during pre and post-monsoon season, comparison of the level of parameters between surface and subsurface water and relationship of characteristics of water parameters.

Chapter 3 - Seasonal Variability of Geochemical Parameters of Surface Water

Chapter 3, deals with the level of water parameters (*TDS, EC, iron, magnesium, calcium, sodium*, *lead*, *fluoride*, mercury and *potassium*) in surface water for the period of monsoon, pre-monsoon, and post-monsoon season. Relationship of parameters in different seasons is also studied.

Chapter 4 - Spatial and Seasonal Pattern of Geochemical Properties of Soil

This section includes the analysis of amount of *iron* and *nitrite* in soil and the role of grain size and river in the concentration of the two parameters.

Chapter 5 - Assessment and Suitability of Industrial Waste Disposal Sites Using GIS

The chapter deal with the identification of Industrial Waste Disposal Sites (IWDS) and its impact on subsurface water. The model for most suitable IWDS is generated.

Chapter 6 – Human Health in the Neighbourhood of Chemical and Petrochemical Industries

In this chapter, the health condition of the people living in the neighbourhood of the industrial belt was discussed. The influence of water contamination and socio-economic factors on human health have been studied

Chapter 7 - Inferences and Suggestion

The chapter includes summarisation of all the findings and suggestion for better health condition.

Resume

In this first chapter, the main basics of the present research that is research problem, review of literature, study area and database and methodology are incorporated. The next chapter will discuss about the concentration of water parameters in both the surface and sub-surface water.

Fig.1.9: Sample Analysis, Department of Geography, Faculty of Science, The M.S. University of Baroda