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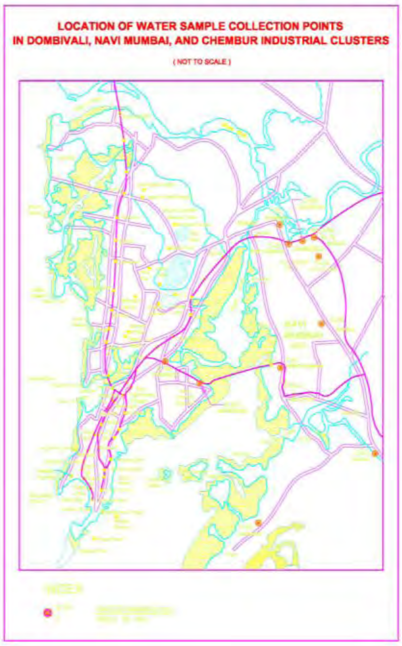
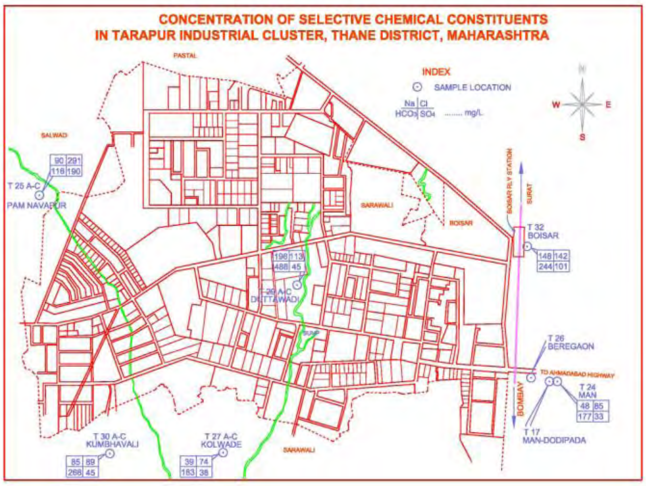
GOVT OF INDIA
MINISTRY OF WATER RESOURCES
CENTRAL GROUND WATER BOARD

GROUND WATER CONTAMINATION AROUND INDUSTRIAL CLUSTERS IN MIDC AREAS OF DOMBIVALI, NAVI MUMBAI, CHEMBUR, MUMBAI DISTRICT AND TARAPUR, THANE DISTRICT, MAHARASHTRA





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GROUND WATER CONTAMINATION AROUND INDUSTRIAL CLUSTERS IN MIDC AREAS OF DOMBIVALI, NAVI MUMBAI, CHEMBUR, MUMBAI DISTRICT AND TARAPUR, THANE DISTRICT, MAHARASHTRA

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GROUND WATER CONTAMINATION AROUND INDUSTRIAL CLUSTERS IN MIDC AREAS OF DOMBIVALI, NAVI MUMBAI, CHEMBUR, MUMBAI DISTRICT AND TARAPUR, THANE DISTRICT, MAHARASHTRA

1. INTRODUCTION

Maharashtra State is one of the industrially most developed states of India. Formation of Maharashtra Industrial Development Corporation (MIDC) has boosted the industrial growth in the State. The MIDC is instrumental in creating basic as well as most advanced infrastructure which has facilitated the development of different types of industries in many parts of the State. Though state of art facilities were provided for water supply, effluent treatment and waste disposal of the industries, yet the possibilities of pollution may exist. The present study is under taken to assess the impact of industrial pollution on water resources especially the ground water. The investigation is taken up as part of AAP 2011-2012 with the aim to identify pollution of ground water, its sources and suggest possible remedial measures.

1.1 Purpose and Scope

Since Mumbai and Thane are among the most industrially developed districts in the State, the pollution by industries is an important threat to the ground water regime; hence the special studies were carried out in the districts to ascertain the pollution threat. The industrial effluents generated from the metallurgical, chemical, mechanical, electrical and refinery industries from the industrial belt of the districts are the main source of ground water pollution in urban areas besides the sewerage pollution. The high permeability of weathered, fractured basalt and alluvium aquifers at shallow depth is favorable factor for transporting contamination in ground water. The report discusses the various problems of ground water contamination with respect to industrial development in select MIDC clusters/enclaves of Dombivli, Navi Mumbai, Chembur, Belapur of Mumbia district and Tarapur of Thane district. Apart from identification of ground water contamination, measures to protect the water resources are brought out in detail. The hydrogeological conditions, ground water chemistry and contamination are discussed in detail in the following chapters of the report.

1.2 Location, Extent and Accessibility

Both the industrial conglomerates are situated between Western Ghats on eastern side and Arabian Sea coast on western side. Dombivli, Navi Mumbai, Chembur, Belapur of Mumbai district are located within city limits en-route to Mumbai/Thane from Panvel. The Mumbai and Thane cities are located within a distance of 20km though they are connected with urban settlements. All these MIDC estates of Mumbai district are well connected by a net work of roads and are linked with local train of Central Railway which passes through East Thane-Kalyan-Ulhasnagar. Long distance south bound trains originating from CST/Dadar-Panvel-Lonavala-Pune provide rail transport to these MIDC areas.

The Tarapur MIDC (Phase I and II) is situated at Boiser (Toposheet 47A/9 at about 10km southwest of Tarapur village which is famous for having two atomic power stations. The Tarapur MIDC is located at about 15km west of Mumbai-Ahmadabad NH road. The MIDC is closer to Mumbai-Surat-Ahmadabad railway line; western railway line passes through Thane-Vasai-Palgarh and Dahanu talukas.. The industrial unit is well connected by road to national high way, via state high way running from Manor-Palgarh-Boiser-Tarapur to Dahanu. A direct road linking MIDC to NH originates at about 5km north of Manor.

1.3 Previous work

Central Ground Water Board, Central Region in the year 1990 carried out study to evaluate the impact of industrialization on ground water in Tarapur-Belapur industrial belt, Kairna, Kahidi Pada and Ghasoli industrial areas. Dr P K Naik et al have carried out ground water pollution studies around Tarapur MIDC in the year 2002-2003. Shri Sourab Gupta has compiled different hydrogeological features of the Thane district in the District Report in the year 2005. Shri Gupta also elaborated on industries related contamination of ground water in the report. Ground Water Management Studies were carried out by Dr. AGS Reddy in Parts of SW parts of Thane district during 2010-11. A detail account on ground water contamination and sea water intrusion is given in the findings.

1.4 Acknowledgement

The continuance guidance of Shri Pradeep Dube, Regional Director and Shri SSP. Mishra, Superintending Hydrogeologist & OIC and Shri Sourabh Gupta, Scientist-D (Sr. Hg) SUO, Pune, during the field work is gratefully acknowledged. The co-operation extended by the officers of MIDC is gratefully acknowledged. The efforts of Dr. Ramesh Kumar, Assistant Chemist, Regional Chemical Laboratory, Central Ground Water Board, Central Region for chemical data is duly acknowledged. The author is also indebted to Dr. P.K. Jain, Scientist-D, S/Shri A. Manzar, Scientist-B and Rahul R. Shende, Assistant Hydrogeologist, Report Processing Cell and staff of Drawing Section for processing and finalization of report and maps.

2. HYDROMETEOROLOGY AND PHYSIOGRAPHY

Climate of the area is characterized by high humidity throughout the year and an oppressive summer followed by well distributed and heavy rainfall during the southwest monsoon season. The cold season starts from December to February followed by summer from March to May. The southwest monsoon season is from June to September while October and November constitute the post monsoon season. Being the coastal area the variation of temperature during the day and the night is not high. After February, temperatures progressively increase till May, which is the hottest month. The mean daily maximum temperature is 32.9°C and mean daily minimum temperature is 26.8°C. The humidity is very high throughout the year.

2.1 Rainfall

During southwest monsoon months the average humidity is around 85%. The area is blessed with SW monsoon and receives good quantity of rainfall ranging from 1600 to 3300mm. The intensity of rainfall is lower in north parts (Dhahanu) and higher in southern part (Vasai). The meteorological observatory located at Dahanu is the nearest available weather station for Tarapur MIDC. The IMD normal annual rainfall recorded at the observatory is 1834mm, whereas ten years average annual rainfall for the period 1999-2009 is 2058mm.

2.2 Physiography

Physiographically, the study area is a part of Deccan Plateau. The hill ranges in the area belong to the Sahyadari ranges of the Western Ghat. The area represents a rolling topography and low hills sinking slowly into the plains with relatively broader valley. The important geographical features noticed in the studied MIDC areas are denudation hills which are formed due to differential erosion and weathering. The industrial infrastructure is developed mostly around relatively flat areas. Other important land feature associated with MIDC units is its location in coastal plain in western part. This unit is fairly low lying covered with alluvium and tidal mudflats. This part is separated from hilly region by a well-defined narrow ridge of hills that run north to south. The general appearance of this unit is submergence as can be seen from low tidal flats, tidal marshes, tidal inlets and wave cut plat forms.

2.3 Drainage

In general, rivers and their tributaries of Vaitarna and Ulhas River have deep course and show characteristic meandering pattern at places. The drainage pattern is controlled by major joints in the rock formations. The river gradients are high and force of water in monsoon is very great due to high rainfall. Creeks developed in between the elevated region intrude into main lands which serve as discharge channels for local drainage and industrial effluents.

2.4 Soils

Generally, major part of the study area has black cotton soil called regur formed by weathering of trap rocks. Sandy soil and older alluvial deposits of the Vaitharna and Ulhas Rivers are also found in pockets along the banks of these rivers.

3. GEOLOGY

The area in underlain by the basaltic lava flows belonging to Deccan Traps of Upper Cretaceous to Lower Eocene age. At times, these flows are inter-bedded with agglomerates and tuffs. Basaltic flows of Deccan Trap formation are mostly exposed in the area. However, at places they are covered by laterites, soils, marshy land and alluvium along the river courses. The western part is covered with coastal alluvium and calcareous sandstone as tidal flats. The general geological sequence is as follows…

Period	Formation	Lithology
Recent	Alluvium	Soil, Kankar, Clay, Silt, Sand
Cainozoic	Laterite	Reddish to deep brown, Pisolitic
Upper Cretaceous to Lower Eocene	Deccan Trap	Basaltic lava flows with inter-trappean beds

3.1 Deccan Traps

The basaltic lava flows of the Deccan Trap is the major rock formation of the area and total 8 flows have been demarcated from 509 to 987 m above MSL by G.S.I.. Predominantly the Deccan Trap flows are simple “aa” types. The thickness of individual flow ranges from few meters to as much as 37 m. The aa flows generally show a thin zone of grayish basal clinker, a prominent middle section of dark dense rock and a top section of reddish altered breccia. The breccia comprises of angular and rounded reddish vesicular or massive trap pulverized rock material zeolites. The top surface of aa flows are represented by several centimeters of red bole. The middle dense section shows columnar or rectangular joints and conspicuous spheroidal weathering. All the Pahoehoe and aa flows are seen to have horizontal disposition with minor tilts here and there. In general they show a gentle easterly dip of 1 in 300 to 1 in 110.

Some of the flows are porphyritic in nature due to occurrence of plagioclase association with basalt. These lathes do not show any preferred orientation and occur randomly and also show criss-cross disposition. Each flow is characterized by the prominent units of vesicular and massive basalt. The flow contacts are demarcated based on (i) the occurrence of red or green bole or tuff (ii) chilled fine grained basalt at the base containing pipe amygdules (iii) highly vesicular and zeolitic upper parts (iv) textural and lithological characteristics and (v) distinct slope breaks.

3.2 Alluvium

The alluvium consisting of clay, sand and gravel mostly occur in small lenticular patches mostly along the bank of rivers towards the northern and eastern part of the study area. The shallow alluvium ranges in thickness from less than a meter to 18 m and directly overlie the Deccan Traps. The loosely cemented sands and gravels are probably derived from the traps. Besides the above patches, thin alluvium covers are also found at the banks of small streams occurring in area. Alluvium is more potential for ground water than the Deccan Trap. Coastal alluvial sediments are calcareous in nature. The alluvium is found along the rivers draining the coast and along the creeks and is composed of gravel, silt and clay. It ranges in thickness from 10 to 20m. Along the coast, alluvium is composed of soft, low-density clay deposits commonly referred as mud flats.

4. HYDROGEOLOGY

Hydrogeology is concerned primarily with the mode of occurrence, movement and distribution of water occurring in the sub surface in relation to the geological environment. The occurrence and movement of water in the subsurface is broadly governed by geological framework that is nature of rock formation including their porosity (primary and secondary) and permeability. Hydrogeological particulars of the wells inventoried and water samples collected are presented as Appendix 1.

4.1 Water Bearing Properties of Formations

The water bearing properties of rock formation depend upon the open space available for storage of water. The interconnection of such open spaces to transmit water at sufficient rate is governed by permeability. The capacity to yield water is governed by storativity, which indicate the amount that can be released from storage on per unit reduction of hydraulic head over unit area.

4.1.1 Deccan Trap

Deccan Trap basalts represent a thick pile of nearly horizontal layered formation. The porosity and permeability change within an individual flow and also from flow to flow and place to place, thus showing heterogenous and anisotropic nature. The basaltic lava flows occurring in the area are predominantly 'pahoehoe' type with few 'aa' type of flows. The primary porosity due to vesicles being filled with secondary minerals like zeolite, chert and quartz is poor or negligible and the vesicles are seldom interconnected. However, water moves along the margins of the unit, which form the main bulk of flow. The secondary porosity through cooling joints, partition planes, cracks and fissures play a more important role in the ground water movement. The weathered portions of both vesicular and massive units have better porosity and permeability. The red bole capping the top of the flows are usually composed of mixture of fragmentary materials and clayey particles and thus act as aquiclude.

Weathering is the important phenomena affecting water-bearing properties of basalt. Intensity of weathering is less in hilly region as seen in the eastern part of the district while it is higher in plain area. The depth of weathering is in general up to 5 m with a maximum of 20 m.

4.1.2 Alluvium

Alluvium occurs in the western part of the area along the coast and river courses and are lacustrine in nature. Along the coast, alluvium consists of clayey and mud deposits. These are non-porous and constitute poor aquifer formation. On the other hand the beach sands, which have primary porosity in the form of inter granular pore spaces constitute good aquifer and occur in the form of narrow coastal strip with limited thickness. The quality of water is slightly brackish and pumping from this formation has to be restricted to prevent ingress of seawater.

4.2 Occurrence of Ground Water

The ground water in the area occurs under water table and confined conditions. It occurs in weathered, jointed and fractured portions of different basaltic flows as well as at inter-flow junctions as observed in dug wells. There is hydraulic continuity in the weathered and jointed basalt in the plains and valley regions, where it is possible to identify a continuous water table aquifer with in a depth of 15 m bgl.

Geomorphology plays an important role in the occurrence and movement of ground water. Most of the ground water abstraction structures are located in valley areas, low-lying areas along the streams and undulating plains. The valley areas are more productive as they receive more run off from the adjacent hills and due to high thickness of weathered mantle, the percentage of percolation to shallow aquifer is more. On elevated plateau top, having good areal extent, a local water table develops in the top most layers. The wells in the hilly areas show rapid decline of water levels during the period following post monsoon and practically go dry in peak summer. In foothill area, water table is relatively shallower and sustains perennial yield in dug wells. Physiography of the area is such that there is general slope towards west coast, which facilitate both the surface flow during monsoon and subsurface out flow during non monsoon period.

4.3 Ground Water Abstraction Structures

4.3.1 Deccan Trap

In the area dug wells are developed down to 10 to 12m with a diameter of 6 to 8m to exploit weathered and shallow fractured part of the basalt. The dug wells are generally developed in valley or topographically low portion. The yield of dug wells tapping phreatic aquifer ranges between 85 and 152cum/day which have 5 to 12m depth range. The diameter of bore wells range from 115 to 150 mm, but maximum bore wells are having 150-mm diameter, whereas the depth ranges from 15 to 92 m bgl. The bore wells have a discharge of 2 to 4lps. It is noticed and reported that the yields of the wells drastically get reduced in summer months beginning form March up to June end or onset of monsoon.

4.3.2 Alluvium

The alluvium, which largely constitutes of coastal alluvium, is confined to western part and is of lacustrine nature. Small diameter (2 to 3m) dug wells are found to developed in this aquifer down to the depth of 6 to 8m which are mostly lined up to bottom. The yield of dug wells tapping phreatic aquifer ranges between 122 and 252 cum/day. There is possibility of encountering saline or brackish waters beyond 8 to 10m depth, hence deeper dug wells are not developed in many coastal portions. The bore holes of moderate depth of 20 to 30 m are drilled in areas where alluvium thickness is high and weathered and fractured/vesicular zones in basalt are encountered underneath the alluvium in upland areas at about 1 to 1.5km away from sea coast line. The bore wells have a discharge range of 2 to 4pls.

4.4 Depth to Water Level

Depth to water level varies depending upon hydrogeological framework, level of ground water development and topography of the area. It also varies with time. The general rise during monsoon and decline after monsoon till the next monsoon is witnessed in the region. The water levels collected from dug wells during water sampling in July 2011and January 2012 are discussed in following paragraphs and the same is given in **Plate1** for Dombivali, Navi Mumbai and Chembur Industrial Clusters and **Plate2** for Tarapur Industrial Cluster.

4.4.1 Depth to Water Level (July 2011)

The depth to water level ranges between 0 and 2.41 m bgl in major part of the areas whereas water level of more than 2 m is observed in the Ajivali, Chembur and Man. The water levels are shallow due to high rain fall and being close to sea. The depth to water levels are relatively deep in Mumbai district MIDC areas as scope of rainfall recharge is very limited due to concretization and ground water extraction is observed at few locations (Appendix 1).

4.4.2 Post-monsoon Depth to Water Level (January 2012)

The water levels of less than 2m bgl depth are observed in major part of the area during post-monsoon period. Shallow water levels (0.50 to 2.0m) are noticed in and around Ucheli and Mumbra creek. The depth to water level variation is not distinct between pre and post-monsoon seasons in the studied MIDC areas.

4.4.3 Seasonal water level fluctuation (July 2011 to January 2012)

The seasonal water level fluctuation in general ranges from 0 to 1m in major part of the area. The higher fluctuation of 1 to 2m is observed in the eastern part of Tarapur MIDC which being the recharge zone. Water levels are almost static in Mumbai and Navi Mumbai MIDC areas between the observed periodic due to limited extraction.

5. MAHARASHTRA INDUSTRIAL DEVELOPMENT CORPORATION (MIDC)

In this chapter, brief introduction about the development of industrial complexes in the form of MIDCs in different parts of Maharashtra State is described. The available infrastructures with special emphasis on water supply and effluent treatment as well as disposal in each of the studied industrial cluster are mentioned in the following paragraphs.

5.1 Introduction

Maharashtra Industrial Development Corporation (MIDC) was started on August 1, 1962 to identify and develop major infrastructures facilities in different locations of the State to help entrepreneurs set up industrial units in those areas. The key historical policy decisions taken by MIDC certainly changed the social economic scenario of the state as its activities spread in the interior.

5.2 Basic Infrastructure Facilities

5.2.1 Water Supply

The important policy decision of setting up "independent filtered /potable water supply system of adequate capacity" as essential infrastructure for industrial development was taken by MIDC right in the beginning. Among the various services provided by the Corporation, an assured pure water supply can be regarded as a unique specialty of the MIDC. The decision to provide water supply to nearby domestic population from the capabilities created by MIDC of their own water supply system resulted in a phenomenal urban growth in the nearby small towns and villages. The growth of Kalyan complex was results of this key policy decision taken by MIDC. For the purpose of regulating the water supply operations of the Corporation the Government of Maharashtra has prescribed a legal and financial relationship between the Government and the Corporation. MIDC supply of treated potable water to all industrial units is as below.

- Total Installed Capacity of the system: 1940 MLD
- Current Utilization : 1286 MLD

Consumer Base

- Industrial 26564 ; Consumers 579 MLD
- Domestic 2829 ; Consumers 707 MLD

MIDC's sources of water

- Irrigation dams 65%
- MIDC dams 34%
- Others 1%

Total Reservation Available

- Domestic 12485 MLD
  Industrial 4055 MLD

5.2.2 Effluent Treatment and Waste Disposal Mechanism

Apart from providing sufficient water to industries the MIDC also created infrastructure to treat and dispose off industrial effluents at all the industrial clusters.

Drainage (effluent disposal) and CETP Schemes

The Corporation has Effluent Disposal (Drainage) schemes only in selected Industrial areas having chemical industries. Such schemes are designed to collect and discharge the treated effluent only. Also with a view to arrest pollution, the Corporation has started the operations like Hazardous Waste Management and Common Effluent Plants on Joint venture basis with the help of local industries associations.

Hazardous Waste Management

MIDC has developed 224 industrial areas all over state of Maharashtra for achieving its goal of rapid, orderly and uniform growth of industries all over the state. Out of these industrial areas, following industrial areas are Chemical Industrial Areas which were covered in the current study.

- Tarapur Industrial Area.
- Dombivli Industrial Area.
- Ambernath Industrial Area.
- Badlapur Industrial Area.
- Kalyan-Bhivandi Industrial Area.
- Taloja Industrial Area.

Chemical Industries not only generates effluent but solid hazardous waste as well, the management of which is also of prime importance. It is planned to take up the development of hazardous waste management facility through privatization on line with the financial arrangements as per the liquid waste management projects.

5.2.3 Taloja Hazardous Waste Management Project

To begin with MIDC has taken up the development of integrated hazardous waste collection, transport, treatment, storage and disposal facility at Taloja. Land admeasuring 39 hectares has been allotted for this purpose at village Chal, Tal- Panvel, District-Raigad. It is located to the west of MIDC area. The environmental impact assessment studies as required under the Hazardous Waste (M&H) Rules, 1989 is being carried out by Central Fuel Research Institute, Dhanbad (Bihar). The secured landfill facility was commissioned in November 2002.

In the Chemical Industrial Areas, MIDC has provided effluent collection and disposal system along with other infrastructure facilities. The effluent collected from the industrial area is disposed off in a creek or sea as approved by MPCB/ NIO. As per the Environment (Protection) Act 1986, large and medium scale industries are expected to provide treatment for detoxification, primary and secondary treatment to the effluent generated by them before it is discharged into the common collection system. Small-scale industries are expected to discharge the effluent after providing treatment for detoxification and primary treatment, into the common collection system.

5.2.4 CETP Projects:

In the first phase to treat the effluent collected from the industries to the disposable norms stipulated in the Environment Protection Act, 1986 and in the second phase it will be treated to the recycling standards. MIDC has entered into the Memorandum of Understanding (MoU) with the Industries Association from Tarapur, Badlapur, Ambernath, Dombivli, Thane-Belapur, Kalyan-Bhivandi. The Primary effluent treatment by tenant and most of the CETP projects are Commissioned. The industrial effluents are treated and disposed as per guidelines of Enviromental Protection Act.

5.3 Technical Details of Select Industrial Clusters

The basic information like location, extent, available effluent treatment and waste disposal mechanism along with prominent industrial units existing in each studied MIDC is mentioned below

5.3.1. Tarapur (Group A) : The industrial areas are at a distance of one km from Boisar railway station on the western railway line and about 15 km from Mumbai-Ahmadabad national highway from Manor Phata. It is also about 100 km from the international airport at Mumbai.

Prominent Industries located in MIDC-Tarapur.

In this industrial area fillowing textile, pharmaceuticals, plastics as well as engineering units are operatin

1. Tata Iron & Steel Limited- India's largest integrated private sector steel company,
2. M/s Jindal Iron & Steel Industries- leading manufacturer of flat steel products in India.
3. JISCO is the market leader in galvanized steel products,
4. Lupin Limited is one of India's largest manufacturers of bulk actives and formulations.
5. Aarti Drugs Ltd Pharmaceuticals, Camlin is a 65 year old group in India, with its presence in Pharmaceuticals, Consumer Products and Fine Chemicals.
6. Zeus International Export Pvt. Ltd-Crimped and Textured Yarn,
7. Bright Brothers Ltd.- Plastic Moulded Goods,
8. Hickson & Dadajee Ltd- Dyes and Dyes Intermediates,

9. M/s Galaxy Surfactants Ltd.- Anionic/Cotton/Nonionic Surfactant,

10.M/s Dicitex Decor Exports- Polyester Viscose, Cotton & Blended

Common Effluent Disposal Facility: This area has a well developed Chemical Zone which is provided with a Central Effluent Treatment Plant to control solid and liquid effluents.

The Infrastructure comprises roads, water supply, street lights, drainage lines in Tarapur and Additional Tarapur Industrial Areas.

5.3.2 Dombivli (Group A)- The Dombivali industrial area was established by MIDC in 1964.

This area comprises of revenue villages like Sagaon-Sonarpada, Asde-Golivali, Gajbandhan-Patharli, and Chole in Kalyan taluka, Thane district. The area is located on the Kalyan-Shil and

Kalyan-Dombivali roads. In this area, industrial plots and sheds, residential and commercial plots are well demarcated and have been developed as Phase-I and II with a residential zone.

The industrial area is approachable from Mumbai-Pune National Highway 4 via the Kalyan-Shil Phata and also from Mumbai-Agra National Highway 3 via the Bhiwandi-Kalyan Road. It is about 45 km from Mumbai International Airport and 15 km from Thane city. This area is three km from Dombivali railway station and five km from Kalyan junction on the Central Railway.

Prominent Industries Located in MIDC- Dombivli

1. Gharda Chemical Industries- Chemical Products,
2. Sharda Textiles- Textiles, Coral Cosmetics, Himedia Laboratories-provide ready to use Culture

Media to Scientists, Researchers and Small companies, high-tech know-how for manufacturing Microbiological Culture

3. Metropolitan Exichem Pvt. Ltd,
4. Eskay Industries-Manufacturers & exporters of Quality Brass Electronics Components.

Common Effluent Disposal Facility: MIDC has provided an underground effluent collection system to collect the treated effluent from industrial units of the area; the treated effluent is finally discharged into the Kalyan creek via a disposal line. The CETP is also operating in the Dombivali Industrial Area.

Water: The Corporation has made its own arrangements for supplying pure water to the industrial and residential units of the area. MIDC also supplies drinking water to the villages surrounding the area. The entire quantity of water is lifted from the Barvi dam through pipelines from the Badlapur, Ambernath and Dombivali industrial areas.

5.3.3. Badlapur (Group A): This industrial area is 56 km from the Mumbai International Airport and about 2 Kms from the Badlapur Railway station on the Central Railway line. Kalyan is the nearest major junction on this line. MIDC has developed this industrial area within the limits of Kulgaon Badlapur Municipal Council. This area is reserved primarily for Chemical industries. The area has been developed in different blocks and carved out keeping in mind the needs of small scale and large scale industries.

Prominent Industries Located in MIDC, Badlapur

1.Emtex Industries Pvt. Ltd,
2.Bidhata Industries Ltd - Textile,
3.Honavar Electronics Ltd- Electronic Products,
4.Precision Engg. Tools & Co.- Tools,
5.Industrial Tubes Mfg. Pvt. Ltd- Tubes,
6.Pioneer Agro Industries – Seeds,
7.D.K. Pharma Chem Pvt. Ltd- Pharmaceuticals,
8.M/s Mandan Textiles Pvt. Ltd- Processing Polyester & any other Synthetic,
9.M/s Trimurti Synthetics Ltd.- Processing of Synthetics Textiles,
10.M/s Indian Leather Cloth Industries- Textile Processing
11.M/s Harjas Plastic & Metal- Bicycle Components,

Common Effluent Disposal Facility: MIDC has developed an effluent collection and disposal scheme, where all effluent is collected in various sumps of different capacities and the same is pumped through a pipeline at Waldhuni Nalla as suggested by the Maharashtra Pollution Control Board, Badlapur.

MIDC has made its own arrangements for filtered water supply to the industrial area, by a 400 mm diameter PSC pipeline, from Barvi dam. The corporation has laid a network of pipelines in Badlapur,. Ambernath and Domvibali Industrial Areas.

5.3.4 Kalyan-Bhivandi - The Kalyan Bhiwandi Industrial area is six kms from Kalyan and Bhiwandi cities and is within the Gram Panchayat limits. The Vasai-Diwa railway line passes close to the industrial area and is useful to industrialists for transportation. The industrial area is located within the village limits of Saravali and Gove in Kalyan taluka, Thane district. The area is situated on the Kalyan Bhiwandi road, at a distance of about 40 km from Mumbai city. Moreover, it is very close to Kalyan junction on the Central Railway line.

Prominent Industries Located in MIDC- Kalyan-Bhivandi

1. Laxmi Board & Paper Mills Pvt. Ltd- Paper Products,
2. Godhwani Brothers, Poly Pharma Pvt.- Pharmacetuicals Ltd.
3. Meghdoot Chemicals Pvt. Ltd.- Morani Chemicals Pvt. Ltd. Chemicals,

Common Facility Centre

Water: The main infrastructure in this industrial area comprises water supply, The areas main source of water is the Barvi dam; adequate supply of water is available. The corporation has made its own arrangements for distribution of water to the industries.

5.3.5 Taloja (Group A): Accessible by road, rail, air, and water as it is located on theboundary of Mumbai and within the limits of Navi Mumbai. Located on old Mumbai-Pune national highway, about 10 Kms from Panvel town. The nearest domestic air terminus and international airport are at Santa Cruz and Sahar, about 50 Kms away. The water transport facility is at Mumbai-Port trust. Konkan Railway passes through this area.

Common Effluent Disposal Facility

A common effluent disposal scheme of 18 MLD capacity, phase I -10 MLD and Phase II - 8 MLD has been undertaken and completed by MIDC in order to make the area eco-friendly. This scheme is being operated as a joint venture between MIDC and Taloja Manufacturer Association and takes care of effluent collection, treatment and disposal. The Common Effluent Treatment Plant has been commissioned in August 2000. MIDC has constructed a water supply scheme to supply 32 MLD of water to the industrial area from Barvi Dam grid, owned by MIDC.

Prominent Industries Located in MIDC- Taloja

1. M/s Indian Aluminium Company Ltd. Product Name Aluminium Rolled Products
2. M/s Exide Battery- Battery
3. M/s Kellogg India Ltd- Breakfast Cereals
4. M/s E-Merck India Ltd - Polybion, Nasivion
5. M/s Hikal Ltd. - T.B.Z.
6. M/s Deepak Fertilizers & Petrochemicals Ltd. - Liquid Ammonia, Methanol, A.N.P.
7. ROHM and HAAS - Adhesive and Sealants and Coatings Products Manufacturing

5.3.6 Murbad (Group B): Murbad and additional Murbad Industrial Areas are located near the Kalyan-Ahmadnagar State Highway. By road, the area is 85 km from Mumbai, 40 km from Thane city, and 85 km from the international airport at Mumbai. These industrial areas are 20 km from Kalyan as well as from the Ulhasnagar Municipal Corporation. From Kalyan junction these areas are closer to the Central Railway line. The well known Barvi Dam Project is in the vicinity of Murbad Industrial area which is advantageous to newly coming up industrial units. Murbad and Addl. Murbad are two of the best industrial areas in Thane region where infrastructure like water supply are available. Water-water supply from Barvi dam is easily available to this area. Prominent Industries located in MIDC- Murbad (Group B) Murbad and additional Murbad Industrial Areas are

1. Oriental Containers Ltd. - Tin Containers

2. Hindustan Gas Industries
3. Maharashtra Tubes Ltd
4. Lloyd Steel Ltd- Steel Products
5. Tiger Steel Engineering (I) P.Ltd-False Ceiling, Steel Structures, Metal Roofing & Cladding Systems, Insulated Panels.
6. M/s Praxiar India Pvt. Ltd - Liquified Carbonic Gas.

The MIDC management, apart from providing state of art infrastructure for promotion of Industrial growth in Maharashtra state has also emphasized on arranging safe drinking water to
Industries and nearby habitations. The effluent treatment and waste disposal mechanism is
also very well developed in the studied industrial clusters by MIDC in association with individual major industries.

6. GROUND WATER POLLUTION FROM INDUSTRIES IN MIDC AREAS

In this chapter, the studies carried out by the CGWB, Central Region in Thane district are described to furnish back ground information to the current investigations. Since Thane is one of the most industrially developed districts in the State, the pollution by industries is an important threat to the ground water regime, hence the special studies were carried out to ascertain the pollution threat. The details of the earlier studies are discussed below.

6.1 Ground Water Pollution from Industries

6.1.1 Thane-Belapur Industrial Area

In view of the possibility of ground water quality problems could result from Industrial activity, the studies were undertaken by C.G.W.B, CR in year 1990 to evaluate the impact of Industrialization on ground water in Thane-Belapur industrial belt, Kairna, Khadi Pada and Ghansoli areas. Thane-Belapur industrial belt falls in Thane Municipal Corporation area. Total area of Thane Municipal Corporation (TMC) is 147sq.km. with a population of 4,47,170. Thane City has become industrial town during 1960-70 since then the industries are fast growing in the area. Thane-Belapur industries belt is the prime industrial area next to MIDC, where maximum industries are located.

It was reported that about 2000 small, medium and large industrial units are located in Thane, out of which 504 units (about 25%) are of chemical type. Out of 504 units, 17units are large scale, 83 medium and 404 are of small scale. Total industrial solid waste is approximately 50 t/day. About 16,160 m^3 of wastewater carrying load, of effluents is being discharged in Thane city. Ultimately this wastewater is being discharged in Thane creek either directly through nallas or through sewers, pipes lines. The wastewater thus discharged into nallahs and leakage from the pipelined etc will enter into ground water system and deteriorated the quality of ground water in the area. These contaminated ground water will have high concentration of pH, COD, BOD and other major chemical constituents.

TMC is regularly monitoring the discharged waste water from 35 major chemical industrial units and reported that collection of load is 20,401 m^3/day which contains approximately 5,689 kg/day of COD, 1588 kg/day of BOD and 1448 kg/day of suspended solids.

6.1.1.1 Impact of Industrialization on Ground Water Quality

The area surveyed has three main chemical industries, ICI India limited, Alkali India limited and Shaw label company. Five ground water samples at different location in Karna, Khadipada, Ghansoli area have been collected for detailed study, In addition to these, 2 water samples have also been collected from upstream part of the area to compare the areas of contaminated and uncontaminated groundwater. These two samples were collected from Thane City and Kairna and were considered background sample, which may reflect the change ground water in quality in polluted area.

The comparison of chemical analyses of all 5 ground water samples of contaminated/affected area with that of the two background ground water samples, representing uncontaminated/unaffected area indicates that all major chemical constituents are having higher concentration in affected area. The average values of concentration of major chemical constituent thus obtained from the affected parts are TH=548 mg/l, Ca=126 mg/l, Mg=56.42 mg/l Cl=367 mg/l, TDS=548 mg/l, SO_4=116.6 mg/l, Na=149.4 mg/l. These values when compared to the uncontaminated area where the average value of chemical constituents are TH=450 mg/l, Ca=74 mg/l, Mg=64.5 mg/l,Cl=259 mg/l, TDS=760 mg/l, SO_4=80 mg/l, show that the ground water in vicinity of industries is being deteriorated due to industrial activity.

6.1.1.2 Hydro-Geochemical Nature of Ground Water

The hydro-geochemical nature of ground water indicates the type of water in a particular area and serves as a back ground water quality in differentiating the contaminated/uncontaminated ground water in a particular area. To determine the type of water in an area, the average values of cation and anion in epm were taken and percentage of each cation and anion were calculated. The results thus obtained are summarized in Table 6.1 .

Table 6.1– Hydrochemical Nature of Ground Water

			Cations					Anions				Type of water
Area	pH	TDS	Units	Ca^{++}	Mg^{++}	Na^{++}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{-}	
Affec-ted area	**8.18**	**975**	**Av. Conc (EPM)**	**6.32**	**4.64**	**6.49**	**0.119**	**6.00**	**4.32**	**10.3**	**2.43**	**Na-Cl**
			%	**35.9**	**26.4**	**36.94**	**0.67**	**25.9**	**18.67**	**44.8**	**10.5**	
Unaffec-ted	**7.71**	**760**	**Av. Conc (EPM)**	**3.70**	**5.3**	**4.7**	**0.48**	**Nil**	**4.70**	**7.30**	**1.66**	**Mg-Cl**
			%	**26.0**	**37.3**	**33.14**	**3.38**	**Nil**	**34.40**	**53.4**	**12.1**	

The results obtained from table indicate that in un-affected (background) area, ground water is of Magnesium Chloride (Mg-Cl) type, whereas in affected area it is of Sodium Chloride (Na-Cl) type. The chloride anion is predominant in both the areas, and among cations, magnesium is predominant in unaffected area and sodium is predominant in affected area. This indicates possibility of ground water pollution by addition of sodium cations in the affected area due to hectic industrial activity. Further, the average value of TDS in unaffected area is 760 mg/l where as in the affected area it is 975 mg/l. Also change in pH from 7.71 to 8.18 indicates deterioration of ground water in the area and percolation of industrial effluents to ground water.

Further, three ground water samples from affected part were analyzed for inorganic trace element like As, Cd, Cr, Cu, Pb, Ni, Ti and Zn to see if it can aid in detecting in ground water pollution. The analysis results are summarized in Table 6.2.

Table 6.2- Results of Trace Element Analysis of Samples from Thane - Belapur Area.

S. No.	Parameters	Kairna	Ghansoli	Khadipada
1.	As	<0.001	<0.001	<0.001
2.	Cd	<0.001	<0.001	<0.001
3.	Cr	Nil	Nil	Nil
4.	Cu	<0.001	<0.001	<0.001
5.	Pb	<0.001	<0.001	<0.001
6.	Ni	<0.001	<0.001	<0.001
7.	Ti	<0.001	<0.001	<0.001
8.	Zn	<0.001	<0.001	<0.001

Note: - All the parameters are in mg/l

The concentration of trace element is much below the permissible limits (0.01mg/l). Hence it is concluded that pollution has not increased the concentration of trace elements.

6.1.2 Ground Water Pollution Studies around Tarapur M.I.D.C. Area, Thane

Tarapur MIDC area is located at Boiser (Toposheet No 47A/9) about 10 Km southwest of Tarapur, which is famous for two Atomic power installation that is the Tarapur Atomic Power Station (TAPS) and Bhabha Atomic Research Center (BARC). Tarapur MIDC area occupies an area of 1,130 ha with about 800 industrial units. Nearly 2,00,000 people live around the MIDC area in discreet villages. Though Municipal Corporation is supplying the villages with water, but water supply is not regular. Therefore, ground water is the alternative source for drinking and other domestic purposes.

In the industrial area, accumulation of industrial effluents through leakages in pipeline is a common scenario. There are cases where effluents are directly disposed in the open fields.

A total no. of 131 samples were collected from various sources for different types of chemical analyses and their details are given in Table 6.3.

Table 6.3- Samples Collected from Different Sources in Tarapur MIDC area, Thane.

Source	Number of samples collected for different analysis			
	Major element	Heavy Metals	Biological Oxygen Demand (BOD)	Chemical Oxygen Demand (COD)
Dug well	15	12	-	-
Bore well	18	14	-	-
Dug-cum-Bore well	5	5	-	-

Effluent Sump and channel	9	7	7	7
Creek	6	5	3	3
Ocean	6	5	2	2
Total	59	48	12	12

Chemical analyses of samples include determination of the concentration of major ions and heavy metals. The analyses of Ca/Mg ratio show that concentration of Ca exceeds the concentration of Mg in about 50% of the samples in both dug wells and bore wells. In the rest 50%, Mg is dominant cation especially in the southwestern part of Mumbra Creek. The excess concentration of Mg than Ca indicates contamination by some external source. The result of analyses is given in Table 6.4.

The results of the chemical analyses show that the area in general is characterized by hard water possibly due to its hydraulic connection with the sea. Although the ground water has high salinity hazard, it is good enough for irrigation purpose. The linear piper diagram indicate that; 65% of the water samples are dominated by alkaline earth's (Ca and Mg) while in about 35%, especially around the MIDC area and Mumbra Creek, alkali (Na and K) exceeds alkaline earth's. Shallow aquifers are characterized by both weak acids (HCO_3 and CO_3) and strong acids (SO_4 and Cl) in equal percentage. However, deeper aquifers (73%) are mostly characteristics by strong acids (SO_4 and Cl) exceeding weak acids. In case of sumps and effluent channels, strong alkalies (Na and K) and strong acids (SO_4 and Cl) dominate the samples. Maintenance of pH in three effluent collecting sumps has not been adequate with pH value varying between 1.00 and 5.66.

Table 6.4 - Minimum, Maximum and Average Values of Ion Concentration

Parameter	**Dugwells**			**Bore wells**			**ISI**	**1993**
	Min	**Max**	**Avg.**	**Min**	**Max**	**Avg.**	**DL**	**MPL**
PH	6.50	8.3	7.69	6.50	9.30	7.71	6.5	8.5
EC	760	3350	1478	620	15400	2612	-	-
TDS	371	1898	788	316	8152	1388	500	2000
TH	140	600	313	105	5040	655	300	600
Ca	18	126	54	20	800	103	75	200
Mg	17	84	43	12	734	96	30	100
Na	26	590	161	21	1290	241	-	-
K	0.2	54	11	Trace	25	5	-	-
HCO_3	226	671	391	186	476	340	-	-
Cl	53	858	218	35	4644	596	250	1000
SO_4	23	186	84	20	850	159	200	400
NO_3	2	171	25	1.86	76	20	45	100

Cu	0.0005	0.030	0.014	0.004	0.061	0.015	0.05	1.50
Fe	0.044	3.322	0.587	0.035	2.313	0.435	0.30	1.00
Zn	0.026	0.600	0.159	0.009	0.485	0.076	5.00	15.00
Pb	0.014	0.014	0.014	0.015	0.136	0.060	0.05	0.05
Cd	0.003	0.009	0.006	0.016	0.055	0.030	0.061	0.01
Mn	0.007	1.975	0.221	0.013	0.725	0.119	0.10	0.30

Here, Min- Minimum, Max- maximum, Avg.- Average, DL- Desirable Limit and PL- Permissible limit

The Mumbra creek water is highly polluted. The pH, TDS, Na and Cl values start increasing seaward while concentration of SO_4, Fe, Mn, Pb and Zn starts decreasing. Low pH value and high concentration of heavy metals in the creek water may be attributed to indiscriminate disposal of industrial effluents. There are indications of seawater intrusion around Mumbra creek in the surface water as evidenced by Mg/Ca, Na/Ca and Cl/HCO_3 ratios in ground water samples. Because of the fact the Mumbra creek is highly polluted, the ground water around this creek is vulnerable to contamination.

7. GROUND WATER CHEMISTRY

Chemical quality of ground water is very important aspect of ground water management studies as it decides the suitability of water for irrigation and drinking purposes. The chemical composition of the natural groundwater is affected by the mineralogical composition of host formation apart from influence of contaminants by point-source or non-point source seepage into aquifer. The ground water quality deterioration can be assessed and remedial measures initiated in time to arrest further damage to ground water. In order to ascertain the chemical quality of ground water with special emphasis on impact of industrialization and seepage of contaminants into local aquifer, the water samples were collected from different ground water structures in varied hydrogeological environs spread over the studied MIDC areas in Mumbai and Thane districts. The water samples were collected from irrigation wells where poor water quality is reported from the deeper aquifers. To study the seasonal variation in water chemistry, 30 ground water samples were collected in July 2011 for pre-monsoon and 13 in January 2012 representing post-monsoon period (**Plate3** for Dombivali, Navi Mumbai and Chembur Industrial Clusters and **Plate4** for Tarapur Industrial Cluster). In order to study the trace elements, BOD and COD in both the seasons, three sets of water samples were collected from wells of four villages which are located close o the pharmacy and chemical industries in MIDC Tarapur area. However the samples were analysed for major chemical constituents only. The water samples were analysed in July 2012 at Chemical laboratory of Central Ground Water Board, Central Region, Nagpur.

7.1. Water Quality in Pre-monsoon

The results of chemical analysis of pre-monsoon water samples, along with ranges, mean values are presented in ***Appendix 2***. The basic statistics of results of major element concentration are given in Table 7.1. The concentration of important and selective chemical constituents such as Na, Cl, HCO_3 and SO_4 are given in (**Plate5** for Dombivali, Navi Mumbai and Chembur Industrial Clusters and **Plate6** for Tarapur Industrial Cluster).

Table 7.1- The basic statistics of concentration of major element for the pre-monsoon ground water samples.

	pH	EC	TH	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4	NO_3	F
Average	6.96	864	250	17.42	50.13	84	11.06	0.00	216	126	71.82	20.52	0.39
Minimum	6.35	200	60	8.00	6.08	20	1.00	0.00	61	25	3.56	1.00	0.08
Maximum	7.45	2500	850	50.00	176.32	210	50.00	0.00	488	755	304.24	86.00	1.22

(All parameters are in mg/l, except EC µ S/cm and pH)

7.1.1 Physical Characteristics

The groundwater of the area is generally colorless and odorless. The pH value of a solution is the negative logarithm of hydrogen ions in moles per liter. The groundwater of the area is generally neutral in nature with the pH varying from 6.35 (Sagoon) to 7.45 (Duttawadi).

7.2 Chemical characteristics

7.2.1 Specific Electrical Conductance

The term specific electrical conductance denotes the behaviour of a medium to the passage of electricity. Conductivity is defined as the conductance of a cube of substance one centimeter a side and is reported in mhos/cm. The conductivity of most natural waters is much less than unity. Thus for convenience the conductivity is expressed in micro mhos/cm.

The specific electrical conductance (expressed in micro mhos/cm at 25°C) of the groundwater in most of the area is within desirable limit, as 48% of the water sample show concentration of less than 750 micro mhos/cm. 50% show concentration within permissible limit (between 750 and 2000 micro mhos/cm at 25°C) and only one show concentration beyond permissible limit (more than 2000 micro mhos/cm at 25°C). The higher electrical conductivity values (1000 to 1500 micro mhos/cm at 25°C) are observed in Tarapur MIDC area which could be due to influence of seawater ingression. The higher values of electrical conductivity i.e., 2500 micro mhos/cm at 25°C is observed at Pimpleshwar (Dombivli MIDC) which reflect water contamination as the sampled well exists amidst industries in Dombivli. But for these abnormalities in major part of the area no salinity problem exists except in small pockets in isolated parts.

7.2.2 Total Dissolved Solids

Total dissolved solid is an important parameter for determining the quality of groundwater as the solids dissolved in groundwater may affect its quality. The term Total Dissolved Solids (TDS) refers to solids dissolved in water. The groundwater samples of the area classified on the basis of TDS are given below in Table 7.2.

Table 7.2- Classification of Types of Water on the basis of TDS

Type of Water	Range of Total Dissolved Solids (mg/l)	No. of Sample	% of Sample
Fresh	<1000	30	98
Slightly Saline	1000-3000	1	2
Moderately Saline	3000-10000	Nil	Nil
Highly Saline	10000-35000	Nil	Nil
Brine	>35000	Nil	Nil

The above table indicates that 99% of the groundwater samples fall in the fresh water category and the remaining 2% falls in the slightly saline category. Total dissolved solids in the groundwater in the most of the area are within the highest desirable limits of the recommended norms for drinking purpose which is less than 500 mg/l, except in the southwestern and coastal areas of MIDC clusters like at villages Ajivali (590 mg/l) and Nawada (665mg/l) in Navi Mumbai area. At Pimpaleshwar (1428mg/l) where the total dissolved solids is very high but is within the permissible limit.

7.2.3 Total Hardness as $CaCO_3$

Total hardness is the sum of calcium and magnesium concentration expressed in terms of $CaCo_3$ in mg/l. Total hardness as $CaCO_3$ in the groundwater of the area is ranging from 600 to 850 mg/l. It is less than 300 mg/l in most of the samples (78%), which is within the desirable limits. Total hardness is high (300 to 500mg/l) in Agroli (425mg/l), Man-Dandipada (305mg/l), Duttawadi (350mg/l). The total hardness is within permissible limits (300 to 600mg/l) at all locations except at Pimplehswar (850mg/l) where it is beyond permissible limit.

7.2.4 Calcium

The calcium content of the groundwater in all studied MIDC segments is within desirable limits (less than 75 mg/l). The higher concentration is observed in Pimplehswar (50mg/l) where calcium contents are high but within the desirable range.

7.2.5 Magnesium

The magnesium content of groundwater in major part of the area is high being more than the desirable limits (30 mg/l) in 71% of the analysed samples. The Mg is less (<30mg/l) only at Duttawadi (23mg/l) and Man (29mg/l) in Tarapur MIDC whereas it is within desirable limits in samples collected from Chembur, Nawada, Dahisar and Mumbra of MIDCs located in Thane and Navi Mumbai city. The Mg concentration is higher in Tarapur MIDC than other studied MIDCs. The magnesium content is above the permissible limit of 100mg/l at Pam (123mg/l) and Pimpaleshwar (176mg/l). This higher concentration of Mg indicates influx of seawater into ground water apart from industrial contamination.

7.2.6 Sodium

Sodium is one of the principal cation found in the groundwater. The major sources of sodium in basalt are feldspars, which form the major portion of the rock. Sodium content in groundwater in major part of the area is less than 100 mg/l in majority of the samples (76%). The sodium content in the groundwater is high (100-150mg/l) at Pam, Boiser and Kalawada of Tarapur MIDC and it is very high at Nawad (190mg/l), Duttawada (195mg/l) and Pimpaleshwar (210mg/l). Influence of coastal climate can be one of the reasons for this anomaly apart from possibility of industrial contamination on shallow aquifers.

7.2.7 Potassium

Potassium is liberated with great difficulty from the potassium feldspars, which are the main source of potassium in the basalt. The potassium feldspars are very resistant to water. Thus the concentration of potassium is generally much lower than sodium. In the area, the potassium concentration is less than 10mg/l in most of the samples (76%) and is very high (40 to 50mg/l) in Duttawadi and Nawada.

7.2.8 Bicarbonate and Carbonate

The carbon dioxide from the atmosphere and decay of organic matter dissolved by the circulating water appears as bicarbonate HCO^-_3 and carbonate (CO^{--}_3) ions in groundwater. The water reacts with the carbon dioxide and forms a weak bicarbonic acid. The dissociation of weak bicarbonic acid takes place producing hydrogen and bicarbonate ions. As carbon dioxide supply gets decreased the bicarbonate ions further dissociate and give rise to hydrogen and carbonate ions.

$$H_2O+CO_2\ (aq)= H_2CO_3\ (aq)$$

$$H_2CO_3\ (aq) = H^+ + H\ CO^-_3$$

$$H\ CO^-_3 = H^+ +CO^-_3$$

The pH of the water indicates the form in which carbon dioxide is present. The presence of carbonic acid is indicated when the pH is less than 4.50, bicarbonate if the pH is between 4.50 and 8.2 and carbonate if the pH is more than 8.20. The percentage of bicarbonic acid is maximum when the pH is 4.50. When the pH approaches 8.30 the bicarbonate ions have a major concentration. As the pH increases more than 8.30 the dissociation of bicarbonate ions produces carbonate ions whose percentage reaches maximum as pH increases. In the district the pH of groundwater ranges between 7.60 and 8.40 indicating that only bicarbonate ions exist in the groundwater and carbonate ions are absent. The bicarbonates are below the desirable limits (less than 500 mg/l) in all analysed samples of the area. High bicarbonate is observed in the groundwater samples of Nawada (317mg/l) and Duttawadi (488mg/l) but it is very much within permissible limits of 1000mg/l.

7.2.9 Nitrate as NO_3

The basaltic rocks contain very small amount of nitrogen and hence the concentration of nitrate (oxidized form of nitrogen) in the groundwater is very low. The nitrogen in the atmosphere and soil are generally added to the groundwater in the form of nitrate. The higher concentration of nitrates in the groundwater can be attributed to anthropogenic sources. The domestic wastes, industrial wastes, sewage, fertilizers used for agriculture, animal and human excreta mainly contain the nitrogen in the oxidized as well as reducing form.

The nitrate content is within the desirable and permissible limits (less than 45 mg/l) in 81% of the samples. It is in more than permissible limits at only at one location (Sagoon 52mg/l) in Dambivli MIDC and in three locations at Man-Dodipada (86mg/l), Kolwadi (46-50mg/l) and Boiser (79mg/l) in Tarapur MIDC which can be attributed to local anthropogenic activity due improper solid-waste and sewerage disposal mechanism. Nitrate is <10mg/l in about 50% of the tested samples emphasizing the ground water mostly free from contamination.

7.2.10 Sulphate as SO_4

The sulphate occurs in the form of sulphides in basalts. These sulphides are oxidized forming sulphates during weathering in contact with aerated water. The concentration of sulphates in the groundwater of basaltic terrain is generally very low. High concentrations of sulphates in the groundwater from basaltic area may be the indication of contamination of groundwater by external sources.

The sulphate content is within the desirable limit (less than 200 mg/l) in the 81% of the area ranging from 3 to 304 mg/l average being 72mh/l. It is high but within permissible limits (<400mg/l) at Agroli (304mh/l), Pimpleshwar (178mg/l), Pan (190mg/l) and Boiser (101mg/l). The high sulphate content at these locations indicates impact of contamination.

7.2.11 Chloride

The chloride ion is present in all natural waters but its concentration is very low. In basaltic terrain there is no apparent source of chloride in the groundwater. The contribution of chlorides in the groundwater from the rocks is very low. The high concentration of chloride in the groundwater is mainly due to anthropogenic sources. The chloride content in the groundwater of the area in is within the desirable limits (250mg/l) except in Pam (291 mg/l) and Pimpleshwar (755mg/l) where it is within permissible limit. In Pimpleshwar, which is within the chemical industrial hub of Dombivli MIDC, the chlorides are very high is nearing the maximum permissible limit of 1000mg/l.

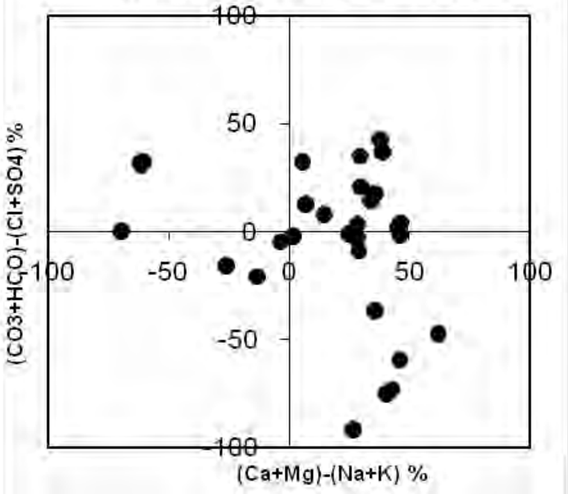
7.2.17 Fluoride

The concentration of fluoride in groundwater is generally limited due to low solubility of most of the fluorides. It is contributed to ground water due to dissolution of fluorite and fluorapatite mineral due to geogenic (natural) process. The fluoride content in the groundwater of the area is within the desirable limits (less than 1.0 mg/l) at all locations except at Duttwadi (1.21mg/l). The fluoride content is ranging from below detectable level to 0.08 to 1.22 mg/l with an average of 0.39mg/l.

7.3 Classification of Ground Water

The analytical data of all water samples are plotted on the Modified Piper plot (**Fig. 1a**) which indicate majority of the samples belong to Ca-Mg-HCO_3 (43%) and Ca-Mg-Cl type (30%), few belong to Na-Cl type (18%) and very few occupy the Na-HCO_3 block (9%). The mixed nature of the ground water facies may be due to local hydrogeological variations and marginal contamination.

Fig. 1a. Modified Piper Diagram-Premonsoon



7.4 Water quality in Post-monsoon

During post-monsoon season representative samples were collected from select locations. The details of chemical analysis of water samples collected during post-monsoon are presented along with ranges, mean values in ***Appendix 3***. The basic statistics major element results are given in Table 7.3.

Table-7.3 The Basic Statistics Major Element Concentration in Post-monsoon Ground water Samples.

	pH	EC	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F
Average	6.80	583	150	16.17	26.65	65.08	9.67	0.00	212	70	24.11	3.92	0.19
Minimum	6.15	200	60	8.00	4.86	18.00	1.00	0.00	98	18	2.03	0.00	0.04
Maximum	7.25	1770	375	24.00	80.26	270.00	26.00	0.00	512	273	88.00	10.00	0.42

(Except all parameters are in mg/l, EC µ S/cm)

The chemical analysis results of the water samples collected during post-monsoon from MIDC areas show that water is fairly good and all the tested parameters are within the maximum permissible limits of BIS drinking water standards. The pH in ground water varies from 7.25 to 6.15. It is acidic and not suitable for drinking purposes at Bioser (6.15) and Pam (6.35). The specific electrical conductance of the groundwater in most of the area (except at two locations) is within desirable limit as all the water sample show concentration in the range of 200 to 670 micro mhos/cm at 25°C (less than 750 micro mhos/cm). Specific electrical conductance is high at Mankhurd (1770 micro mhos/cm) and Man (1210micro mhos/cm). Total hardness is less than 300 mg/l in most of the samples (78%), which is within the desirable limits and it is high but within permissible limits of 600mg/l at Mankhurd (305mg/l) and Man (375mg/l). The calcium content of the groundwater in all studied MIDC segments is within desirable limits (less than 75 mg/l). The magnesium content of groundwater in major part of the area is high being more than the desirable limits (30 mg/l) in 73% of the analysed samples. It is high in samples of Mankhurd (66mg/l) and Man (80mg/l) but being <100mg/l, the water is suitable for drinking purposes. Sodium content in groundwater in major part of the area is less than 100 mg/l in all the samples except at Mankurd where it is very high being 270mg/l. In the area, the potassium concentration is less than 10mg/l in most of the samples (77%) and is high (10 to 22mg/l) at three location Kalawada, sagoon Mankurdh and is very high at Man (26mg/l). The bicarbonates are below the desirable limits (less than 500 mg/l) in all analysed samples of the area. Marginally high bicarbonate is observed in the groundwater sample of Mankurdh (512mg/l) but it is very much within permissible limits of 1000mg/l. The nitrate content is within the desirable and permissible limits (less than 45 mg/l) in all the samples. It is in less than 10mg/l at many locations indicating pristine nature groundwater with reference to domestic contamination. The sulphate content is within the desirable limit (less than 200 mg/l) in all samples and ranges from 2 to 88 mg/l with average being 24mg/l. The chloride content in the groundwater of the area in is within the desirable limits (250mg/l) except in Mankurdh (2731 mg/l) where it is within permissible limit. It is less than 100mg/l in most of the samples. The fluoride content in the groundwater of the area is within the desirable limits (less than 1.0mg/l) at all locations and is less than 0.5mg/l in all the samples (average is only 0.19mg/l) indicating the water is free from excess fluoride content.

7.5 Heavy metal contamination

The ground water samples collected in September 2010 from MIDC clusters located in Mumbai, Navi Mumbai and Thane districts were analyzed for important heavy metals like Cu, Mn, Fe, Pb and Zn concentration. The results indicate that the ground water is largely free form heavy metal contamination as many of the analyzed trace metals were found in either below detectable limits (BDL) or within the desirable limits of BIS drinking water standards (Table). However the Mn (Manganese) is in high concentration at six locations being above desirable limits (0.10mg/l) at three locations viz Nawade (Navi-Mumbai MIDC), Gharivali (Dombivali MIDC), Belgaon (Khutal Pada- Tarapur MIDC). It is in more than permissible limits (0.30mg/l) at another three sampled sites of MIDCs which are Chembur (Chembur MIDC) Agroli (Navi-Mumbai MIDC) Sagaon (Dombivali MIDC). Ground water is more contaminated with Mn in Agroli area as Mn concentration is very high being 1.506mg/l followed by Chembur where it is recorded as 0.961mg/l. The Pb (Lead) is in more than the limits (0.05mg/l no relaxation) at Mankhurd (Chembur MIDC), Sagaon and Gharivali (Dombivali MIDC). The ground water at Mankhurd is highly contaminated with respect to Pb as it is 0.684mg/l. The locations of high concentration of Mn and Pb in Dombivali, Mumbai and Chembur Industrial Clusters are shown in **Plate 7** and **Plate 8** respectively. The presence of high content of few heavy metals in some MIDC clusters which are mostly in urban areas could be due to leakage of industrial effluents from discharge channels and their subsequent migration down to phreatic aquifers. Presence of many manufacturing industries and metal processing unit near these MIDC clusters including petroleum storage facility at Chembur could be some the reasons for heavy meal (Mn and Pb) concentration at few locations closer to studied MIDCs.

Table-7.4 Heavy metal concentration in MIDC clusters located in Mumbai, Navi Mumbai and Thane districts.

Sl. No	Location	Cu	Mn	Fe	Pb	Zn	Cluster
1	Chembur	BDL	**0.961**	BDL	0.037	0.103	Chembur
2	Mankhurd	BDL	BDL	BDL	0.684	0.011	Chembur
3	Agroli	BDL	**1.506**	BDL	0.052	0.262	Navi-Mumbai
4	Targhar	0.006	BDL	BDL	BDL	BDL	Navi-Mumbai
5	Nawade	BDL	0.288	BDL	0.013	0.299	Navi-Mumbai
6	Mumbra	BDL	BDL	BDL	BDL	BDL	Navi-Mumbai

Sl. No	Location	Cu	Mn	Fe	Pb	Zn	Cluster
7	Pimpleshwar	BDL	BDL	BDL	0.026	2.39	Dombivali
8	Sagaon	BDL	**0.329**	BDL	0.074	0.1	Dombivali
9	Gharivali	BDL	0.172	BDL		0.028	Dombivali
10	Hetutane	BDL	BDL	BDL	0.029	0.866	Dombivali
11	Belgaon (Khutal Pada)	BDL	0.105	BDL	0.01	0.702	Tarapur
12	Mandodhipad a	BDL	BDL	BDL	0.023	0.028	Tarapur
13	Dattawadi	BDL	0.021	0.02 9	0.02	BDL	Tarapur
14	Kumbhavali	BDL	BDL	BDL	BDL	BDL	Tarapur
15	Kolawade	BDL	BDL	BDL	BDL	BDL	Tarapur
16	Ajivali	BDL	BDL	BDL	BDL	BDL	Navi-Mumbai
0.288	Concentration in more than permissible limits of BIS Drinking Water Standards						
0.961	Concentration in more than desirable limits of BIS Drinking Water Standards						

7.6 Classification of Ground Water

Water facies in post-monsoon show minor modifications due to addition of fresh water, the groundwater is more of Ca-Mg-HCO_3 type (52%) and Na- HCO_3 type(48%) in post-monsoon (**Fig. 1b**). The Na content has risen in post-monsoon than Cl indicating dilution of contamination. Unparallel increase of NO_3 with Cl and SO_4 show marginal contamination of ground water at Mankhurd. In post-monsoon, the heavy rainfall in the region might be flushing out the pollutants if any and diluting the influence of contaminants on ground water. The heavy inflows into sea water through creeks also take away industrial and domestic wastes into sea reducing the chances of seepage of pollutants into aquifers.

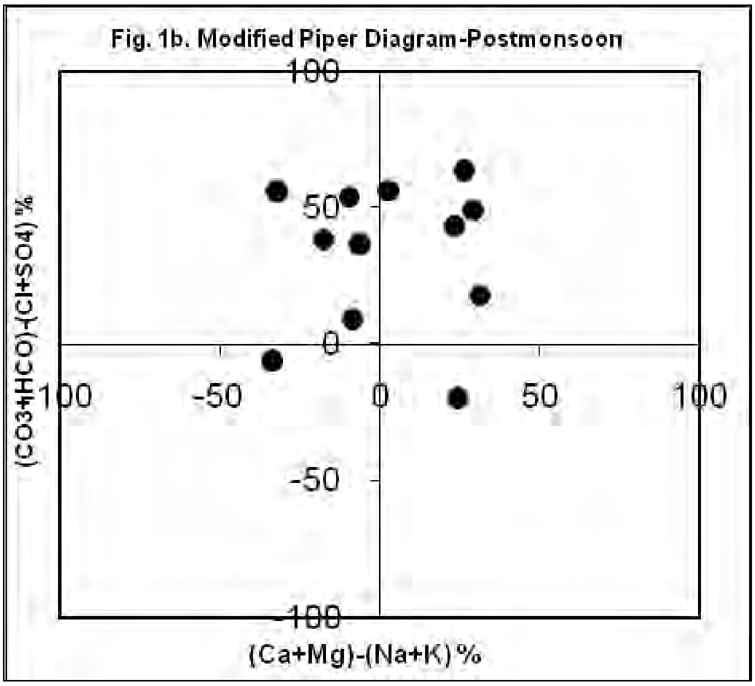


Fig. 1b. Modified Piper Diagram-Postmonsoon

7.7 Suitability of Groundwater for Drinking Purposes

The suitability of ground water in the studied MIDC areas for drinking purpose is decided based on the drinking water standards (IS-10500-93) prescribed by the Bureau of Indian Standards (BIS). The number of samples falling in desirable, permissible range is presented below in Table 7.5. The samples having concentration of above permissible limits are presented in (**Plate9** for Dombivali, Navi Mumbai and Chembur Industrial Clusters and **Plate10** for Tarapur Industrial Cluster).

Table 7.5 – Suitability of Ground water for Drinking Purpose as per BIS Standards.

Parameter	**Drinking water standards (IS-10500-93)**		**Total No. of Samples**		**No. of samples within DL**		**No. of samples within (DL to MPL)**		**No. of samples >MPL**	
	DL	MPL	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon	Pre-monsoon	Post-monsoon
PH	6.5-8.5	No relaxation	31	12	30	10	-	-	1	2
TDS (mg/l)	500	2000	31	12	2	10	14	2	0	0
TH (mg/l)	300	600	31	12	23	10	7	2	1	0
Ca (mg/l)	75	200	31	12	31	12	0	0	0	0
Mg (mg/l)	30	100	31	12	9	8	4	4	4	0
Cl (mg/l)	250	1000	31	12	27	0	2	1	4	0
SO_4 (mg/l)	200	400	31	12	30	12	1	0	0	0
NO_3 (mg/l)	45	No relaxation	31	12	25	12	-	-	6	0
F (mg/l)	1	1.5	31	12	28	100	3	0	0	0

Here DL- Desirable Limit, MPL- Maximum Permissible Limit.

On the basis of above Table 7.4 it can be concluded that the potability of ground water remains unaffected in many of the ground water samples as very few samples in pre-monsoon and post-monsoon have concentration of some of the tested parameters (pH, TH, Mg, Cl, NO_3) above the maximum permissible limits. The number of samples falling within the desirable limits in pre-monsoon is high especially with respect to TDS, TH, Mg and Cl thus suggesting that the ground water is susceptible for contamination though the water is suitable for drinking purpose. Some of the samples fall within the maximum permissible limits for the parameters which indicate that the ground water can be utilized for drinking purposes in the absence of any other alternate source.

7.8 Suitability of Ground Water for Irrigation

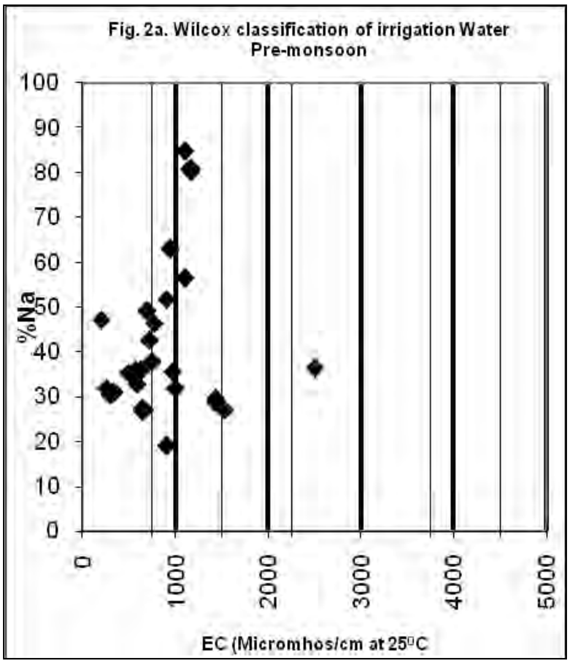
The quality of ground water is assessed for its suitability for irrigation purposes based on various indices and plots such as SAR, %Na, RSC besides concentration of certain soil tolerance elements. The suitability assessment of ground water for irrigation purpose based on various parameters for premonsoon and postmonsoon season is given in Appendix-4 and 5 respectively.

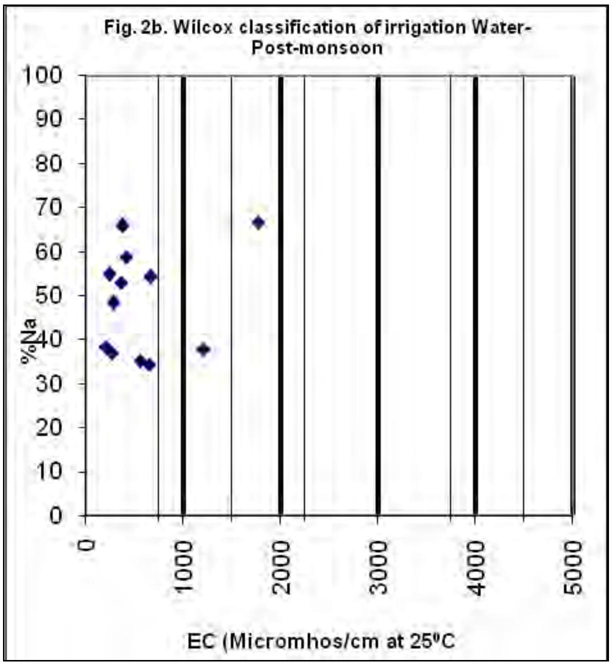
7.8.1 Percent Sodium:

Percent sodium (%Na) in ground water is an important parameter in deciding the suitability of water for irrigation as Na reacts with soil resulting in decreasing permeability of soil. The %Na can be determined applying following formula.

$$\%Na = ((Na+K) / (Ca+Mg+Na+K))*100$$

The %Na values when plotted against EC in Wilcox (1948) diagram for pre and post monsoon season **(Fig. – 2a &b)** shows that majority of the samples fall in excellent to permissible category and the ground water is suitable for irrigation. Majority of the samples of both the seasons are suitable for irrigation as they are of low sodium hazard



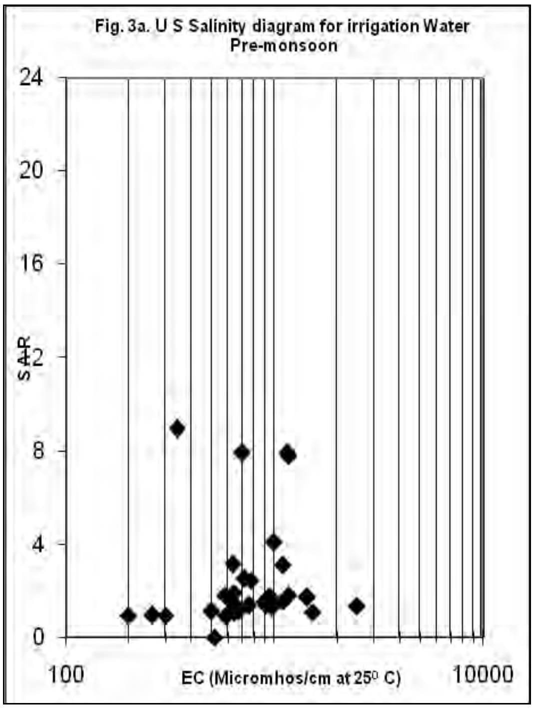


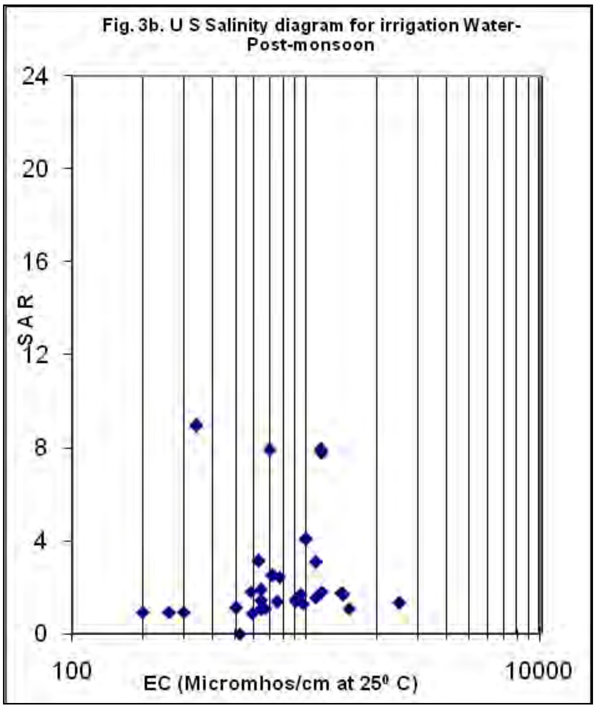
7.8.2 Sodium Absorption Ratio (SAR):

The sodium hazard is expressed by determining the sodium adsorption ratio (SAR). The sodium alkali hazard or Sodium Absorption Ratio (SAR) of water can be determined by following formula in which all the values are in meq/l units.

$$SAR = Na / \sqrt{(Ca+Mg) / 2}.$$

The SAR values are low at many locations but it ranges between 80 and 85 at Nawada and Duttawadi making unfit for irrigation. The US Salinity Diagram for irrigation waters is applied using the total dissolved solids content, measured in terms of specific electrical conductance, which gives the salinity hazard of irrigation water. The electrical conductivity values and the SAR values for Premonsoon and Postmonsoon are plotted on the USSL (United States Salinity Laboratory) diagram (USSL1954) and shown in **Fig. 3a & b**. Most of the samples fall in C_2S_1, C_3S_1 category which indicate low to medium salinity hazard. Salt resistant crops can be cultivated in high salinity areas and other suitable crops can be grown in sodic soil.





7.8.3 Residual Sodium Carbonate (RSC):

The residual alkalinity of water is denoted by Residual Sodium Carbonate (RSC) which conveys hazards effect of CO_3 + HCO_3 in the irrigation water for agriculture (Eaton 1950). The RSC can be calculated using equation mentioned below where the ionic strength is expressed in meq/l.

$$RSC= (HCO_3 + CO_3) – (Ca + Mg)$$

The RSC value of < 1.25 are considered good for irrigation, where as those with in 1.25 to 2.50 are marginally suitable and samples with > 2.50 of RSC value are not suitable for irrigation (Eaton 1950, Rechards 1954). The RSC values are high in ground water of Nawada (3.50) and Duttawadi (5.70) indicating that these waters not suitable for irrigation.

7.8.4 Kelley's Index (KI): The Kelley's Index (Kelley 1951) determined for sodium hazard is estimated using Equation motioned below in which cations are in meq/l units.

$$KI= Na/Ca+Mg$$

The water with KI value of >1 is considered as of poor quality for irrigation. Except the samples collected from Nawada (4.86) and Duttawadi (3.68) all other samples have KI value in <1.0 indicating that but for these locations the ground water around MIDCs is generally suitable for irrigation.

7.8.5 Magnesium Ratio (MR):

Magnesium Ratio (MR) is calculated applying following equation in which the ions are expressed in meq/l.

$$MR = (Mg*100) / (Ca+Mg)$$

MR value >50 is considered unsuitable for irrigation. Higher Mg content than Ca in GW effect the soil by converting it alkaline, not only leading to decreasing in yield but also making it unsuitable for cultivation as it affects the soil quality. All the samples in both the seasons have very low MR (<12) making the ground water quite suitable for irrigation.

7.8.6 Permeability Index (PI):

Doneen (1964) formulated an equation to determine the permeability index (PI) to study the suitability of water for irrigation as continuous application of water may affect soil permeability by precipitation of certain elements in the top soil thus reducing void space hindering water dynamics. The PT can be determined applying following formula in which all the ions are in meq/l.

$$PI = ((Na+ (\sqrt{HCO_3}) / (Ca+Mg+Na))*100$$

The PI of the area shows that most of the samples fall in class-II category (PI 25%-75%) in both seasons but 26% of the samples in pre-monsoon and 75% in post-monsoon fall in Class-I (PI >75%) making it gradually unsuitable for irrigation (Appendix 4 and 5).

7.8.7 Plots:

The various chemical plots and indices show that the water is of Na – HCO_3 type and is of shallow meteoric origin. The salinity index and chlorinity index plots indicate that the water is suitable for irrigation as majority of the samples fall in class I and II blocks (Appendices 1 & 3). The water samples from majority of the area in MIDCs indicate that the groundwater is having low sodium hazard with medium salinity hazard and thus is suitable for irrigation purpose. The ground waters of Nawada and Duttawadi, where many of the tested indices are found to be high, can be used for irrigating by applying suitable soil supplements and adopting salt resistant crops.

7.9 Suitability of Ground water for Industrial Purposes:

Ground water quality needs to be assessed with reference to its usefulness for industrial purposes as some of the industries might consume ground water in various processes. Since the current study focused on water contamination in industrial clusters, the ground water is assessed with reference to evaluate its suitability for industrial proposes. The water in specific quality is a must to protect the necessary machinery from scaling or corrosion effects. Thus it is imperative to periodically monitor the water chemistry applying various equations using different indices of the analysed parameters (Reddy A G S et al 2012). The calculated indices values of entire sample belonging to pre and post monsoon with respect to their suitability to industrial purpose are presented in **Appendix 4 and 5**.

7.9.1 Corrosivity Ratio (CR):

The Corrosivity ratio (CR) is calculated using the under mentioned formula in which the ions are in mg/l units.

$$CR = ((Cl/35.50 + 2(SO_4/96)) / 2(HCO_3 + CO_3/100)$$

The CR value of water with less than or equal to 1 is considered good where as more than 1 indicates corrosive nature and is not fit for passing through metal pipes (Ryner 1944; Raman 1985) and it is not suitable for industrial or domestic purposes. In pre-monsoon majority (75%) of the samples are found suitable for industrial use as CR is <1 whereas samples of Pimpaleshwar (Dombivli MIDC), Agroli (Belapur MIDC), Pam, Boiser, Duttawadi, and Kalwada (Tarapur MIDC) are having >1 CR value making them unfit for industrial use (Table 6). In post- monsoon all samples except that of Mumbra has CR <1 value indicating that the ground water is less contaminated.

7.9.2 Langelier saturation Index (LSI):

LSI is a measure to study the suitability of water for industrial purposes with reference to these affects. LSI helps in predicting the calcium carbonate stability of water and its ability to precipitate or dissolve. Apart from damaging the instruments / machinery, the scaling or corrosion properties of ground water will also bodily damage the house hold pipelines, fixtures water heating vessels, thus it is essential to study the calcium carbonate stability of water by determining LSI value which is calculated using following formula (Equation No A&B).

LSI = pH – pHs   Equation - A

Where-

pH is actual / observed pH of Ground water

pHs is calculated / theoretical pH at saturation in $CaCO_3$, which can be calculated using following equation B

pHs = (9.3+ A+B) - (C+D) (Edstrom 1998)   Equation - B

Where the constants

A = (log10 [TDS] - 1)/10

B = -13.12 * Log10 (^{O}C + 273) +34.55

C = Log10 [Ca^{+2} as $CaCO_3$] –0.4   and

D = Log10 [alkalinity as $CaCO_3$] - 0.4

Based on the LSI value the following classification can be made (Carrier 1965)

2.0 : Scale forming but non-corrosive

0.5 : Slightly scale forming and corrosive

0.02 : Balanced but pitting - corrosion possible

-0.5 : Slightly corrosive but non-scale forming

-2.0 : Serious corrosion

The positive value of the LSI indicates the over-saturation of water thus tendency of $CaCO_3$ deposition and a negative saturation has tendency for corrosion. The saturation index is used to evaluate the scale forming and scale dissolving tendencies of water. If the saturation index is zero (pH=pHs), the water is in equilibrium and there is no net tendency of either scaling or corroding. The water samples in pre-monsoon show tendency for corrosion as majority (except four samples) of the tested samples have the LSI between -1 to -2 (**Appendix 4** and **5**) making the ground water unfit for specific industrial uses like in boilers, cooling towers etc as the ground water is susceptible for corrosion. In post-monsoon the water is showing significant improvement in quality as all the samples have about -0.5 LSI and are quite suitable for many industrial application as these have tendency for slightly corrosive but non-scale forming.

7.9.3 Ryznar stability Index (RSI):

The Ryznar stability Index (RSI) is another method of identifying dissolving or precipitation nature of $CaCO_3$ of the ground water (Roberge 1999). It can be assessed using the equation mentioned below.

$$RSI = 2(pH_s) – (pH_w)$$

Where –

pH_s is the pH at saturation in $CaCO_3$ and

pH_w is the measured pH of water.

The RSI value of <<6 indicates increasing tendency for scale forming with a decreasing index, where as a value of >>7 suggests formation of no corrosion protective film. Water with RSI of >>8 suggest tendency for corrosion (Kunwar Singh 2006). RSI values of samples presented in appendix 4 and 5 indicate that all samples of pre and post-monsoon have tendency for corrosion as the RSI is >9. Since the studied MIDCs are located closer to sea coast, the impact of marine climate on the phreartic aquifer can be expected. The poor quality of ground water with reference to its suitability for industrial uses does not substantiate that the water contamination is due to industrialization in these areas as erratic acidic and alkaline nature of formation in coastal aquifer is expected due to sea water intrusion or presence of marine sediments at moderate depths which have trapped brackish waters.

8. GROUND WATER CONTAMINATION

The appraisal of water chemistry attains significance, more so for a contaminated aquifer, so as to facilitate understanding the process of pollution and ability of the groundwater to assimilate extraneous elements. The chemical contaminants more commonly follow the preferred paths in any aquatic medium during dispersion and get absorbed. Industrialization coupled with massive urbanization leads to irreparable damage of the surrounding natural resources in spite of preventive measures taken up by the respective industrial units and local governing bodies. The extent of damage will be more pronounced and have immediate implications in the case of water bodies, specially the groundwater reservoirs, as they have limited mobility and flushing capacity. Based on the concentration of tested parameters in comparison with back ground values and water potability standards, the extent of contamination of ground water in MIDC areas studied is elaborated in following paragraphs.

8.1 Anomalous Concentration of analysed Parameters:

The groundwater is having the mean pH of 6.96 and as at many locations in the MIDC the groundwater is having the pH in the range of 6.50 to 7.00 showing negligible effect of industrial contamination. Higher EC and TDS at Pimpaleshwar (Dombivali MIDC) could be the effect of partial industrial contamination as the well is located midst of the chemical industries. Na is >100 mg/l at Pimpleshwar, Duttawadi, Pam, Narwada and Bioser but the higher Na in open wells located at Pimpleshwar and Duttawadi indicate impact of industrial contamination as well as coastal climate. Higher Na in other wells, which are mostly from deeper horizons (BW) could be due to lithological contribution. K is high (~50mg/l) at Duttawadi (Tarapur MIDC) which could be due to seepage from industrial effluents. Higher Cl (755mg/l) at Pimpleshwar indicates industrial influence on local aquifer. Very high SO_4 (304mg/l) at Agroli, Pimplaeshwar and Pam indicate the spreading of industrial effluents into groundwater body. NO_3 content is >45mg/l at four locations (Sagoan, Man, Kakwada and Boiser Tarapur MIDC from HPBW located in residential areas) indicating influence of domestic sewerage. Unorganized development of hutments close to industrial hubs could be leading to nitrate contamination near MIDC lay outs due to improper disposal of domestic as well as solid waste from unlined sewerage and drainage channels. Fluoride is high (1.22mg/l) at Duttawadi which is contributed from aquifer material and is a localized phenomenon due to lithogical variations.

8.2. Sources and Causes of Water Contamination

The groundwater within MIDC clusters having high content of EC, TH, Mg^{2+}, Cl^-, SO_4^{2-} and NO_3^- prove that the industrial effluents are not only causing direct contamination of water but domestic sewerage is also responsible for ion enrichment at some locations.

Ca/Mg meq/l ratio shows that most of the samples have Mg in excess of Ca in both the seasons. The excess concentration of Mg than Ca indicates contamination by some external source. The higher concentration of Na^+, Cl^-, SO_4^{2-} and NO_3^- in the groundwater is an indication of man-made source. Higher concentrations of Cl^-, SO_4^{2-}, NO_3^- and TDS in some samples indicate anthropogenic impact on water quality. Large quantities of acids and calcium carbonate materials are used by industries in the production of pharmaceuticals, paints, rubber products etc, most of which are drained out in the form of effluents without proper treatment into open channels leading to percolation of these elements into groundwater in and around MIDCs which prove to be potential pollutants as point sources. Dominance of Cl^- and SO_4^{2-} among the two sets of samples especially in pre-monsoon (Pimpaleshwar and Pam) and similar assemblage of SO_4^{2-}-NO_3^- (Sagoon and Boiser) accentuate that their contribution into groundwater could be from industrial sources. Percentage content of Cl^- is higher than those of SO_4^{2-}+NO_3^- in 61% of samples whereas SO_4^{2-} is higher than K^+ +NO_3^- in 65% of samples which proving that the nitrate input is from industrial as well as human habitation sources. The results also illustrate that fertilizers are not responsible for higher nitrate content in water of the area as some sample contain comparable percentage of nitrates to sulpahtes. Apart from industrial effluents, domestic sewerage could be responsible for higher Cl^- and NO_3^- as the solid waste disposal mechanism is in very poor state in the area. Some parts of the study area are occupied by industrial and urban land-use, therefore some nitrate leaching from landfill sites and industrial effluents cannot be neglected (Reddy A G S 2012). Abundance of SO_4^{2-} (23% of samples in pre-monsoon season have >100mg/l concentration) could be due to industrial effluents as other possible source of gypsum dissolution is ruled out due to lack of stoichiometric proportion between Ca and SO_4^{2-} . Higher content of Cl^- (four samples in pre-monsoon and two in post-monsoon have >200mg/l) can be attributed to the anthropogenic sources as the Cl- derives mainly from the non-lithological sources and then its concentration in the groundwater never exceeds 200mg/l. The Cl^- can be contributed especially from the surface sources through the domestic wastewaters, septic tanks, irrigation-return flows and chemical fertilizers (Todd 1980; Hem 1991). Marine environment could be also one the reasons for high concentration of Cl, Na, Mg and SO_4^{2-} as these MIDC are located close to sea coast. Effect of groundwater pollution is visible in core areas of MIDC in shallow phreatic aquifer and the pollutants are dissipating laterally and their concentration is decreasing progressively from middle of industrial cluster (Naik K Pradeep 2003 and Sourab Gupta 2005). The contamination is more in samples collected from shallow wells (~10m deep) than those from deep wells. The level of contamination is showing seasonal variations.

The ground water samples at few locations show higher acidity, alkalinity and sodicity making the water unfit for irrigation and industrial purposes. The anomalous concentration of some parameters of few samples falling in core area of the MIDC could be the result of industrial contamination but the high content of some ions in other samples could be from lithological and coastal environmental sources.

8.3. Evaluation of Groundwater Contamination:

Evaluation of the ground water chemistry in the aquifer system based on ionic constituents by adopting various graphical methods and interpreting different indices is attempted with an aim to identify the sources of contamination and to delineate the caused for inconsistent accumulation of certain ionic in ground water of select MIDCs. The milli-equivalent parts per litre (meq/l) values of different ionic constituents were plotted to study the influence of industrial contamination of ground water regime of the MIDCs. The simultaneous increase of Na-Cl in most of the samples show that these ions are contributed from aquifer material and higher Cl content in few samples could due to anthropogenic contamination (**Fig. 4a & b**). The NO_3 vs Cl, SO_4, and K plots (**Fig. 5a to 5c**) emphasizes that at few locations (Agroli, Pimpleshwar and Pam) the ground water is effected by industrial contamination which could be due to leakage from industrial effluents discharge pipe lines or direct seepage of effluents from industries as these areas are located very close and within in the industrial hub. Very low NO_3 in these samples rules out the domestic sewerage contamination. The other plots exhibit that ground water is inflicted with industrial contamination only at one location (Pimpleshwar) as the data plots of this sample fall apart from others and occupy the contaminated water zone. The well is a shallow open well taping water from phreatic zone and is located within chemical industries area of Dombivli thus its water is showing the signs of industrial contamination. The ground water at Agroli (CIDCO ; Belapur MIDC) also show marginal industrial contamination so also at Pam (Tarapur MIDC). As the studied MIDCs have effluent treatment facility and dispose-off the industrial wastes into sea there is very limited scope for groundwater contamination. But in the process of effluent transportation leakages could be resulting in point source contamination damaging local shallow sub-surface water zones. However since the ground water is not used for drinking purpose no adverse effect on human health is reported from these areas. The water requirement for industrial purpose and drinking use are totally met form surface water and MIDC along with local administration supply the drinking water from its surface water sources to local habitations ensuring safe and potable water reaches to people nearby MIDC areas.

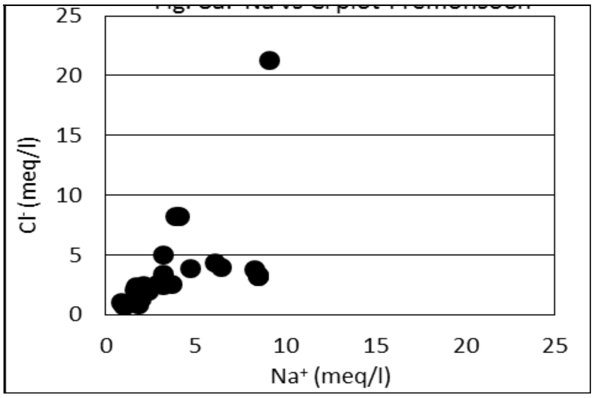


Fig. 4a: Na v/s. Cl Plot – Premonsoon

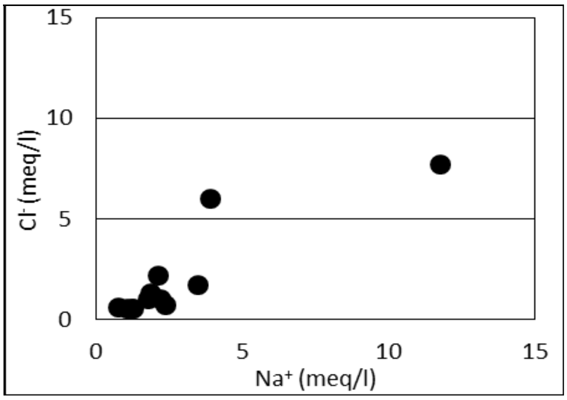


Fig. 4b: Na v/s. Cl Plot – Postmonsoon

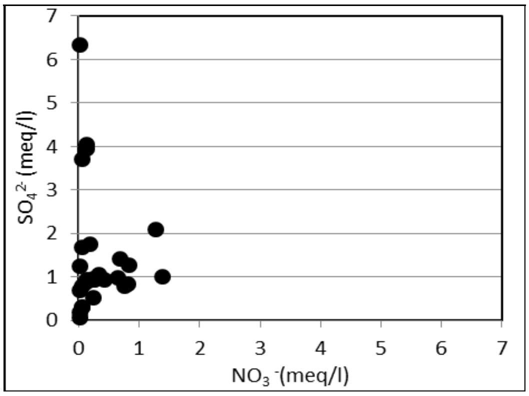


Fig. 5a: NO_3 v/s. SO_4 Plot – Premonsoon

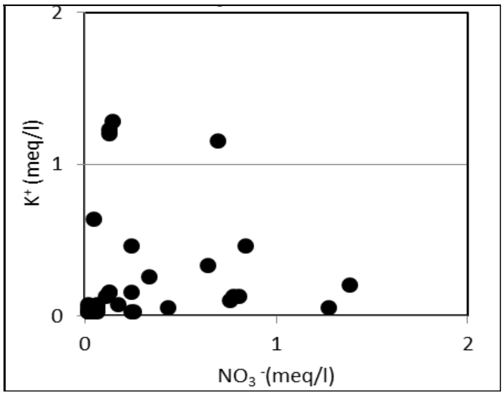


Fig. 5b: NO_3 v/s. K Plot – Premonsoon

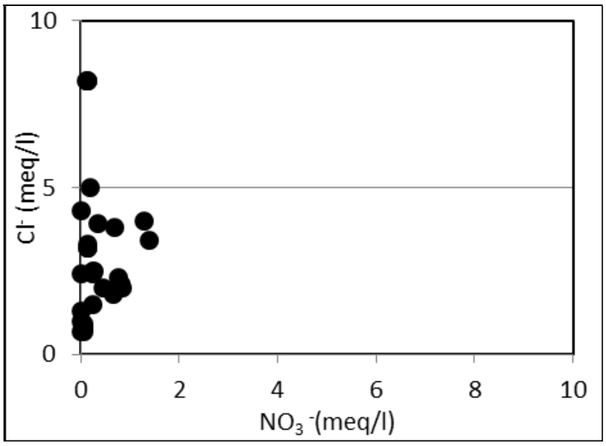


Fig. 5c: NO_3 v/s. Cl Plot – Premonsoon

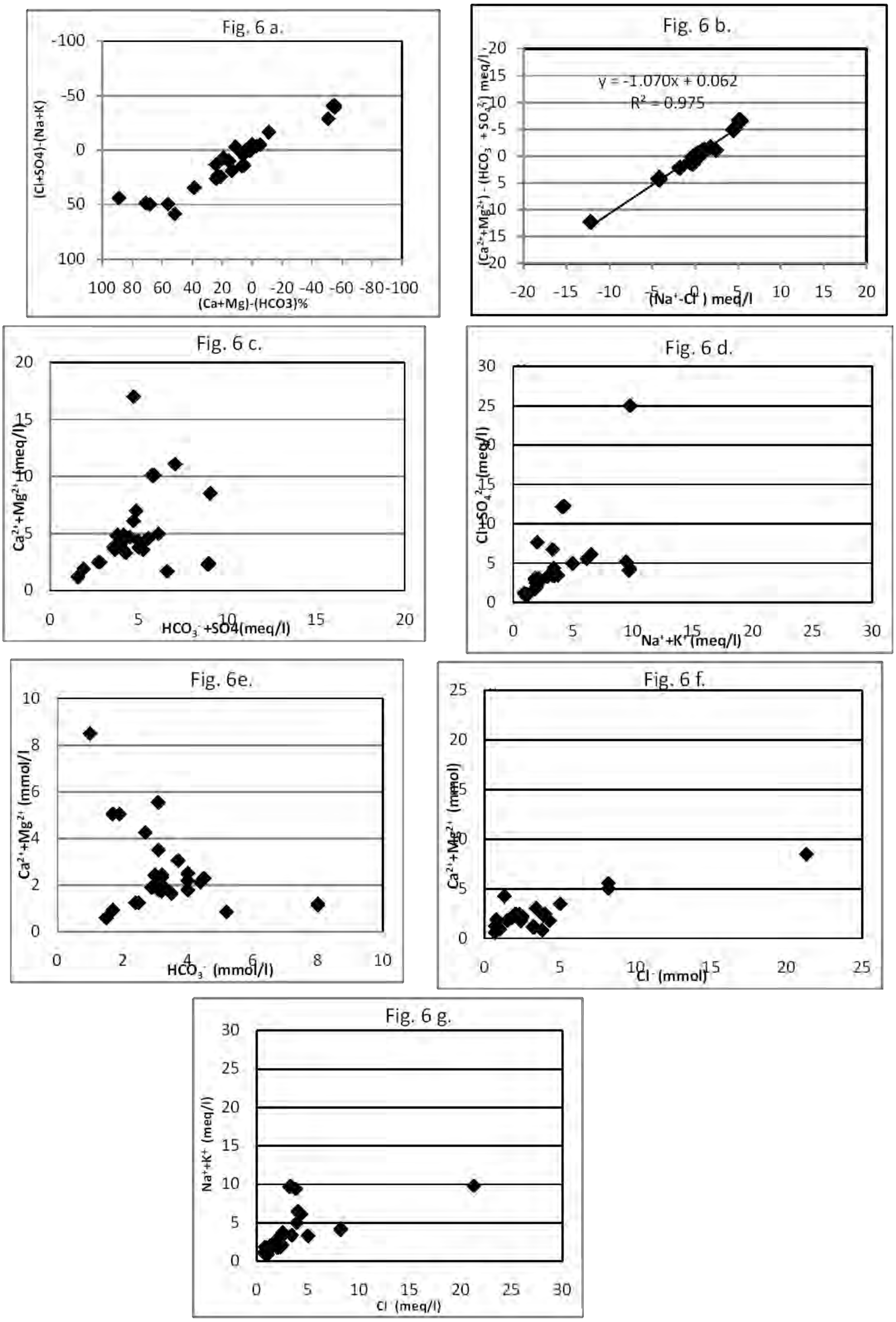


Fig. 6 a to g: Cross plots of various ionic constituents - Pre-monsoon

9. CONCLUSIONS AND RECOMMENDATIONS

Based on the hydrochemical study and major element chemistry of ground water in and around industrial clusters of Mumbai and Thane districts the following conclusions are drawn and feasible recommendations are made to arrest and improve the ground water quality in MIDC area.

9.1 Conclusions

1. The MIDC has established adequate infrastructure facilities for providing suitable water for both industrial and domestic uses as well as effluent treatment and waste disposal mechanism is put in place. But due to inefficient functioning of ETPs and leakages at some locations combined with laxity on the part of industrial management the areas are selectively susceptible for water contamination.

2. The present study aims to identify and discuss the various problems of ground water contamination with respect to industrial development in MDC enclaves of Dombivli, Nai Mumbai, Belapur, Chembur which are located in Mumbai-Thane cities. The Tarapur MIDC (Phase I and II) is situated at Bioser of Palghar taluka at about 10km SW of Tarapur Village which has the famous Tarapur Atomic Power Plant. The MIDC units of Mumbai and Thane are located on plains terrain closer to coastal belt of Arabian sea near Creeks.

3. Climate of the district is characterized by high humidity throughout the year, an oppressive summer followed by well distributed and heavy rainfall during the southwest monsoon season. The area is blessed with SW monsoon and receives good quantity of rainfall ranging from 1600 to 3300mm.

4. The important geographical feature noticed in studied MIDC areas are denudation hills which are formed due to differential erosion and weathering. The industrial infrastructure is developed mostly around relatively flat areas. Other important land feature associated with MIDC units is located in coastal plain in western part.

5. The area in underlain by the basaltic lava flows belonging to Deccan traps of Upper Cretaceous to Lower Eocene age and Recent alluvium along the coastline in

western part which is covered with coastal alluvium and calcareous Sandstone as tidal flats.

6. Weathering is the important phenomena affecting water-bearing properties of basalt. Intensity of weathering is higher in plain area. The depth of weathering is in general up to 5 m and maximum it is up to 20 m. The alluvium which largely constitute of coastal alluvium is confined to western part and potential alluvial aquifers with potable water extend down to 8 to 10m.

7. The depth to water level ranges between 0 and 2.5 m bgl in major part of the areas in pe-monsoon and is in <2m range in post-monsoon. The decline in water level is marginal as annual fall in water level is <0.05m/yr water levels are almost stable due good rainfall and less ground water extraction in the area.

8. 23 ground water samples in pre-monsoon and 16 samples in post-monsoon were collected from different types of wells representing different aquifers and hydrogeological units from the study area in the MIDCs. Apart from these samples four sets of samples were also collected for trace element analysis, COD and BOD tests.

9. Majority of the analysed elements are well within the maximum permissible limits of BIS drinking water standards. In pre-monsoon pH is more than MPL in one sample, Mg in four samples and NO3 in two samples. In post-monsoon water quality has improved as two samples are found to have only pH above MPL of BIS DWS.

10. As per the irrigation classification and other indices, the ground water is quite suitable for irrigation at all most all the locations. The water is of low sodium (alkaline) hazard and medium salinity hazard. At few locations higher salinity is noticed which could be due to marine environment. The ground water is in general suitable for many industrial applications but since the water has corrosive nature at some locations as per few indices it may not be usefull for specific industrial applications like boilers and cooling towers. However the ground water is not used

for industrial purposes as sufficient safe water is provided by MIDC management at all the MIDC clusters.

11. Local ground water contamination evident in Belapur (Agroli), Dombivli (Pimpleshwar) and Tarapur (Duttawadi and Pam) MIDC areas as few ionic constituents are in higher concretion than the normal (background) values.

12. Higher EC and TDS at Pimpaleshwar (Dombivali MIDC) could be the effect of partial industrial contamination as the well is located midst of the chemical industries. Na is >100 mg/l at Pimpleshwar, Duttawadi, Pam, Narwada and Bioser, the higher Na in open wells located at Pimpleshwar and Duttawadi indicate impact of industrial contamination as well as coastal climate. Higher Cl (755mg/l) at Pimpleshwar indicates industrial influence on local level. Very high SO_4 (304mg/l) at Agroli, Pimplaeshwar and Pam indicate the spreading of industrial effluents into groundwater body. NO_3 content is >45mg/l at four locations (Sagoan, Man, Kakwada and Boiser Tarapur MIDC from HPBW located in residential areas) indicating influence of domestic sewerage.

13. The presence of high content of few heavy metals such as Mn and Pb in some MIDC clusters which are mostly in urban areas could be due to leakage of industrial effluents from discharge channels and their subsequent migration down to phreatic aquifers.

14. Evaluation of the ground water chemistry based using major ionic constituents by adopting various graphical methods emphasizes that at few locations (Agroli, Pimpleshwar and Pam) the ground water is effected by industrial contamination which could be due to leakage from industrial effluents discharge pipe lines or direct seepage of effluents from industries as these areas are located very close and within in the industrial hub.

15. As the studied MIDCs have effluent treatment facility and dispose-off the industrial wastes into sea there is limited scope for groundwater contamination. But in the process of effluent transportation leakages could be resulting in point source contamination damaging the shallow aquifer at local level. However since the ground water is not used for drinking purpose no adverse effect on human health is reported from these areas.

9.2 Recommendations

1. Effluent generated from industries must be properly treated, before its disposal by the industries.
2. Leakage from pipelines carrying industrial waste must be prevented by doing regular checking and repair and effluent should be properly disposed.
3. Major effluent generating industries that have primary effluent treatment facilities must maintain the pH level of their effluents to about 7.5 before disposing in to effluent sump.
4. Disposal of solid wastes and effluents on roadside, and local drainage and open field must be stopped immediately.
5. The pH level of the effluent sumps must be maintained at least 7.5 before disposal in to sea.
6. Disposal of solid wastes must be taken care. These wastes now contribute much to the pollution of the creeks.
7. Area around Tarapur MIDC is susceptible to seawater intrusion, the depth of bore wells adjoining the Mumbra creek and seashore may be restricted to 30-40 m.bgl with limited pumping.
8. Ground water pollution should be monitored frequently in the industrial belt to identify pollution sources and to initiate corrective and regulatory actions through pollution control measures.
9. Safe drinking water must be made available by MIDC management to those living in uncovered neighboring villages and upcoming settlements along with proper sewerage and domestic solid waste disposal mechanism to maintain hygienic living conditions in and around MIDC areas.
10. MIDC should also take full responsibility for environmental protection and prevention of water contamination by scrupulously following the above suggestions on continuous basis.

Appendix 1. Hydrogeologocal details of the wells inventoried and samples collected from Dombivali, Navi Mumbai and Chembur Industrial Clusters

Sl. No	Well No.	Location	District	Type of well	Date of Inventory	Location	MP	Diamater	Total depth	Depth to water level	Depth of weathering	Aquifer material	Geological Horizon	Remarks
							m, agl	m/mm	m,bmp	m,bgl	m,bmp			
1	D-02	TARGHAR	Navi Mumbai	DW	07-07-2011	Behind Bus stand	0.90	6	8	1.42	2	W B	Deccan Trap	Behind CBO Chouk
2	D-01	AJIVALI (KONE)	Raigadh	DW	06-07-2011	Adj to SK Group of Ind., (RA Enterprises)	0.50	3.8	5.2	2.41	4.50	W B	Deccan Trap	At SE corner of Noushad Poultary
3	D-03	AGROLI (CIDCO)	Navi Mumbai	DW	06-07-2011	In the CIDCO Nursary	1.10	6	12	1.3	3	W B	Deccan Trap	With in City
4	D-08	CHEMBUR (MAROLI)	Mumbai	DW	06-07-2011	Nr Ashish Cenema in Maroli	0.80	3.35	8.7	2.11	3	W B	Deccan Trap	Not in use
5	D-09	MANKLURD	Mumbai	BW-Irrig.	06-07-2011	In Suhshanthi Ashram , Oppt to Anushakthi Campus gate	0.30	172	65	2.5	10	W & F B	Deccan Trap	Used for gardening
6	D-07	PIMPLESHWAR	Thane-Dombhivoli	DW	07-07-2011	In Pimpaleshwar Temple	0.90	8.5	18	1.7	6	do	Deccan Trap	With in Dambhivoli MIDC
7	D-08	GHARIVALI	Thane-Dombhivoli	DW	07-07-2011	AT center of vilage	1.10	3.1	10.5	2.01	4	W B	Deccan Trap	Used for washing only
8	D-19	SAGOON	Thane-Dombhivoli	DW	07-07-2011	In Pragathi darshan Soct.,	1.10	3.1	10.5	1.6	5	W B	Deccan Trap	do
9	D-24	Hetutane	Thane-Dombhivoli	DW	07-07-2011	Nr ZP H School	1.00	2.6	9	1.51	4	W B	Deccan Trap	Dumped with garbage & abonded
10	D-30	NAWADA	Navi Mumbai	DW	06-07-2011	At entance of vilage	0.60	5.5	6.5	GL	2	W B	Deccan Trap	Used for washing

Sl. No	Well No.	Location	District	Type of well	Date of Inventory	Location	MP	Diamater	Total depth	Depth to water level	Depth of weathering	Aquifer material	Geological Horizon	Remarks
														only
11	T-22	DAHISAR	Thane-Mumbra	DW	06-07-2011	At Factory adj to Mumbra-Panvel rd	1.50	5.15	8.83	GL	4	W B	Deccan Trap	partly collapsed rarely used
12	T-23	MUMBRA	do	DW	06-07-2011	Below flyover nr RL track	1.00	2.3	8	0.5	4	W B	Deccan Trap	Used for washing only
13	T-26	BALAOAN (KHUTAL PADA)	Thane-Palghar	DW	08-07-2011	In the fields of Sh Kulad nr Tarapur Phata	1.10	2	5	GL	2	W B	Deccan Trap	Irrigation use
14	T-17	MAN-DODIPADA	do	DW	08-07-2011	Oppt to Aganwadi	1.00	3	7	2.19	1	W B	Deccan Trap	Used for washing only
15	T-29A	DUTTAWADI	do	DW	08-07-2011	In middle of the village	1.00	5.5	8	0.73	4	W B	Deccan Trap	do
16	T-29B	DUTTAWADI	do	BW	08-07-2011	In between village and Fact., of Tarapur MIDC	0.68	172.00	80	5.6	4	W & F B	Deccan Trap	Used for water supply to factories by BW owner
17	T-29C	DUTTAWADI	do	BW	08-07-2011	500 m W of village	0.55	172	65	3.45	5	do	Deccan Trap	do
18	T-31A to 31C	KUMBHAVALI	do	HPBW	08-07-2011	with in thwe village nr Aganwadi	0.45	172	45	4	3	do	Deccan Trap	Used for domestic pourposes
21	T-27A	KALAWADE	do	DW	08-07-2011	In middle of village	1.00	2.5	8.5	0.2	3	W B	Deccan Trap	Used for washing only

Sl. No	Well No.	Location	District	Type of well	Date of Inventory	Location	MP	Diamater	Total depth	Depth to water level	Depth of weathering	Aquifer material	Geological Horizon	Remarks
22	T-27B-27C	KALWADE	do	BW	08-07-2011	Nr stream, at abou 300m from Pharma compinies	0.55	172	80	3	4	W &F B	Deccan Trap	Used for water supply to factories by BW owner
24	T-25A-25C	PAM	do	BW-Irrig.	08-07-2011	At nr Navapur rd at Pharma companies in Tarapur MIDC	0.45	172	80	6	5	do	Deccan Trap	Used for irrigation
27	T-24	MAN	do	DW	08-07-2011	At Maruthy mandir	0.72	1.85	6.37	0.8	2	W B	Deccan Trap	Used for washing only
28	T-28	PAM-Deep BW	do	BW-Irrig.	08-07-2011	At west end of Pharma compinies afj to Pam village rd	0.65	172	35	3.3	4	W &F B	Deccan Trap	Used for water supply to factories by BW owner
29	T-32	BOISAR	Thane-Boiser	BW	08-07-2011	In Shvneri Appts in Khairapada	0.35	172	40	3.5	5	do	Deccan Trap	Used for washing only
30	T-15	DUTTAWADI	Thane-Palghar	HP-BW	08-07-2011	Nr GP Office, Adj ro Bioser rd	0.65	172	35	4	3	do	Deccan Trap	do
31	T-12	KALWADA	do	HP-BW	08-07-2011	Nr School	0.85	172	60	5	4	do	Deccan Trap	do

Here, W- Weathered, F- Fractured and B- Basalt

Appendix 2. Results of chemical analysis of ground water samples of Dombivali, Navi Mumbai and Chembur Industrial Clusters, Premonsoon (July 2011)

Sl. No.	Sample No.	LOCATION	pH	EC	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F	TDS
				µ S/cm	Mg/L (milligrams/liter)											
1	D-24	HETUTNE	6.85	520	180	12	36	44	1	0	189	53	26	15	0.12	282
2	D-02	TARGHAR	7.05	640	245	14	51	40	2	0	195	71	45	27	0.23	348
3	D-01	AJIVALI	7.20	500	165	14	32	41	1	0	214	32	37	3	0.84	268
4	D-03	AGROLI(CIDCO)	6.85	910	425	14	95	45	2	0	165	46	304	1	0.28	590
5	D-08	CHEMBUR(MAROLI)	6.75	260	95	14	15	20	1	0	104	35	9	1	0.08	147
6	D-09	MARKLURD	6.95	590	190	14	38	42	1	0	201	28	81	4	0.25	309
7	D-07	PIMPLESHWAR	6.80	2500	850	50	176	210	25	0	61	755	178	3	0.22	1428
8	D-08	GHARIVALI	6.81	630	205	26	34	45	13	0	183	64	48	40	0.24	361
9	D-19	SAGOON	6.35	750	235	32	38	55	18	0	195	71	62	52	0.28	425
10	D-30	NAWADA	6.55	1100	85	12	13	190	45	0	317	135	67	43	0.34	665
11	T-22	DAHISAR	6.73	340	125	16	21	24	3	0	153	25	14	4	0.28	184
12	T-23	MUMBRA	6.70	300	125	32	11	24	2	0	146	28	15	4	0.18	190
13	T-26	BALAOAN(KHAKUPADA)	6.85	200	60	14	6	23	3	0	92	25	4	1	0.14	121
14	T-17	MAN-DONDIPOODA	6.70	970	305	14	66	73	8	0	226	121	48	86	0.39	529
15	T-29A	DUTTAWADI	7.34	1170	120	10	23	196	48	0	488	113	45	8	1.22	689
16	T-29B	DUTTAWADI	7.45	1170	115	12	21	195	47	0	488	113	43	8	1.21	684
17	T-29C	DUTTAWADI	7.35	1160	115	8	23	195	50	0	488	117	45	9	1.22	692
18	T-31A	KUMBHAVALI	7.25	700	175	14	34	74	6	0	195	85	46	15	0.43	372
19	T-31B	KUMBHAVALI	7.15	770	215	14	44	85	1	0	268	89	45	16	0.43	428
20	T-31C	KUMBHAVALI	7.10	720	220	16	44	65	18	0	244	89	45	15	0.45	414
21	T-27A	KALWADE	7.05	640	240	16	49	38	5	0	183	74	40	50	0.25	364

Sl. No.	**Sample No.**	**LOCATION**	**pH**	**EC**	**TH**	**Ca**	**Mg**	**Na**	**K**	**CO3**	**HCO3**	**Cl**	**SO4**	**NO3**	**F**	**TDS**
22	T-27B	KALWADE	7.07	640	240	18	47	39	4	0	183	74	38	47	0.24	359
23	T-27C	KALWADE	7.00	670	245	8	55	39	5	0	183	82	39	48	0.25	367
24	T-25A	PAM	7.05	1530	555	20	123	92	5	0	189	291	190	7	0.27	822
25	T-25B	PAM	7.02	1440	505	18	112	90	6	0	116	291	190	8	0.25	773
26	T-25C	PAM	7.20	1430	505	18	112	94	6	0	104	291	194	8	0.26	775
27	T-24	MAN	6.60	580	190	28	29	48	1	0	177	85	33	1	0.20	314
28	T-28	PAM-Deep BW	6.75	900	230	12	49	108	10	0	275	138	50	21	0.42	526
29	T-32	BOISAR	6.85	1100	250	22	47	148	2	0	244	142	101	79	0.48	664
30	T-15	DUTTAWADI	6.95	1000	350	12	78	74	3	0	189	177	84	11	0.38	534
31	T-12	KALWADA	7.45	950	180	16	34	140	1	0	244	152	60	1	0.31	527
		MEAN	**6.96**	**864**	**250**	**17.42**	**50.13**	**84**	**11.06**	**0**	**216**	**126**	**71.82**	**20.52**	**0.39**	**489**
		MINIMUM	**6.35**	**200**	**60**	**8.00**	**6.08**	**20**	**1.00**	**0**	**61**	**25**	**3.56**	**1.00**	**0.08**	**121**
		MAXIMUM	**7.45**	**2500**	**850**	**50.00**	**176.32**	**210**	**50.00**	**0**	**488**	**755**	**304.24**	**86.00**	**1.22**	**1428**

Appendix 3. Results of chemical analysis of ground water samples fromDombivali, Navi Mumbai and Chembur Industrial Clusters-Postmonsoon (January 2012)

Sl. No.	Sample No.	LOCATION	pH	EC	TH	Ca	Mg	Na	K	CO3	HCO3	Cl	SO4	NO3	F	TDS
				µ S/cm	mg/L (milligrams/liter)											
1	T-37	BOISAR	6.15	560	190	16	36	43	8	0	275	46	11	1	0.20	299
2	T-15	DUTTAWADI	6.85	650	225	8	50	49	9	0	244	78	28	4	0.18	348
3	D-30	NAWADA	6.75	270	95	24	9	25	1	0	153	18	3	0	0.06	155
4	T-12B	KALWADA	6.60	670	160	20	27	80	13	0	226	60	68	10	0.08	391
5	D-19	SAGOAN	7.10	410	90	16	12	51	14	0	171	35	12	10	0.30	236
6	D-09	MANKHURD	7.23	1770	305	14	66	270	17	0	512	273	88	5	0.22	989
7	T-28	PAM	6.35	200	75	16	9	18	6	0	98	21	2	9	0.04	130
8	T-22	DALUSAR	6.82	280	75	22	5	29	6	0	134	18	5	0	0.26	152
9	T-17	MAN-DONDIPADA	6.72	360	85	14	12	41	5	0	153	35	8	2	0.42	195
10	D-08A	GUNDULE (Alt well)	6.95	370	65	12	9	55	5	0	177	25	6	2	0.10	202
11	D-07	PIMPLESHWAR	6.85	240	60	14	6	30	6	0	122	18	5	1	0.20	141
12	T-24	MAN	7.25	1210	375	18	80	90	26	0	287	213	53	3	0.21	626
		MEAN	**6.80**	**583**	**150**	**16.17**	**26.65**	**65.08**	**9.67**	**0.00**	**212**	**70**	**24.11**	**3.92**	**0.19**	**322**
		MINIMUM	**6.15**	**200**	**60**	**8.00**	**4.86**	**18.00**	**1.00**	**0.00**	**98**	**18**	**2.03**	**0.00**	**0.04**	**130**
		MAXIMUM	**7.25**	**1770**	**375**	**24.00**	**80.26**	**270.00**	**26.00**	**0.00**	**512**	**273**	**88.00**	**10.00**	**0.42**	**989**

Appendix 4. Suitability assessment of Pre-monsoon ground water samples for different purposes in Dombivali, Navi Mumbai and Chembur Industrial Clusters

	Ground Water Sample details		Irrigation purposes						Industrial purposes		
Sl. No.	**Sample No.**	**Locations**	**Sodium Absorption Ratio**	**Residual Sodium Carbonate**	**Percent Sodium**	**Kelley's Index:**	**Magnesium Ratio**	**Permeability Index**	**Corrosive Ratio**	**Langelier saturation Index**	**Ryznar stablity Index**
			Meq/l								
1	D-24	HETUTNE	1.43	-0.50	34.99	0.53	5.00	66.61	0.537	-1.817	10.484
2	D-02	TARGHAR	1.11	-1.70	26.75	0.35	6.00	53.12	0.754	-1.589	10.228
3	D-01	AJIVALI	1.39	0.20	35.39	0.54	3.72	71.86	0.393	-1.397	9.994
4	D-03	AGROLI(CIDCO)	0.95	-5.81	19.10	0.23	11.15	34.41	2.318	-1.835	10.520
5	D-08	CHEMBUR(MAROLI)	0.89	-0.20	32.02	0.46	1.72	78.45	0.569	-2.193	11.137
6	D-09	MARKLURD	1.32	-0.50	32.75	0.48	4.43	64.72	0.618	-1.728	10.406
7	D-07	PIMPLESHWAR	3.13	-16.01	36.48	0.54	5.80	38.75	20.478	-1.780	10.361
8	D-08	GHARIVALI	1.37	-1.10	35.82	0.48	2.16	60.88	0.762	-1.598	10.006
9	D-19	SAGOON	1.56	-1.50	37.75	0.51	1.94	58.93	0.840	-1.933	10.215
10	D-30	NAWADA	8.96	3.50	84.70	4.86	1.83	105.82	0.820	-1.952	10.454
11	T-22	DAHISAR	0.93	0.00	30.93	0.42	2.13	74.05	0.328	-2.021	10.772
12	T-23	MUMBRA	0.93	-0.10	30.45	0.42	0.56	73.16	0.379	-1.748	10.195
13	T-26	BALAOAN(KHAKUPADA)	1.29	0.30	47.29	0.83	0.71	101.11	0.423	-2.205	11.259
14	T-17	MAN-DONDIPOODA	1.82	-2.40	35.63	0.52	7.72	54.94	0.975	-1.872	10.444
15	T-29A	DUTTAWADI	7.78	5.60	80.24	3.55	3.80	103.91	0.424	-0.998	9.336
16	T-29B	DUTTAWADI	7.90	5.70	80.79	3.68	2.84	104.89	0.419	-0.875	9.200
17	T-29C	DUTTAWADI	7.90	5.70	80.92	3.68	4.75	104.89	0.434	-1.182	9.715
18	T-31A	KUMBHAVALI	2.43	-0.30	49.05	0.92	4.00	74.51	0.861	-1.448	10.147
19	T-31B	KUMBHAVALI	2.52	0.10	46.38	0.86	5.15	72.43	0.640	-1.301	9.753
20	T-31C	KUMBHAVALI	1.90	-0.40	42.74	0.64	4.50	66.77	0.706	-1.440	9.981

	Ground Water Sample details		Irrigation purposes						Industrial purposes		
Sl. No.	**Sample No.**	**Locations**	**Sodium Absorption Ratio**	**Residual Sodium Carbonate**	**Percent Sodium**	**Kelley's Index:**	**Magnesium Ratio**	**Permeability Index**	**Corrosive Ratio**	**Langelier saturation Index**	**Ryznar stablity Index**
			Meq/l								
21	T-27A	KALWADE	1.07	-1.80	27.04	0.34	5.00	52.43	0.799	-1.593	10.236
22	T-27B	KALWADE	1.09	-1.80	27.24	0.35	4.34	52.75	0.788	-1.431	9.931
23	T-27C	KALWADE	1.08	-1.90	27.11	0.35	11.26	51.95	0.849	-1.944	10.887
24	T-25A	PAM	1.70	-8.01	27.10	0.36	10.11	38.13	3.211	-1.478	10.005
25	T-25B	PAM	1.74	-8.21	28.69	0.39	10.23	37.74	5.240	-1.773	10.567
26	T-25C	PAM	1.82	-8.41	29.56	0.40	10.23	37.98	5.903	-1.620	10.440
27	T-24	MAN	1.51	-0.90	35.72	0.55	1.72	64.36	0.872	-1.725	10.051
28	T-28	PAM-Deep BW	3.10	-0.10	51.83	1.02	6.67	73.31	0.901	-1.751	10.253
29	T-32	BOISAR	4.07	-1.00	56.46	1.29	3.55	73.75	1.249	-1.478	9.806
30	T-15	DUTTAWADI	1.72	-3.90	31.99	0.46	10.67	48.70	1.783	-1.815	10.579
31	T-12	KALWADA	4.54	0.40	62.92	1.69	3.50	83.47	1.136	-1.165	9.780

Appendix 5. Suitability assessment of Post-monsoon ground water samples for different pourposes in Dombivali, Navi Mumbai and Chembur Industrial Clusters

	Ground Water Sample details		Industrial purposes								
Sl No	Sample No	Locations	Sodium Absorption Ratio	Residual Sodium Carbonate	Percent Sodium	Kelley's Index:	Magnesium Ratio	Permeability Index	Corrosive Ratio	Langelier saturation Index	Ryznar stablity Index
			Meq/l								
1	T-37	BOISAR	1.36	0.70	35.30	0.49	3.75	70.37	0.2796	-2.2301	10.610
2	T-15	DUTTAWADI	1.42	-0.50	34.39	0.47	10.26	62.27	0.5704	-1.9353	10.721
3	D-30	NAWADA	1.12	0.60	36.92	0.57	0.58	89.31	0.1834	-1.7591	10.268
4	T-12B	KALWADA	2.75	0.50	54.34	1.09	2.20	80.87	0.6883	-1.7932	10.186
5	D-19	SAGOAN	2.34	1.00	58.85	1.23	1.25	96.83	0.3648	-1.5687	10.237
6	D-09	MANKHURD	6.72	2.30	66.61	1.92	7.72	82.04	0.9294	-1.0420	9.314
7	T-28	PAM	0.90	0.10	38.42	0.52	0.88	89.68	0.3287	-2.5211	11.392
8	T-22	DALUSAR	1.46	0.70	48.53	0.84	0.36	99.38	0.2282	-1.7952	10.410
9	T-17	MAN-DONDIPADA	1.93	0.80	52.91	1.05	1.43	96.57	0.3842	-2.0288	10.778
10	D-08A	GUNDULE (Alt well)	2.97	1.60	65.95	1.84	1.17	110.90	0.2356	-1.8057	10.561
11	D-07	PIMPLESHWAR	1.68	0.80	54.84	1.09	0.71	108.54	0.2452	-2.0557	10.961
12	T-24	MAN	2.02	-2.80	37.89	0.52	7.34	53.26	1.2360	-1.1557	9.561

Plate-1

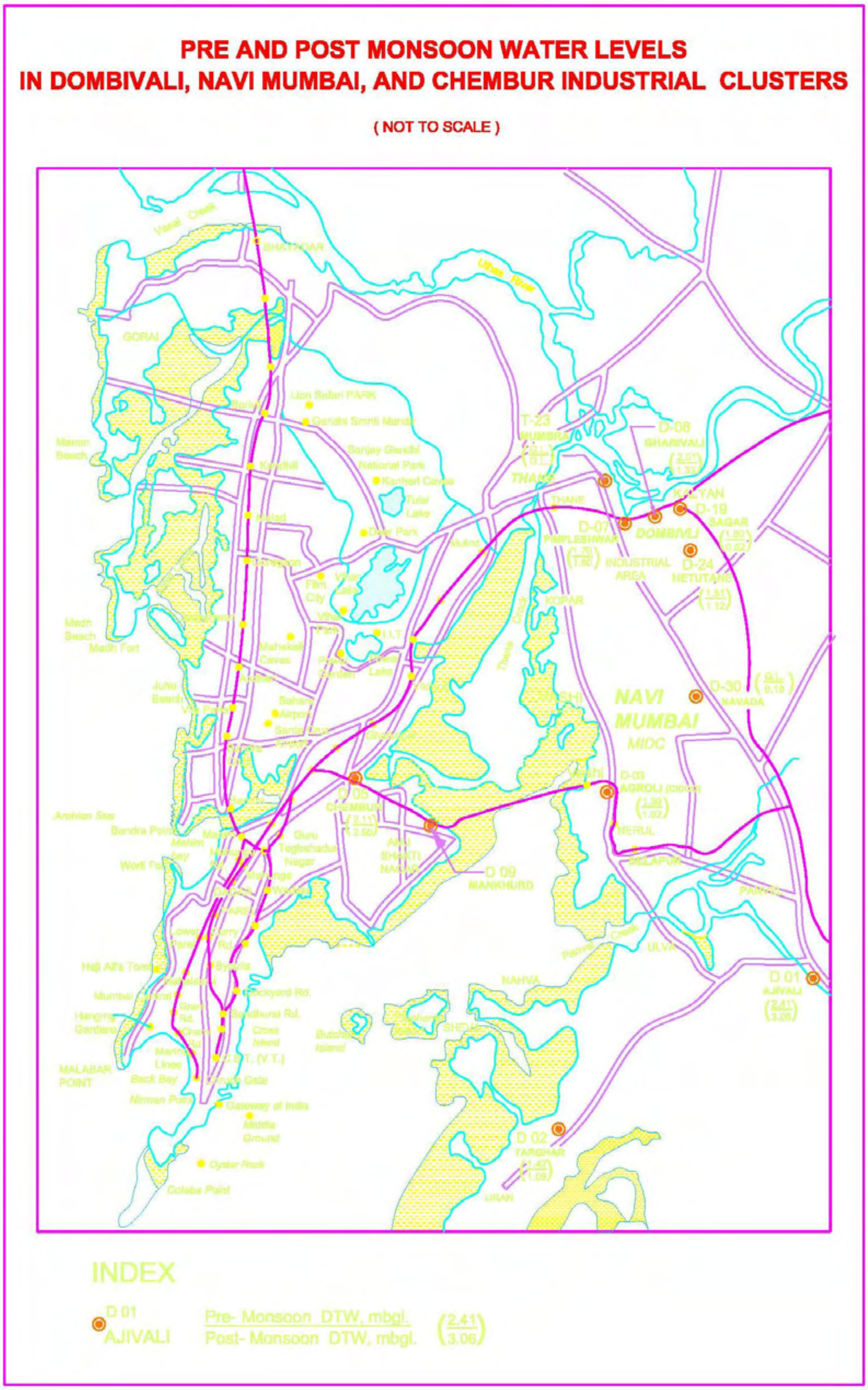

PRE AND POST MONSOON WATER LEVELS
IN DOMBIVALI, NAVI MUMBAI, AND CHEMBUR INDUSTRIAL CLUSTERS
(NOT TO SCALE)
INDEX
D 01
AJIVALI
Pre- Monsoon DTW, mbgl.
Post- Monsoon DTW, mbgl.
(2.41 / 3.06)

Plate-2

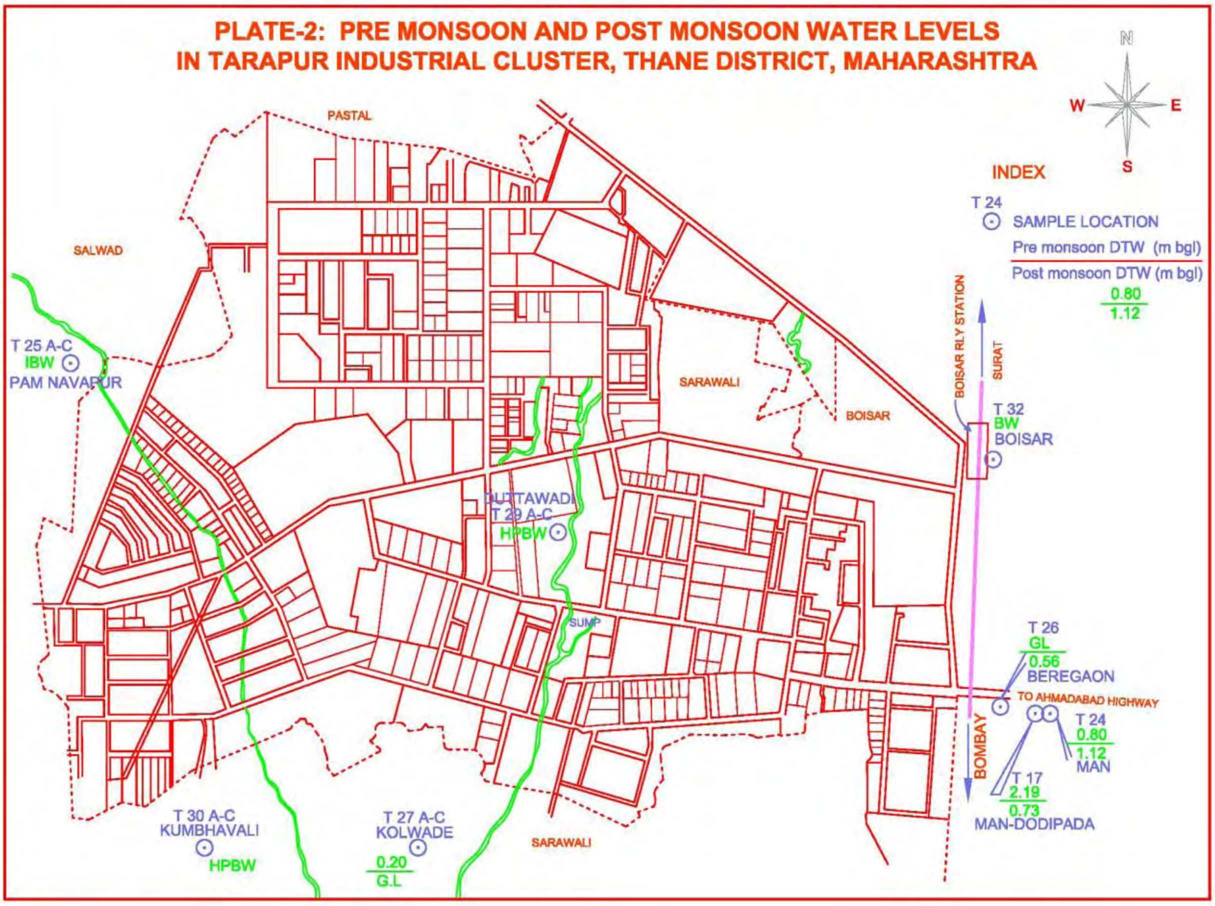


PLATE-2: PRE MONSOON AND POST MONSOON WATER LEVELS
IN TARAPUR INDUSTRIAL CLUSTER, THANE DISTRICT, MAHARASHTRA
N
W
E
S
INDEX
T 24
SAMPLE LOCATION
Pre monsoon DTW (m bgl)
Post monsoon DTW (m bgl)
0.80
1.12
PASTAL
SALWAD
T 25 A-C
IBW
PAM NAVAPUR
SARAWALI
BOISAR
BOISAR RLY STATION
SURAT
T 32
BW
BOISAR
DUTTAWADI
T 29 A-C
HPBW
SUMP
T 26
GL
0.56
BEREGAON
TO AHMADABAD HIGHWAY
T 24
0.80
1.12
MAN
BOMBAY
T 17
2.19
0.73
MAN-DODIPADA
T 30 A-C
KUMBHAVALI
HPBW
T 27 A-C
KOLWADE
0.20
G.L
SARAWALI

Plate-3

LOCATION OF WATER SAMPLE COLLECTION POINTS IN DOMBIVALI, NAVI MUMBAI, AND CHEMBUR INDUSTRIAL CLUSTERS

(NOT TO SCALE)

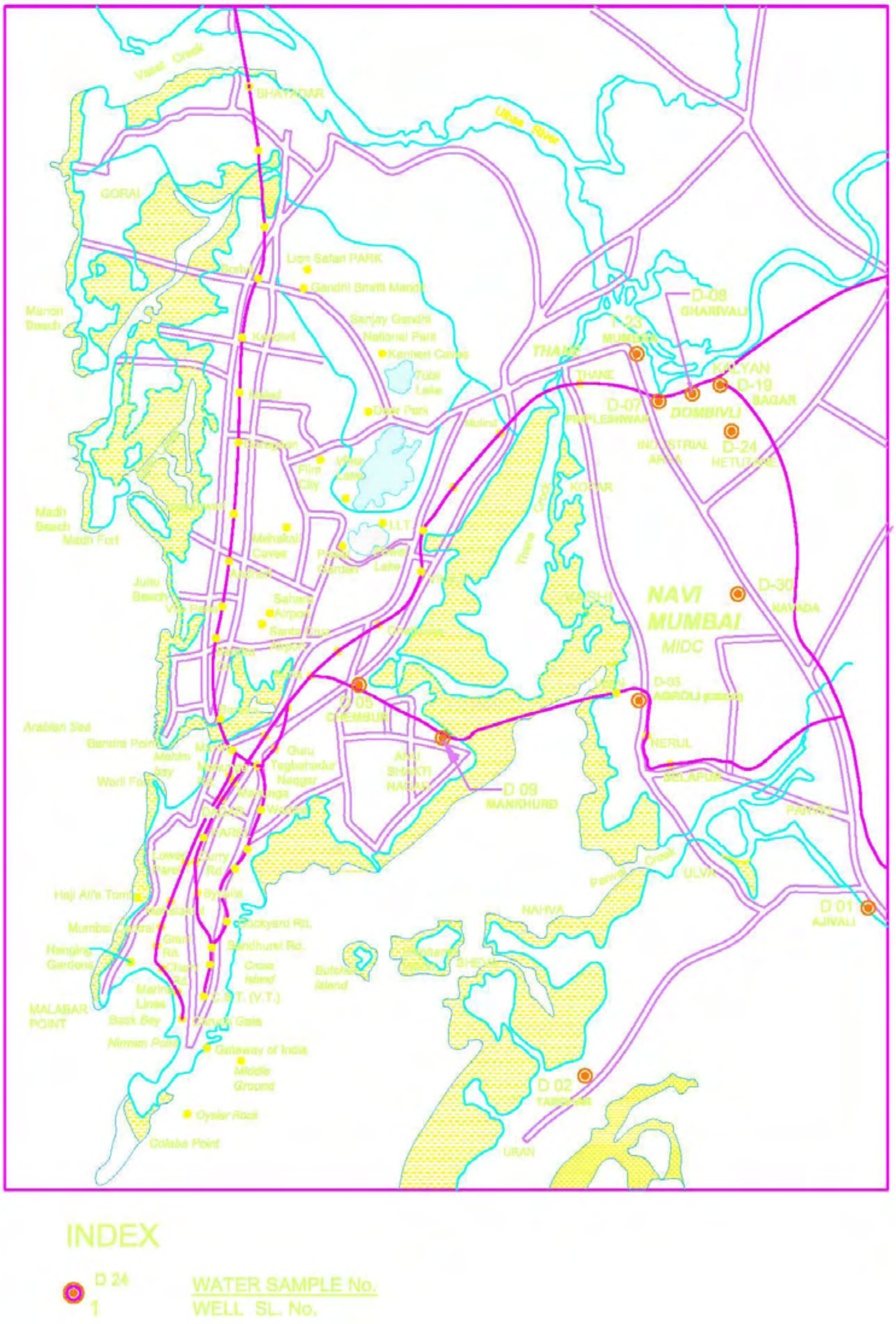


Plate-4

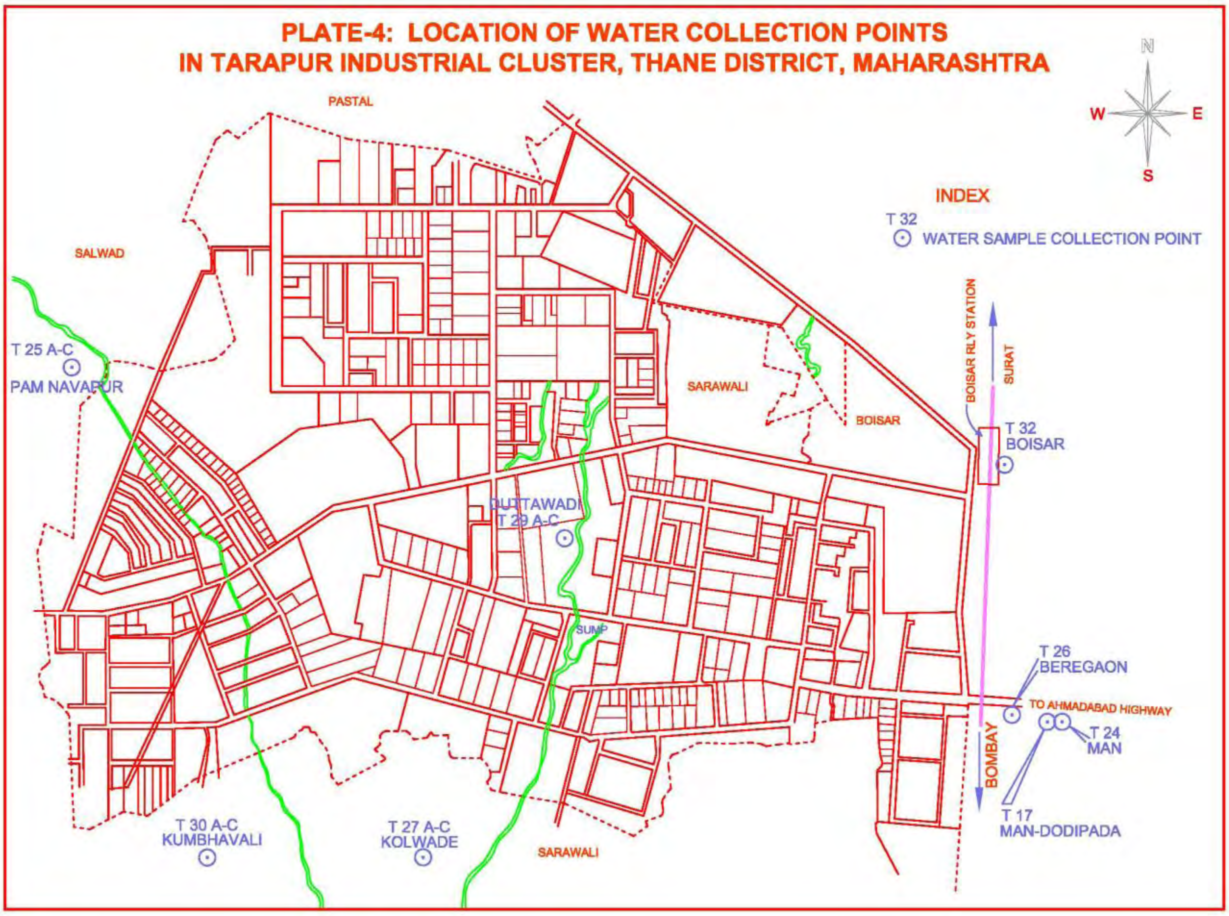


PLATE-4: LOCATION OF WATER COLLECTION POINTS
IN TARAPUR INDUSTRIAL CLUSTER, THANE DISTRICT, MAHARASHTRA
N
W
E
S
INDEX
T 32
WATER SAMPLE COLLECTION POINT
PASTAL
SALWAD
T 25 A-C
PAM NAVAPUR
SARAWALI
BOISAR
BOISAR RLY STATION
SURAT
T 32
BOISAR
DUTTAWADI
T 29 A-C
SUMP
T 26
BEREGAON
TO AHMADABAD HIGHWAY
T 24
MAN
BOMBAY
T 17
MAN-DODIPADA
T 30 A-C
KUMBHAVALI
T 27 A-C
KOLWADE
SARAWALI

Plate-5

CONCENTRATION OF SELECTIVE CHEMICAL CONSTITUENTS IN DOMBIVALI, NAVI MUMBAI AND CHEMBUR INDUSTRIAL CLUSTERS
(Na, HCO_3, Cl & SO_4)

(NOT TO SCALE)

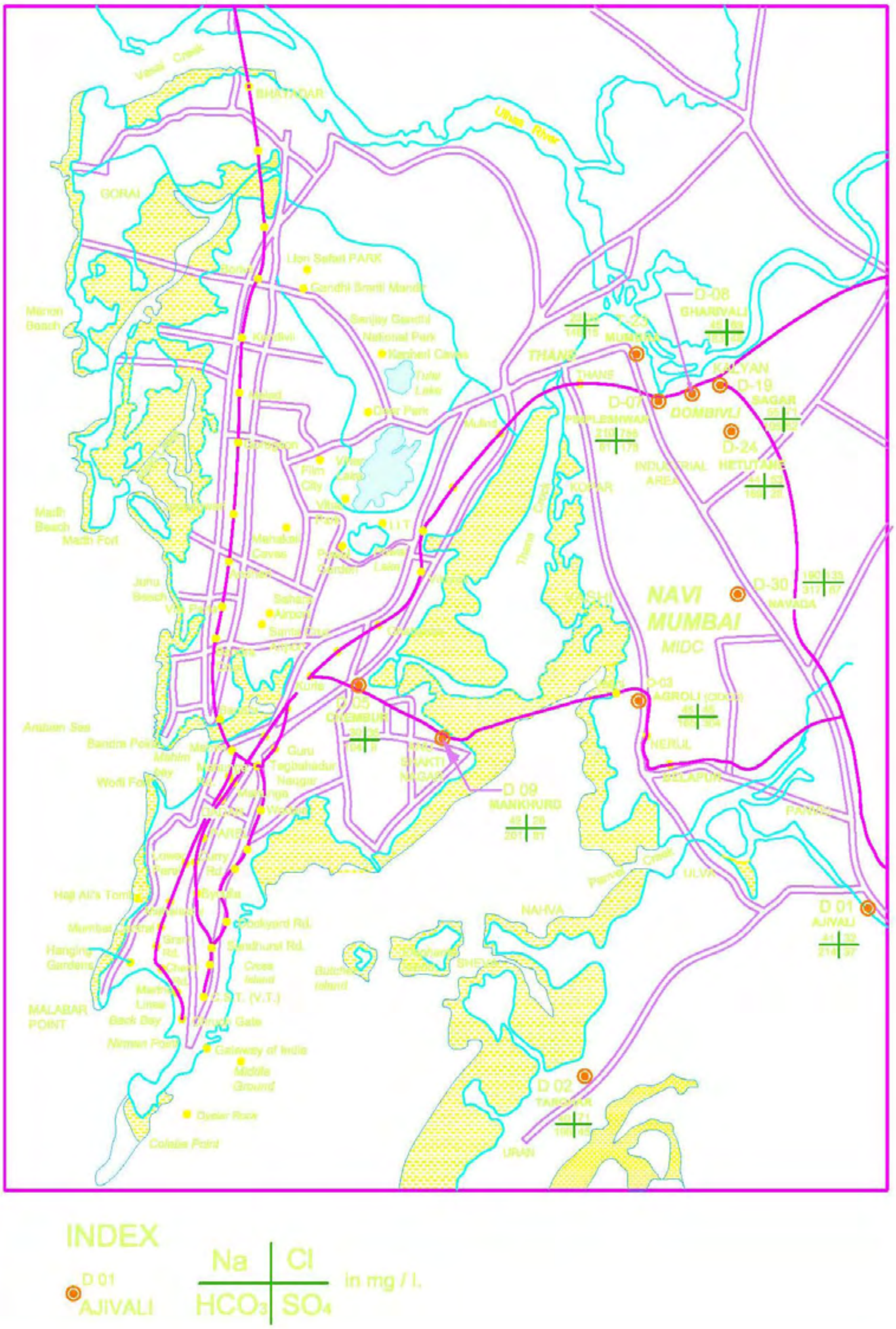


Plate-6

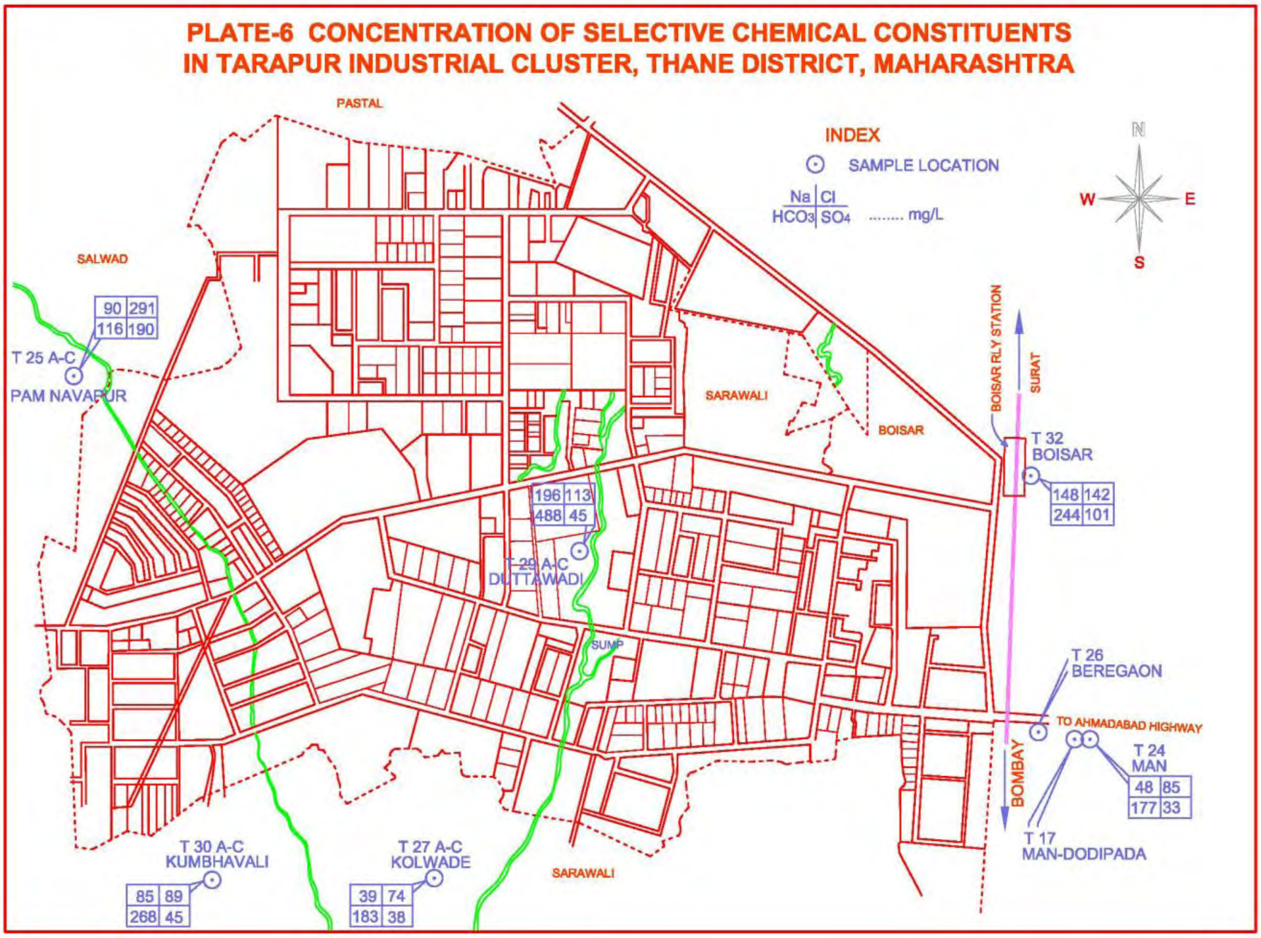


PLATE-6 CONCENTRATION OF SELECTIVE CHEMICAL CONSTITUENTS
IN TARAPUR INDUSTRIAL CLUSTER, THANE DISTRICT, MAHARASHTRA
INDEX
SAMPLE LOCATION
Na | Cl
HCO3 | SO4 .... mg/L
N
W
E
S
PASTAL
SALWAD
SARAWALI
BOISAR
BOISAR RLY STATION
SURAT
BOMBAY
TO AHMADABAD HIGHWAY
SUMP
T 25 A-C
PAM NAVAPUR
90 291
116 190
T 29 A-C
DUTTAWADI
196 113
488 45
T 32
BOISAR
148 142
244 101
T 26
BEREGAON
T 24
MAN
48 85
177 33
T 17
MAN-DODIPADA
T 30 A-C
KUMBHAVALI
85 89
268 45
T 27 A-C
KOLWADE
39 74
183 38

Plate-7

LOCATION OF WELLS SHOWING MORE THAN PERMISSIBLE LIMIT CONCENTRATION OF MANGNESE IN DOMBIVALI, NAVI MUMBAI AND CHEMBUR INDUSTRIAL CLUSTERS

(NOT TO SCALE)

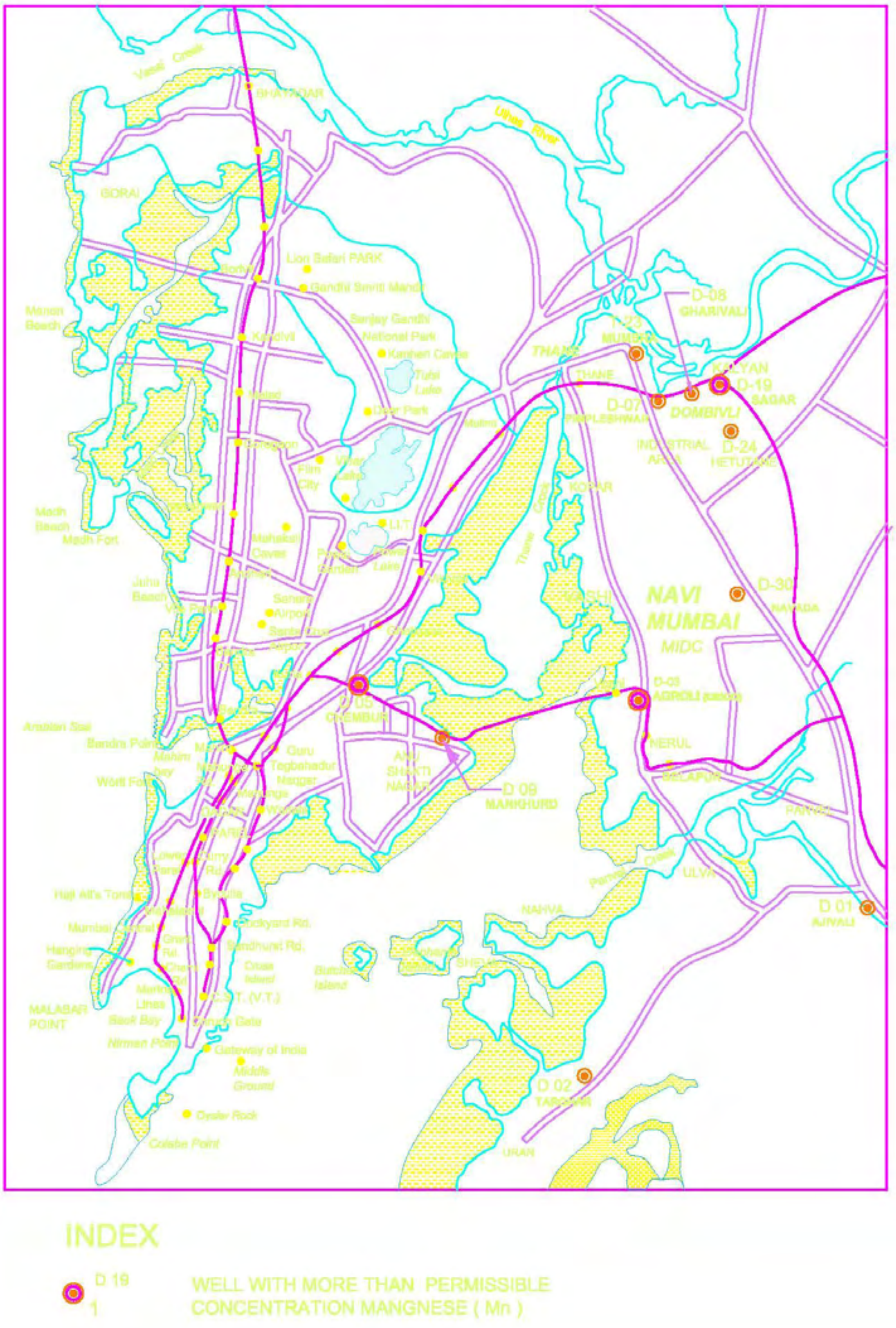


Plate-8

LOCATION OF WELLS SHOWING MORE THAN PERMISSIBLE LIMIT CONCENTRATION OF LEAD IN DOMBIVALI, NAVI MUMBAI AND CHEMBUR INDUSTRIAL CLUSTERS

(NOT TO SCALE)

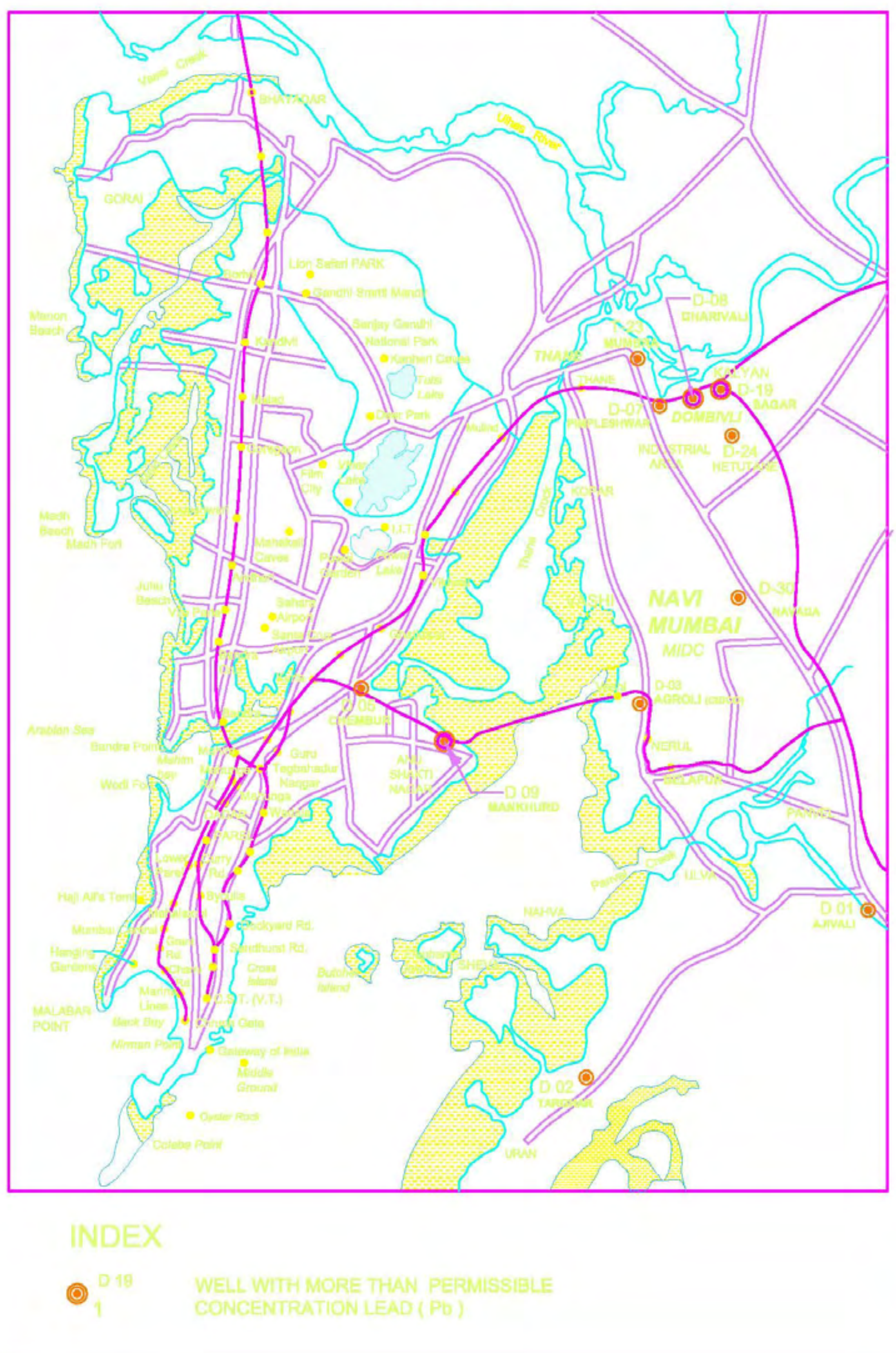
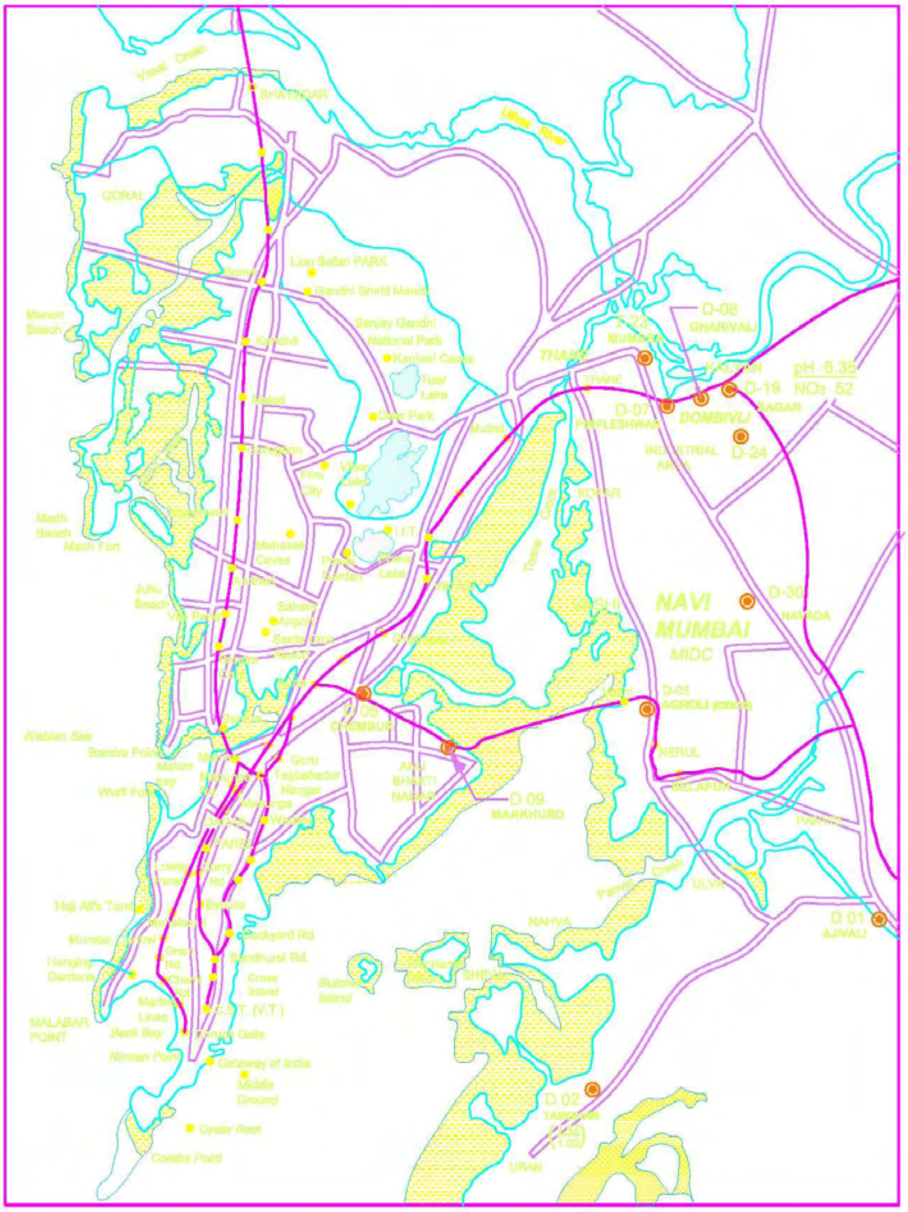


Plate-9

LOCATION OF WELLS SHOWING MORE THAN PERMISSIBLE LIMIT CONCENTRATION OF pH AND NITRATE IN DOMBIVALI, NAVI MUMBAI, AND CHEMBUR INDUSTRIAL CLUSTERS

(NOT TO SCALE)



INDEX

D 19 SAGAR — pH 6.35, NO_3 52

Plate-10

Fig. 4b LOCATION OF WELLS SHOWING PARAMETERS WITH MORE THAN PERMISSIBLE LIMIT IN TARAPUR INDUSTRIAL CLUSTER, THANE DISTRICT, MAHARASHTRA