Industrial Development and Challenges of Water Pollution in Coastal Areas: The Case of Surat, India

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Abstract. Industrialisation plays an important role in the economic development of a country, however, pollution is the inevitable price paid for this development. Surat, a major industrial hub in western India, is located on the bank of the river Tapi and extends up to the Arabian Sea. The city is characterised by the presence of a number of creeks (known as ‘khadis’ in local language). This paper focusses on the industrial development in Surat and the challenges faced by the city due to water pollution. A constant deterioration in the quality of surface water resources has been observed due to discharge of treated or partially treated effluents from the industries. The problem of water pollution becomes critical due to increase in frequency of flooding, risks faced by the city due to climate change and the ineffective environmental governance. The paper provides insights into the challenges faced by the city and the learnings can lead to adoption of policy initiatives and other measures which can effectively address these challenges.

1. Introduction

Indian economy has grown at a high rate after liberalisation in 1991. Liberalisation has reduced the control exercised by the central government and has left a larger scope for state-level initiatives to attract industries. Gujarat state, in India (where Surat is located) has taken major initiatives to promote industries and is now one of the most industrialised state in the country. Within Gujarat, Surat is the second major urban area and has experienced high rate of industrial growth. It is located on the bank of the river Tapi and extends up to the Arabian Sea through gulf of Khambhat. Being a coastal city, it is characterised by the presence of a number of creeks (known as ‘khadis’ in local language). The city has an average elevation of 13 meters. The city is vulnerable to floods and has experienced two major river floods and a creek flood in recent times. The areas lying in flood plain zone of river Tapi in Surat have experienced high rates of growth in population and density [1]. During the rainy season, high tides often inundate settlements located along several creeks. Surat is a hub of textile industry and diamond industry. It has the maximum share of investments (22.9 percent) in large scale manufacturing units in the state and is at number two, with a share of 23.04 percent, when investments in micro, small and medium scale manufacturing units (MSMEs) are considered [2].

Industrial development though important for the economic development, often leads to environmental degradation due to problems of pollution and resource depletion. In the course of industrial growth, natural resources get exploited and are at the receiving end as they often get abused for private gains. Pollution too seems to be the inevitable price paid for this development [3]. The pollution problems
manifest as problems of air quality, disposal of solid wastes and discharge of industrial effluents. Industrial effluents are the source of some of the most toxic pollutants and the most seriously polluted environments. They contribute significantly to the overall water pollution in an area and are considered to be more hazardous than sewage [4].

This paper focusses on the industrial development in Surat and the challenges faced by the city due to water pollution. The data for polluting industries, pollution control facilities and quality of water bodies has been collected from Gujarat Pollution Control Board (GPCB), which is the nodal agency at the state level for enforcing environmental legislation for the protection of the environment. It gives permission to all polluting industries and the pollution control facilities and directs them to comply with the applicable standards. It also regularly monitors quality of the water bodies as well as of the treated effluents from the pollution control facilities. To comment on the performance of the pollution control facilities, the data has been compared with the standards prescribed to these by the regulatory authority under environmental legislation. The data for quality of water bodies has been compared with the standards set by the Central Pollution Control Board (CPCB) based on their 'designated best use' [5]. According to this concept, out of the several uses a water body is put to, the use that demands the highest quality of water is termed as the 'designated best use.' The discussions have been carried out with the key personnel representing concerned government departments, operators of the common pollution control facilities, professionals and NGOs working in the environment field to get better insights into the Case.

The paper has been organised as follows: Section 1 introduces the problem and the key inquiry and also details out the methodology followed. Section 2 focusses on the details of industrial development in Surat and Section 3 discusses the performance of pollution control facilities set up to treat industrial effluents. The quality of water bodies receiving industrial discharges has been discussed in Section 4. The next section details out the challenges faced by the city due to water pollution. Section 6 covers the concluding remarks and the policy inferences following from the discussion in the paper. It also mentions some of the measures which can be adopted to address the challenges faced by the city.

2. Industrialisation in Surat

In Surat, a large number of MSMEs are located in the industrial estates, developed by Gujarat Industrial Development Corporation (GIDC), a government undertaking, which provides developed land and infrastructure to set up industrial units. There are also a few industrial estates developed by private companies which accommodate some of the industrial units. Many of the small industrial units are scattered all across the city. Hazira area, which is right on the coast and also a port, is home to a number of large scale modern industries; prominent among these are Reliance, Essar Steel, Essar Power, Larsen & Toubro, Adani, National Thermal Power Corporation, KRIBHCO, Oil and Natural Gas Corporation etc. The details of the polluting industries in Surat, as registered with GPCB, up to July 2014, is presented in table 1.

| Category | Small | Medium | Large | Total |
|----------|-------|--------|-------|-------|
| Red      | 1202  | 157    | 268   | 1627  |
| Orange   | 169   | 16     | 20    | 205   |
| Green    | 253   | 16     | 18    | 287   |
| Total    | 1624  | 189    | 306   | 2119  |

Source: GPCB

Note: Industrial units are classified into large, medium and small category based on the investment as per the definition given under Micro Small Medium Enterprises (MSME) Act, 2006. CPCB classifies the industries into Red, Orange and green categories based on their pollution potential. Red means the most polluting, orange means the medium polluting and green means the less polluting industries. The same classification is followed by GPCB.
Important point to note from the above table is that the most polluting industries (red category) and belonging to small-scale, forms more than 50 percent of the registered polluting units. The small and medium scale industries account for 40 percent of industrial production, employ limited pollution control technologies and are responsible for an estimated 70 percent of the total industrial pollution load nationwide [6]. The location of industrial areas, common facilities for effluent treatment and the monitoring points for water quality are shown in figure 1. It can be seen that most of these are located along one creek or the other. These creeks finally flow to the gulf of Kambhat and then meet the Arabian Sea.

Figure 1. Location of the Creeks, Industrial Areas, CETPs and Monitoring Points.

Source: Author, details mapped using Google image

3. Environmental infrastructure & its performance
The large-scale industries in Hazira have their own effluent treatment plants and discharge treated effluent directly into the sea. The small-scale industries, which forms a major share of the polluting industries, do not have the financial, managerial and technical capacity to treat the industrial waste water [7]. In addition, there are space constraints faced by these units to set up the individual effluent treatment plants. Till early 2000, most of the industries in Surat used to discharge untreated effluents into the water bodies. After that, common facilities for treatment—common effluent treatment plants (CETPs) were set up, mainly as an intervention enforced by the Courts and pressure from the civil society [2]. The industries which are scattered in Surat city, discharge their treated/untreated effluents into either the sewerage network or the storm water drainage which finally meet any of the creeks. However, it is not possible to segregate the share of the industrial effluents from these discharges. The analysis in this paper, is therefore, limited to the performance of the CETPs in reducing the pollution load. There are five operational CETPs in Surat with a combined capacity of 310.5 MLD to treat industrial waste water [8]. These CETPs have been set up for the industries located in GIDC Pandesara, GIDC Sachin, Gujarat Eco Textile Park Ltd. (GETPL–
private industrial park), GIDC Kadodara and the industrial clusters in Vareli, Jolva, Chaltan, Tantithaiya villages. The details of functional CETPs are listed below in table 2. The industrial effluents after being treated in the CETPs are discharged into any of the creeks.

### Table 2. Details of functional CETPs in Surat.

| S No | Name of CETP                     | Location     | Nature of member units | Discharge point | Mode of reception of effluent | Installed capacity (MLD) |
|------|----------------------------------|--------------|-------------------------|-----------------|-------------------------------|--------------------------|
| 1    | Pandesara Infrastructure Ltd     | GIDC Pandesara| Textile units & chemical units | Bhedwad creek   | Network of pipeline           | 100                      |
| 2    | Sachin Infra Environment Ltd(SIEL) | GIDC Sachin | Textile units           | Unn creek       | Network of pipeline           | 50                       |
| 3    | Globe Enviro Care Ltd (GECL)     | GIDC Sachin | Chemical units          | Unn creek       | Tankers                       | 0.5                      |
| 4    | Palsana Enviro Protection Ltd (PEPL) | Umbhel, Surat | Textile units           | Kadodara creek  | Network of pipeline           | 100                      |
| 5    | Gujarat Eco Textile Park Ltd (GETPL) | Palsana, Surat | Textile units           | Baleshwar creek | Network of pipeline           | 60                       |

Source: The table has been compiled from the data collected from different sources.

All the CETPs mentioned in the above table have physico-chemical treatment as primary treatment and biological treatment as secondary treatment to reduce the pollution load. There are five parameters (pH\(^1\), NH\(_3\)-N\(^2\), BOD\(^3\), TCOL\(^4\) and DO\(^5\)) on which quality of water bodies is classified based on their ‘designated best use’ by the CPCB. Out of these five, only three parameters—pH, NH\(_3\)-N and BOD—are being measured for the CETPs by the regulatory authority. NH\(_3\)-N is not being measured for some of the CETPs which are treating homogenous industrial effluents from the textile units. The effectiveness of the CETPs in treating pollution, as discussed in the following paragraphs is based on these parameters. Since the treatment is with the help of bacteria, the BOD becomes the most important parameter to comment on the effectiveness of the CETPs. As some of the CETPs are treating heterogeneous effluents, COD\(^6\), another important parameter, has also been included in the analysis to study the effectiveness.

The CETPs have been prescribed ‘inlet standards’ for the effluents to be treated by the CETP and ‘outlet standards’ for the treated effluents from the CETP. CETP Pandesara, PEPL and GETPL have been given an inlet standard of 400 mg/l of BOD whereas CETP GECL, which is established for treating chemical

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\(^1\) A figure expressing the acidity or alkalinity of a solution on a logarithmic scale on which 7 is neutral, lower values are more acid, and higher values more alkaline.

\(^2\) NH\(_3\)-N (Ammonical Nitrogen) is highly toxic to fish and other aquatic life and its value in the water bodies should be ≤ 1.2 mg/l.

\(^3\) BOD (Bio-chemical Oxygen Demand) is the amount of dissolved oxygen needed by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period.

\(^4\) TCOL is a measure of the total coliform bacteria present in the water body.

\(^5\) DO is a measure of the amount of oxygen dissolved in the water body.

\(^6\) COD (Chemical Oxygen Demand) indicates the amount of oxygen which is needed for the oxidation of all organic substances in the water.
effluents in GIDC Sachin, has been given an inlet standard of 1500 mg/l of BOD. CETP SIEL has not been prescribed any inlet standard. All the CETPs have been given the same outlet standard for the treated effluent—pH-6.5 to 8.5, NH₃-N-50 mg/l, BOD-30 mg/l and COD-250 mg/l; irrespective of the fact that the inlet standards for the effluents are different for the CETPs. The details of the treatment for all the CETPs has been summarised and presented in table 3.

Table 3. Summary of performance of the CETPs.

| CETPs          | pH in treated effluent | NH₃-N in treated effluent | Inlet standard for BOD | Actual inlet BOD | BOD in treated effluent | Inlet standard COD | Actual inlet COD | COD in treated effluent |
|----------------|------------------------|---------------------------|------------------------|------------------|-------------------------|-------------------|-------------------|-------------------------|
| Prescribed standard for treated effluent | 6.5–8.5 | 50 | 30 | 250 |
| CETP-Pandesara | 7.5 | 9 | 400 | 340 | 107 | 67 | 1000 | 1239 | 419 |
| CETP-SIEL      | 7.3 | Not monitored | - | 319 | 107 | 64 | Not Given | 1152 | 403 |
| CETP-GECL      | 7.4 | 48 | 1500 | 566 | 89 | 78 | 4000 | 2097 | 379 |
| CETP-PEPL      | 7.8 | Not monitored | 400 | 251 | 97 | 60 | 1000 | 891 | 358 |
| CETP-GETPL     | 7.8 | Not monitored | 400 | 221 | 70 | 67 | 1000 | 837 | 284 |

Source: The table has been compiled from the analysis done.

Note: All the standards are in (mg/l) except for pH.

It is observed that the pH and NH₃-N for the treated effluent from all the CETPs meets the prescribed standards, irrespective of whether the nature of inlet effluents is homogenous (effluents are from the same industrial sector) or heterogeneous (effluents are from varied industrial sectors like textiles, chemicals etc.). For the most critical parameters—BOD, none of the CETP is able to meet the prescribed standards of 30 mg/l for the treated effluents. The biological treatment (secondary treatment) employed by the CETPs should result in approx. 85 percent reduction in the organic load. There is not even one CETP which is able to consistently reduce organic pollution load by the expected 85 percent. In terms of exceedance factor of the treated effluent above the permissible standard, it is maximum for the CETP Pandesara and CETP SIEL at 3.6. The minimum exceedance factor is 2.3 for the CETP GETPL. The COD being another important parameter, the analysis has highlighted that the results for the COD reduction by the CETPs are comparable to the BOD reduction. There is not even one CETP which is able to meet the prescribed standard of 250 mg/l for COD in the treated effluent.

In Surat, as for the performance of the pollution control facilities is concerned, these are not able to treat the effluent and meet the permissible norms. The ‘one-size-fits-all’ approach has been adopted for treating the pollution. Though the effluents are different and the inlet norms given to the various CETPs are different, the same process has been adopted for treating the pollution and the standards given for the treated effluent are also the same. This is quite baffling as the reduction in pollution load is directly proportionate to the inlet values and the abatement technology used. Given the fact that all the CETPs have employed similar abatement methods and have been prescribed similar standards for treated effluent, the pollution levels will be directly proportionated to the inlet values. This leads to conclude that the standards are prescribed randomly by the regulator without considering the abatement efficiencies of the
systems. Though the CETPs are regularly monitored by the regulator, still no action has been taken against them for non-compliance with the prescribed standards.

The treated effluents from all the CETPs are discharged into one creek or the other. The ineffective treatment of the effluents by the CETPs and the presence of pollution way above permissible levels has direct association with poor quality of the water bodies receiving industrial discharges. The quality of the receiving water bodies has been discussed in the following section.

4. Quality of waterbodies receiving industrial discharges

The quality of water bodies in Surat has been analysed in this section. It is realised that the state has not done any classification of water bodies (including all rivers) based on ‘designated best use.’ In general, it is an accepted norm that if the interventions for pollution control are effective, then the minimum water quality standards which a water body should meet (bathing standards) is (pH between 6.5–8.5; DO-5 mg/l or more; BOD-5 days 20°C 3 mg/l or less; NH₃-N-1.2 mg/l or less and TC-500 MPN/100 ml or less). These are indicators of pollution, of whether the water can sustain aquatic life. The presence of harmful, faecal related bacteria, viruses and protozoa in the water bodies are responsible for causing illnesses. The analysis of water quality is presented in table 4.

The water quality in the river Tapi is regularly monitored as is done for other major rivers in India. The quality in the river is observed to be good except for coliforms. However, in case of Surat, the industrial effluents are being discharged into numerous creeks and not the main river Tapi. It, therefore, becomes necessary to analyse the water quality of these creeks, but the irony of the situation is that the monitoring of creeks is not regular and has been discontinued lately, therefore, no recent data base is available to know their quality. Important parameter like dissolve oxygen which is a direct indicator of the health of a water body has not being measured at all for creeks by the regulatory authority. The value of BOD has been observed to be high for creeks, indicating high levels of pollution in these creeks. From creeks, the waste water flows to Arabian sea through gulf of Khambhat and nobody notices the pollution. The water pollution goes unnoticed as it gets camouflaged in various creeks along the banks of which industrial areas and CETPs are located. This is serious as Surat city is prone to floods and the presence of pollutants in water bodies above the acceptable levels can have serious implications on human health, livestock, agriculture, property etc.

5. Challenges faced due to pollution

A number of pollution related challenges are stemming from rapid industrial development and presence of high pollution levels in the water bodies receiving industrial discharges which are spread across the city. Following the conventional way, all the studies by the government agencies—Central Pollution Control Board [9], Central Water Commission [10] and Comptroller and Auditor General [11], have analysed the quality of water in the Tapi. The river has the same importance in Surat as the Sabarmati has in Ahmedabad or the Ganga in Varanasi and the Yamuna in Delhi. However, the analysis in this paper points out that in case of Surat, the industrial effluents are being discharged not into the Tapi but into the numerous creeks, which are a typical character of Surat’s geography and the quality of water in these creeks is not meeting with the desirable values. From the creeks, the effluent flows to the Arabian Sea and nobody notices the pollution. This is really serious as Surat city is prone to floods and has experienced two major river floods and one creek flood in the last decade. The results of a study [1] show that 71,000 households in Surat are vulnerable to creek floods and when river floods occur, as many as 4,50,000 households are at threat. Ebenstein (2012) has estimated that the deterioration of water quality by a single grade point (on a six-grade scale) increases the digestive cancer death rate by 9.7 per cent [12]. The presence of slums near creeks make these people more vulnerable as they do not have alternative means of shelter, livelihood or finances to cope with the disasters. “Those with the least resources have the least capacity to adapt and are the most vulnerable.”
In case of Hazira, where a number of very large-scale companies are located, the whole industrial area has developed by reclaiming section of the flood plain and consequently narrowing down the mouth of the Tapi, where it meets the sea. Blocking the network of natural drains by filling up, for the purpose of developing land for industries, may have a direct impact on the city and its people. Major part of Hazira falls under low elevation coastal area (less than 10 m elevation) exposing industries to considerable risk to water related hazards. Most of the current development activities have been planned without taking into consideration a potential threat from the sea level rise. The area faces a high vulnerability to inundation due to sea level rise. The risk becomes manifold as huge investments have been made in the area in infrastructure and industrial development.

Table 4. Quality of the water bodies.

| Waterbody              | Period            | No of readings | pH  | DO | BOD | NH$_3$-N | TCOL | Remarks                                                                 |
|------------------------|-------------------|----------------|-----|----|-----|---------|------|-------------------------------------------------------------------------|
| Standards as per designated best use |                   |                | 6.5–8.5 | 5  | 3   | 1.2     | 500  |                                                                         |
| Unn creek              | July 08-May 10    | 124            | 7.8 | -  | 9   | 5.6     | 14   | Receive discharge from CETP SIEL & GECL                               |
| Gabheni creek          | July 08-May 10    | 124            | 6.7 | -  | 298 | 13.3    | 107  | Located south to GIDC Sachin                                          |
| Koyli creek            | July 08-Sep 13    | 9              | 7.9 | -  | 113 | 8.4     | 58   | Bhedwad creek and Kadodara creek meet this creek                      |
| Baleshwar creek        | No 11-Oct 13      | 45             | 8.1 | -  | 14  | 2.0     | 18   | Receive discharge from CETP GETPL                                   |
| Bhedwad creek          | July 09-July 10   | 10             | 7.1 | -  | 230 | 6.3     | 93   | Receive discharge from CETP Pandesara                                |
| Kadodara creek         | Jun 08-May 13     | 8              | 8.0 | -  | 96  |         | 58   | Receive discharge from CETP PEPL                                    |
| Tapi river (Swami Vivekanand bridge) | May 08-Jun 14    | 17             | 7.93| 6.56| 1   | 0.51    | 71623| Main river flowing through Surat                                    |
| Tapi river (ONGC bridge-Hazira) | Jun 08-Jun 14    | 21             | 8.07| 5.95| 2   | 0.48    | 6264 | Main river flowing through Surat                                    |
The shoreline in gulf of Khambhat has been experiencing changes. A study by Gupta (2014) for the period 1996-2004 has observed that a large area of the gulf shows a serious threat due to changing shoreline [13]. The entire coast has undergone accretion including coastal region around the Tapi and the Hazira port. The main reasons behind this accretion are attributed to the strong tidal currents and a large load of sediments brought through the major rivers. The sediments as well as pollutants under the influence of strong tidal currents undergo dispersion and settle within the Gulf of Khambhat resulting in siltation at a rapid rate. The anthropogenic shoreline change, including ports and harbour development, have added a major new factor into the complexity of natural processes determining coastal landform changes. There have been no studies so far for this area which have estimated the levels of pollutants present in the sediments deposited in the gulf and its impact on the eco-systems.

6. Conclusions & policy inference

Surat may have to prepare to live with the challenges it faces due to its location. The preparedness to deal with the challenges faced by the city has to be multi-dimensional in nature. This would mean understanding all future risks and responding to the changing risks. There are no land use rules in place in Surat to prevent urban development in current and future high-risk zones [14]. The coastal area may, in fact, become some of the most sought-after real estate. The urban planning process comes in actual operation much after the areas have already experienced growth of buildings, roads and commercial activities. This defeats the fundamental purpose of land use planning and ultimately results in legitimising the unplanned growth. Land use planning and the enforcement of development rules based on risk categorization is needed and the local body and development authorities must plan and implement keeping these risks in mind. The current approach of development happening first and then legalisation of development should be replaced with planning first, followed by development. Resettlement of all slums located on creeks is needed immediately and care needs to be taken to prevent further settlements coming up near the risky zones. Surat having a high share of industrial investments, the detailed data on risk zones will help the investors in taking informed decisions while locating their business.

Surat is unique in its character in terms of scale and composition of industries and in terms of the water bodies which receive the industrial effluents. In most of the cities, the waste water is discharged into a single water body e.g. in Ahmedabad, all the domestic sewage and industrial effluents are discharged into the Sabarmati, whereas in Surat, it is discharged into a number of creeks. The water pollution goes undetected as it gets distributed in the various creeks near the industrial areas. However, the approach by the regulator is the same throughout the state i.e. regulator monitors the main river and do not consider the location specific details. There is no comprehensive mechanism to address local-level environmental issues. There is a need to move away from the conventional way of monitoring of the water bodies by supplementing it with site-specific requirements. The case in specific for Surat highlights the fact that the conventional way of monitoring the main river in a city may not always represent the complete picture. The approach which needs to be adopted for Surat has to be different from that adopted for Ahmedabad, i.e., a differentiated approach, even within the same state to address local environmental concerns.

The feeble treatment by the common effluent treatment facilities and the ineffective enforcement by the regulator have resulted in the degradation of the quality of water bodies. The analysis in Section 3 has highlighted that even after many years of establishment, the CETPs have not been able to meet the prescribed standards. At the same time, for the MSMEs—due to the constraints faced by them—there are no other options but to rely on the CETPs [2]. Therefore, it is important to enforce improvement in their working so as to comply with the prescribed norms. Punitive measures should be taken against the defaulters to deal with non-compliance. The existing approaches to ensure environmental compliance needs to be supplemented by other approaches like heavy fines for values above the prescribed standards [15]; public disclosure of information about the pollution and the polluters [16]; supplementing environmental standards with taxes above permissible values [17] etc. The fines under the Water Act have...
not been revised since 1974 and are merely capped at Rs. 10,000. This could be amended so that it acts as a deterrent. Stringent enforcement would be required to ensure environmental compliance and improve quality of water bodies.

The challenges faced by the city due to industrial development and the resultant water pollution can be addressed to some extent if the inferences from the discussion in the paper can be incorporated into the policies adopted for the city.

7. References
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