A Status Report

Revival of Water Body at Wadala

For

Mumbai Metropolitan Region

Environment Improvement Society

By

M-02, SINE,

CSRE Building, 3rd Floor, IITB Campus,

Powai, Mumbai-400076

www.sweepenviro.com

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Chapter 1 : Introduction

1.1 Background

Water bodies are perhaps the only living oasis of cities that not only controls the temperature but also is a source of vegetation. However, time and again these oasis are turned into dumping yards for waste, toilet sheds for informal settlers or unmanaged forestry. Lately, cities all over the world are realizing the importance of these water bodies not only for recharging ground water but also as recreational spots. It also serves as an important source of goods and services for unprivileged class of neighbouring societies who derive food and other economic benefits from these water bodies.

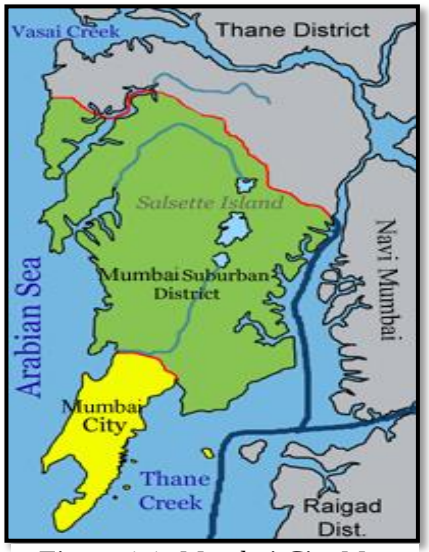


Figure 1.1: Mumbai City Map

Water bodies in urban areas are either natural lake or manmade ponds which meet the water requirements of ever-growing urban population. Urban water bodies are also part of the local hydrological cycle. It helps keeping monsoon waters for the drier periods of the year, to channelize the monsoon water flows thereby preventing water logging, inundation and erosion, and ensuring groundwater recharge. They also support a rich ecosystem, with a great variety of animals and plants. To summarise water bodies serves following purposes in an urban environment.

- Aesthetical value
- Water conservation and groundwater recharge
- Green space
- Recreational hotspots
- Temperature regulation
- Biodiversity hotspots
- Economic benefits

Mumbai city although blessed with a number of water bodies, most of them have lacked proper maintenance and hence cannot fulfil their role to the utmost. Map of Mumbai city as seen in Figure 1.1 gives a clear picture of it being surrounded by water and also having several lakes within the city.

1.2 Ecological Infrastructure

Ecological infrastructure refers to naturally functioning ecosystems that can deliver valuable ecosystem goods and services. It is the nature-based equivalent of built or hard infrastructure, and can be just as important for providing services and underpinning socio-economic development. Ecological infrastructure does this by providing cost effective, long-term solutions to service delivery that can supplement, and sometimes even substitute, built infrastructure solutions. Ecological infrastructure includes mountain catchments, rivers, wetlands, coastal dunes, and nodes and corridors of natural habitat, which together form a network of interconnected structural elements in the landscape.

Ecosystems deliver essential services which includes maintenance of natural elemental cycles, environmental purification, carbon sequestration, protection from natural calamities and climate regulation among others. It has been proved beyond doubt that creating ecological infrastructure through restoring degraded habitats has immense benefits for mankind as a whole.

This is especially true for urban eco-restoration projects. Urban lifestyle today is becoming exceedingly consumer-driven, intensifying an average citizen's carbon and water footprint and widening the gap between man and nature. In Indian scenario, urban lifestyle has come to be symbolized by increased glass and concrete whereas day-by-day reducing green cover and open space.

In urban areas, ecological infrastructures provide recreation and relaxation in aesthetically sound surroundings, in addition to other services. Recreation stems from a basic human need for activities, which is essential for mental and physical well-being of individual and the community as a whole.

Ecological infrastructure is inextricably linked with biodiversity. Increasing urbanization has taken a toll on once rich habitats and niches supporting rich biodiversity – today's tales are those of habitat loss and fragmentation and alarming rates of biodiversity loss. A potential method of offsetting the biodiversity loss is through building more and more ecological infrastructure. As more and more people live in cities, restoration, preservation and enhancement of biodiversity in urban areas has become increasingly important. Enhancement of biodiversity in urban ecosystems can be quite important as some evidences suggest that personal exposure to natural things in everyday life is determinant of sensitivity to environmental issues.

1.3 Integral Role of Urban Natural Resources

Open spaces and natural resources within an urban context, locally serve the function of ecological infrastructure - diluting and sometimes removing environmental pollutants through carbon sequestration; through natural bio-remediation or through phyto-remediation. Mumbai being a coastal city is vulnerable to flooding. Lakes, ponds and water bodies serve as heat sinks and holding ponds in flooding events or harvesting rain water and recharging the aquifer, thus making a positive impact to the local micro-climate as well as mitigating climate change impact due to urbanisation. As per Indian Standards, the open space allocation ought to be 4 acres for 1000 persons, which today is 0.3 Acres for 1000 persons. The nature pockets not only support a wide biodiversity, as open spaces, they serve as recreational, relaxation and visual relief which are critical for the physical well-being & mental well-being of a city dweller.

As per the MCGM records, between 1971 & 1991, coastal wetlands have decreased from 29% to 19% and converted as built up area. The sanctioned and revised Development Plan 1991 - 2013, of the overall proposed land-use has, 17% is allocated to Coastal wetlands.

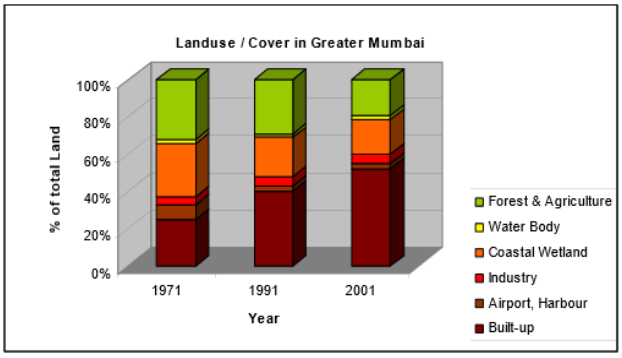


Figure 1.2 Land use in Greater Mumbai

1.4 Urban Drivers to Ecological Change

For our understanding, defined and illustrated below are common terminologies for habitats very often used inter changeably. Following illustrations gives an idea that how each one of them is distinctive and different for other.

Mangroves: *These are various large and extensive types of trees up to medium height and shrubs that grow in saline coastal sediment habitats in the tropics and subtropics (seen in Figure 1.3.)*

Figure 1.3: Mangroves

Mumbai coastal wetlands with Mangroves have been subjected to solid waste, largely plastics; oil and other industrial effluent spills leading to natural destruction. Large areas of the wetland have been cleared by slums and/or builders for development.

Estuarine Wetland: *Deep water tidal habitats with a range of fresh-brackish-marine water chemistry and daily tidal cycles (seen in Figure 1.4).*

With sedimentation & waste accumulation, a lot of the estuaries have been blocked or become narrow rivulets allowing back water only during high tide.

Figure 1.4 Esturine Wetland

Salt Pan: *An un-drained natural depression in which water gathers and leaves a deposit of salt on evaporation (seen in Figure 1.5).*

A lot of the coastal areas of Mumbai were salt pan developed lands providing a livelihood source for the locals. With price of land increasing a lot of these are reclaimed for real estate

Figure 1.5 Salt Pan

Marshy land: *An area of waterlogged soil typically treeless and covered with immersed rushes, cattails & other tall grasses (seen in Figure 1.6).*

Figure 1.6 Marshy Land

Salt Pan and blocked estuarine land parcels on the inland, are sought out by the economically weaker sections as ideal settlement grounds. The uneducated and uninformed populace create slum pockets here and use the area for dumping solid waste and sewage disposal.

The land is in any case a natural depression. As the pollutant levels go high in the stagnant waters, weeds, reeds and other plants take root leading to eutrophication converting the land into a marshy land.

1.5 Goods and Services Provided by Wetland Ecosystems

Wetlands are the most productive ecosystems on earth and perform several vital ecosystem functions. They participate in natural elemental cycles, help in natural remediation of pollutants, stabilize the local micro-climate, recharge the falling groundwater levels and help prevent urban flooding. They are natural habitats to aquatic creatures, many of them are of economic importance. They also add to the aesthetic value and provide the nearby residents with a place to relax and recreate.

A special mention must be made of the wetland avifauna, one of the most fascinating groups of winged animals. Interestingly, they can be the best instruments for invoking the interest of beginners to bird-watching as they provide ample opportunity to observe them for a long time in an unrestricted landscape. On the other hand, other avifaunal species in forests or gardens move frequently in the foliage, and one can see them only for a short duration. The opportunity to watch birds at length is important for laymen to identify them and get interested in them. It is elementary to identify an organism in the first step towards understanding the role it plays in an ecosystem.

Mumbai is particularly an interesting place for bird-watching, considering that the Thane Creek area has been declared an Important Bird Area. The flamingos and other migratory birds, in addition to the already rich resident avifauna, have made the annual bird race in Mumbai a highly zealous affair. Another related aspect is that birds are quite sensitive to changes in habitat structure and composition and are, therefore, excellent indicators of changes and stresses in the urban ecosystem.

To put together, water bodies would provide the following:

- Area development
- Nutrient regulation – mineral cycling
- Cultural values – Aesthetics
- Food production and economic benefits for local community
- Habitat and biodiversity
- Recreation
- Water regulation and water recharge

1.6 Creating Urban Wetlands: Issues to be considered

The pre-project planning aspects that must be considered, in combination with the necessary steps that must be taken, have been presented in Table 1.1.

Table 1.1 Issues and Necessary Steps for Planning the Eco-restoration of an Urban Wetland

Issues	Necessary Steps
Maintaining sufficient water in the water body	• Ensuring that the connect between the wetland and its chief feeding source – sea or river – is not blocked • Deepening and widening the existing area under water (if required) • No concretization so that non-point sources of discharge are not blocked
Maintenance of water quality	• *Ex situ* green technology for water treatment along the banks (Phytorid or IWT) • Green technology in the water body for *in situ* treatment • Regular flushing of the wetland with the large water body – sea/river – it is connected with.

Issues	Necessary Steps
Citizen facilities provided	• Seating benches • Cycling/jogging track around the water body • Raised platform for bird watching • Lush green surroundings • Playground for children • Detail information of the wetland provided and the types of birds through boards and information posters
Maintaining habitats and niches to upkeep and increase the biodiversity	• Ensuring the water feeding source – river/sea, which flushes in the fish that wetland birds will feed on • Florafts serve as perches for birds, butterflies and dragonflies • Mud puddles for butterflies • Plantation of trees and plants that attract birds and butterflies • Retention of as much as possible native vegetation, especially mangroves
Proper lighting of the area	• Solar/Hybrid light poles
Creating socio-economic awareness and ensuring the active involvement and participation of local stakeholders	• Pre-construction survey of stakeholders, making them aware and asking for their opinions and ideas • Proper signs and posters • Ecosystem valuation study to enhance awareness • Maintenance of local Peoples' Biodiversity Register on social media pages like Facebook, Twitter, Google+ etc.
Ensuring optimum usage by all stakeholders, preventing potential pollution and degradation through overuse	• Provision of adequate number of dustbins • Regular upkeep and check on the pollution level maintained • Monitoring of recreational activity in the area and imposing fines to maintain the quality and create awareness to avoid pollution
Financial sustainability of the project maintenance over the ensuing years	• Government funds/opening up a small area for a chargeable public activity

Issues	Necessary Steps
Other Miscellaneous Aspects	• Least possible concretization and glass use • Use of alternate energy-driven technology and instruments • Use of low phosphate or organic fertilizers for new plantations

1.7 Rejuvenation: Motivation and Challenges

Water body rejuvenation projects have been undertaken in India both by government bodies, private firms and NGOs. Several examples stand such as Ooty Lake, Kodaikanal Lake, Katchrali Lake and Hussain Sagar Lake where rejuvenation has been attempted.

Major challenge in such projects remains the availability of fresh and clean water for restoring the water body. This is true for those which are isolated and the only source of refilling is annual precipitation. Water refilling is aimed using treated sewage water to solve the dual purpose of water scarcity and sewage water disposal. Another roadblock stands is the recurrence of past practices due to negligence and lack of proper monitoring, which negate the benefits of rejuvenation. So, revival of the wetland system is a holistic approach, accounting for the natural ecosystem associated with it accompanied with proper public training and participation to eliminate waste disposal and dumping.

It is important to know that creating and maintaining a wetland ecosystem is an elaborate, complex and expensive process. Three aspects govern the upkeep process of the lake:

- Preventing solid waste dumping
- Preventing excess nutrient flow
- Creating awareness among people inhabiting the region surrounding the wetland systems.

It is difficult to completely stop the inflow of the nutrients but it can be restricted to a greater extent avoiding the growth of weeds and eutrophication. But regulated management in terms of de-silting, de-weeding would be required in order to upkeep the natural wetland ecosystem in a sustainable manner.

Wadala water body in itself is a deteriorating wetland ecosystem, due to human interference and solid waste dumping in the area. The water in here is drying up quick, which needs revival to nourish the ecosystem and bring it back to life. A managed disposal mechanism of

generated waste around the water body mainly from the slums in order to preserve the natural ecosystem. The present report brings about the details of the present condition of the water body, the challenges associated and the way to deal with it in a scientific manner to relive the ecosystem.

1.8 The Water Body: Wadala

The Wadala water body of Mumbai city is in need of a major rejuvenation. Majority of this water body is turned into a cesspool and posing health problems for people living around this place. This water body has remained as a neglected spot even in city maps, with no serious actions being taken towards its rejuvenation. Figure 1.7 represents its present environmental status which clearly reveals that there has been negligence to preserve it, which has led to following:

- Storage capacity has been reduced over the years due to silting
- Damaged weir has led to decreased water level
- Natural rainwater channels are either blocked or diverted away from the water body due to housing construction
- Weed coverage over 80% of the total water body area
- Poor sewage management system and open defecation in the area has led to sewage contamination of lake water
- Water effluent and solid waste dumping by local community has contributed to diminishing water quality of the lake

Figure 1.7 Wadala water body Map on Google Earth

Chapter 2 : Work Plan

The overall work plan has been formulated on the basis of overall understanding of the water body through well planned and executed survey and site visits.

2.1 Objectives

Wadala water body revival plans can be summarised into following objectives:

- Removal of solid waste dumped in the active area.
- Treatment of wastewater coming from the slums or other nearby zones, if any.
- Development of the water body as an eco-park or a rejuvenated water body with high ecosystem services.
- Establishment of wetland ecosystem as restored system.
- Creating public awareness about conservation and maintaining the water body through a good case study.

Our focus of concern herein is hence to evaluate the feasibility of achieving the afore mentioned objectives through conservation and rejuvenation of the marshy land - water body at Bhakti Park at Wadala which would lead to the following:

- Serve as an ecological infrastructure at a local level.
- Environmental purification through natural remediation processes for pollutants.
- Mitigate impacts of climate change - flooding and Urban Health Initiative.
- Create it such as to become an important ecological landmark for conservation & develop framework strategy for sustenance.

2.2 Scope of the Work

Development of rejuvenation plan has been divided into three main phases with the various levels of work and development associated with it. The detailed phases have been discussed in Table 2.1 along with the required timeframe to achieve the above defined objectives.

Table 2.1 Scope of the Work

Stages	Report/Activity	Timeline (weeks)
Stage I	1. Waste water characterization 2. Flow measurement and influx study of marine, sewage and storm water	4
Stage II	3. Soil Characterization 4. Bio-diversity and Socio-economic study 5. Conceptual design detail and specification	6
Stage III	6.Report formulation and final submission	2

2.3 Approach &Methodology

The goals for conservation of water bodies have to be tailor made for individual regions, specific to the problems of degradation and on the level of dependence by living beings. This requires reconstruction of the physical conditions; chemical adjustment of both the soil and water; biological manipulation, reintroduction of native flora and fauna, etc.

The interest in the revival plan of the water bodies is dependent on the key stakeholders namely the residents around it and the government stakeholders. The complete revival and its maintenance is controlled by the stakeholders. The study for each is crucial for the rejuvenation of any water body. Many components of the study have been considered for the overall action plan development.

The methodology adopted for feasibility study along with the various stakeholders involved and their relation to the water body has been described in Figure 2.1.

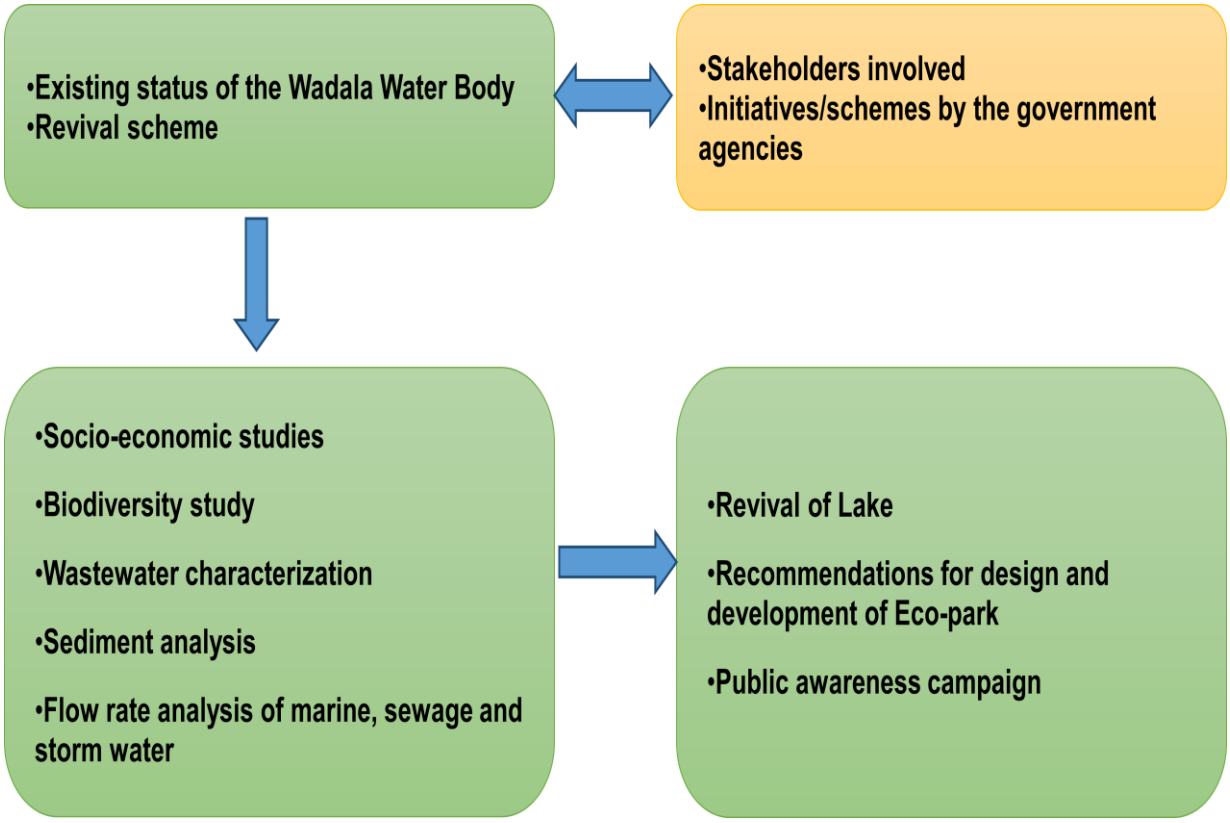


Figure 2.1: Methodology Adapted for Revival Plan of Wadala water body

2.4 Deliverables

The study aimed at understanding of the problems through multiple studies as discussed above. Based on the various environmental components such assessment of status of water, ecology, soil etc. along with biodiversity, local aspirations through socio-economic survey, an attempt has been made to suggest recommendations. The deliverables from the study are:

Environment status assessment

- Status report of all the environmental attributes.
- Area mapping for development and natural resource augmentation.

Ecology study

- Biodiversity study of the water body.
- Improvement plans for the ecological well-being of the water body.
- Recommendations for water body development based on ecosystem approach.

Communication Plan

- Awareness campaign among different stakeholders as part of the rejuvenation plan.
- Host a consultation workshop for sharing the need and status of maintenance of the revival carried out for the Wadala water body.

Chapter 3 : Preliminary Survey Work

3.1 Geographical Location

Wadala is located in the North-eastern Mumbai, in the Municipal North F Ward. Wadala was once considered as a central suburb of the city of Mumbai, but is now well within the city limits. The area is bordered by Dadar on the West, Matunga on the North-west, and Sewri on the South. The eastern areas of Wadala are covered by salt pans, which are on the shores of the Thane creek. It is easily accessible by the Mumbai city's Harbour line of local train network.

The location of the study area has been depicted in Figure 3.1. It is roughly rectangular in shape. On the southern side, the wetland water body is bound by sparse mangroves. There is a belt of slums on its west while on the northern end exclusive residential complexes are under construction. The eastern edge is completely bound by the Sewri-Chembur road and the monorail track. The southern side is connected to the Thane creek.

The study area is well-connected by road and monorail with the Bhakti Park Monorail Station adjacent to it as shown in Figure 3.1.

LAT. - 19°01'27.92"N ⟶ 19°01'49.31"N
LONG. – 72°52'26.43"E ⟶ 72°52'37.96"E

Figure 3.1: Wadala Water Body Location

3.2 Topographical Study and Contouring

The study region has been surveyed as 'total station survey' with a grid size of 10 x 10 m, with a view to assess the current slopes or contours. This survey also aids in deciding the planning of multiple eco-friendly features.

Wadala water body near Bhakti Park monorail station is at a geographically advantageous position to maintain a wetland ecosystem and retain the monsoon waters. Steep slopes flank the northern, north-eastern and north western end of the water body as seen in Figure 3.2, helping to retain water within the area which forms a natural boundary to the Sewri-Chembur road. On the eastern side too, gentle slopes marks the area further separating the area from the main road. The western stretch of the entire water body is marked by gentle slopes which rise approximately 2m above the area (seen in Figure 3.3). The central area of the water body is particularly uneven with gentle slopes covering the entire area. Few trees mark the area at random places which were not very prominent. The relative depression of land surrounded by slopes almost on all sides provide for water storage in the area thus supporting an ecosystem. The Google Earth map along with contour map shows the relative position of slope marking the water body. The total area is approximately under cover by the water body is approximately 45.732 acres and has a multitude of attractive eco-sensitive features.

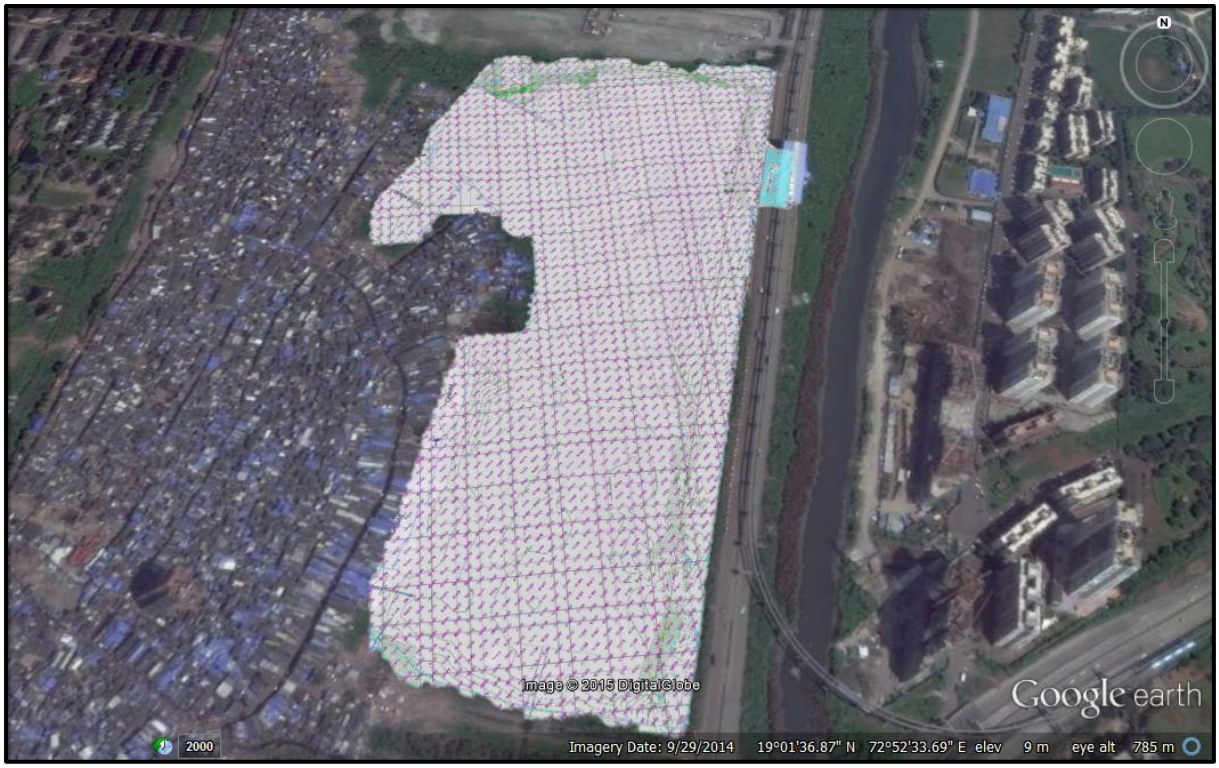


Figure 3.2 Contour Map Overlaid on Google Earth Image

Figure 3.3 Contour Map of Wadala Water Body

3.3. Metamorphosis of the Site

The Google Earth Satellite Imagery below visually depicts the physical transformation of the Site across 2000 till date 2015.

Figure 3.4: Metamorphosis of the Site Over the year from the Year 2000

In Imagery 2000 and 2005:

The site in Figure 3.4 reflects a semblance of ownership and maintenance. We see the site still being used for salt-pans probably serving as a source of livelihood of the neighbourhood. Across the river on the other side, there was no development yet. Salt pan drains are systematically created that run along the entire length. Given the road on the south boundary is loose earth mound, the sub surface water is expected would have drained off to the nallah through it and finally into the river. As also, the sea water ingress across may have happened all across the length of drainage channel created to maintain the salt pan.

Imagery 2010:

Site is no more seen to be used as a Salt Pan. Reclamation of land on north side is seen to have increased. Slum encroachment marginally increased. End of road and land near slum area widened and public toilet & solid waste dump area has come up.

Imagery 2015:

The site now appears edge bound by compacted vacant land on north and concretised road and footpath on east. Slum infiltration has considerably increased from what is seen in year 2010. Site is observed to have 80% of water body covered with weeds and water samples tested clearly indicate it is eutrophied.

Comparison of Imagery 2005 vs 2015 at closer look:

As we take a closer look at the Satellite imagery of 2005 and 2015 for comparison, in Figure 3.5, we see a clear transition of the salt pan land into marshy water body. The increase in slum encroachments would have increased the sewage effluent flow onto the site. The

infiltration of channel water from north side, which is faintly observed in the imagery of 2005, (marked as 1) is clearly blocked by compacted construction wasteland in 2015, (marked A). The concretised road and footpath on the east further leads to the containment of water. Leading to a water body creation. Beyond the road, on the east side one can see the already widening of river probably due to loading and resultant erosion.

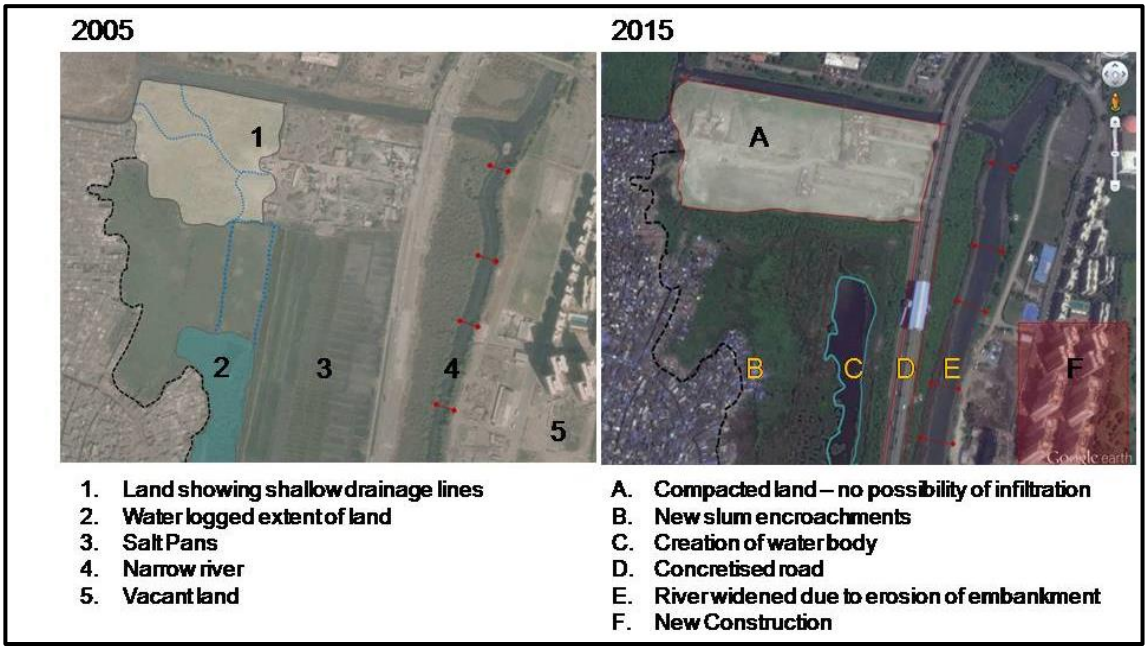


Figure 3.5: Comparative of the Wadala Water Body Site in the Year 2005 and 2015

Impact of the Future:

In addition to the visible transformations at site, the impending growth of the area at large, like construction of new housing societies and respective increase in resident population; the greed for more land to build; an increase in traffic & parking and its resulting noise, emissions, air and storm-water pollution; etc. are all expected to impact the site.

3.3 Socio-economic Assessment

Large slum settlements are illegally bounding the western side of the wetland. The slums are marked by sewage and solid waste discharge and general apathy towards the wetland. Apart from the slums, several housing societies are in the vicinity of the proposed wetland area. The Bhakti Park Monorail Station being in close proximity with the area, daily commuters also get to view the green and blue infrastructure on a daily basis. In future, when it is developed as proposed, it could be good eco-friendly destination to look forward not only for the Mumbai dwellers but also tourists too.

Chapter 4 : Ecology and Environmental Study

4.1 Concept of Biodiversity

Biodiversity may be defined as species, genetic, and ecosystem diversity in an area, sometimes including associated abiotic components such as landscape features, drainage systems, and climate. Biologists most often define biodiversity as the "totality of genes, species, and ecosystems of a region". The Convention on Biological Diversity (CBD) defines biodiversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems." After being referred to, historically, as biological diversity or natural diversity, the term biodiversity was first coined by W. G. Rosen in 1985 and further popularized in 1988 by E. O. Wilson.

Since then, the term Biodiversity has widely captured the attention of stakeholders such as biologists, environmentalists, policy-makers and concerned citizens. Biodiversity supports many lives and livelihoods. It does this by providing essential services. Biodiversity is a source of harvestable goods including food, medicines and building materials. It is essential for regulation of natural processes and the earth's life support systems, e.g., carbon sequestration, soil formation, and purification of water. Moreover, it is a source of spiritual and religious enrichment and well-being. Perhaps most important of all, it is the basis for evolution and adaptation to changing environments, making it essential for survival of life.

During the last century, decrease in biodiversity has been increasingly observed. Estimates reach as high as 140,000 species per year (based on Species-area theory). This figure indicates unsustainable ecological practices, because few species emerge each year. Almost all scientists acknowledge that the rate of species loss is greater now than at any time in human history, with extinctions occurring at rates hundreds of times higher than background extinction rates. As of 2012, some studies suggest that 25% of all mammal species could be extinct in 20 years. This indicates that assessing and preserving biodiversity is a must. Besides, if the task of biodiversity management, restoration or off-setting is to be attempted, a detailed and quantitative survey of existing biodiversity is clearly warranted.

4.2 Methodology

Four belt transects were carried out along the four boundaries of the roughly rectangular plot. Species checklist was prepared considering that the entire area was swampy and relatively inaccessible.

4.2.1 Mangrove Diversity

Mangrove ecosystem is a peculiar habitat found at the interface between land and sea. They are extensions of tropical and sub-tropical forests into the sea. Mangroves are found extensively in the estuarine regions where mud-flats are wide and gently sloping. Besides estuaries, they also inhabit the intertidal regions of shallow bays and creeks where the environment is conducive for the growth of mangroves. Mangroves are flood buffers. They also help to stabilize climate by moderating temperature, humidity, wind and even waves. They are specially adapted to withstand salinity, wave action, and can grow in poor soils. They actually protect the land from the impact of the sea. Growing in the intertidal areas and estuary mouths between land and sea, mangroves provide critical habitat for a diverse marine and terrestrial flora and fauna. Healthy mangrove forests are the key to healthy marine ecology.

Around 15 out of the 35 species of true mangroves found in India have been identified in Mumbai. Owing to high soil salinity.

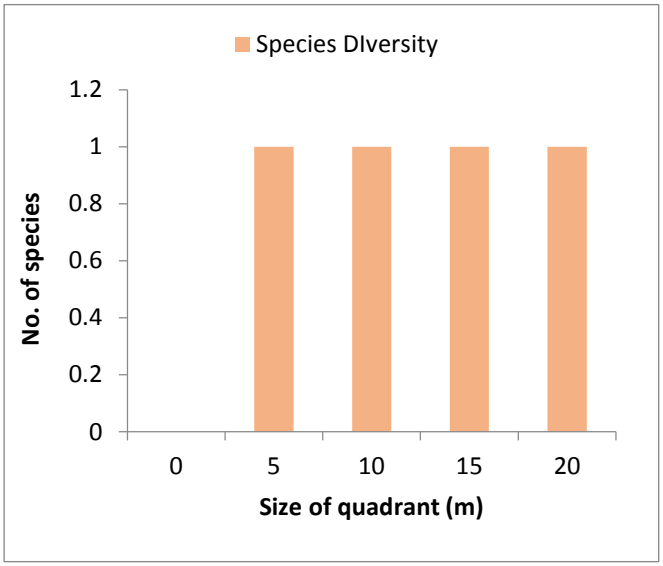


Figure 4.1 Species Area Curve for Mangrove Biodiversity

Methodology Results:

- Based on the species area curve, quadrat size of 10m x 10m was selected
- 4 quadrants of 10m x 10m were laid
- Single species of *Avicennia marina* was observed as reflected in Figure 4.1

4.3 Aquatic Macrophytes

Aquatic macrophytes are green plants that are extremely significant components of an aquatic ecosystem. As emergent, they grow along the banks, as submergents they grow below the water surface and as floating plants they float freely on the water surface. They serve manifold

functions of oxygen production and carbon fixation, additionally provide feeding and breeding grounds to many species of aquatic macro-invertebrates, fish and aquatic birds.

A complete checklist of aquatic macrophytes observed in the Wadala water body is provided in Table 4.1.

Table 4.1: Checklist of Aquatic Macrophytes

FLOATING MACROPHYTES	EMERGENTS
Eichhorneacrassipes (Water hyacinth)	*Cyperusrotundus*
Lemna minor (Duckweed)	*Alternantherasessilis*
	Typhaangustifolia
	Ipomoea aquatica

4.4 Other Plants

Other plants growing in the vicinity of the Wadala water body are referred to in Table 4.2:

Table 4.2: Checklist of Different Types of Plants Growing in the Vicinity

Tree	Shrubs and Climbers	Herbs
Leucaenaleucocephala	*Ricinuscommunis* (Castor)	*Cynodondactylus*(Common grass)
Ficusreligiosa	*Calotropisgigantea*	*Partheniumhysterophorus*(Congress grass)
Ficushispida	*Lantana camara* (Lantana)	*Achyranthesaspera*(Devil's horsewhip/chirchira)
Ailanthus excelsa	*Ipomoea carnea* (Besharam/Bush Morning glory)	
Pithecellobiumdulce	*Ipomoea palmata*	
	Cocciniagrandis (Ivy gourd)	
	Tinosporiacordifolia	

4.5 Avifauna

Avifauna – especially aquatic avifauna – constitute a very special class of birds. These include small birds such as ducks, wagtails, geese, stilts, godwits, moor hens and large, flamboyant ones such as storks, flamingos and ibises. Most common aquatic avifaunal species are the egrets and the herons.

Methodology

The protocol of Point Count was followed. Briefly, a high-elevation monitoring platform was identified – in this case the Bhakti Park Monorail station. From here, timed vigils were kept for 2 hours each during early mornings, noontime and evenings (once for each time-period, making three vigils in total). Number of individual bird species was noted.

Point transect is a form of distance sampling. Distance sampling assumes that the density of animals is constant in the area around the transect lines or points and it provides an estimate of that density. Because distance-sampling methods provide density estimates over rather ill-defined areas, the best way of estimating numbers in a defined area is to conduct a number of replicate distance samplings, randomly or systematically located within it, and calculate a mean. Point transects are particularly suited for highly visible birds – such as wetland birds in this case study.

The precautions that must be taken during taking point counts are:

- Wait for a set time after arrival at the sampling point, allowing the birds to settle.
- Avoid double-counting
- Birds flying above the field-visitor should not be included in the survey, but recorded separately
- Birds flushed out of bushes while approaching a point-count station should be included in the survey, but a mention of the incidence must be made
- For surveys of breeding birds, 2-3 visits/season is recommended

Further, the Simpson's and Shannon's diversity indices were also computed.

Simpson's Index

Simpson's diversity index (D) is a simple mathematical measure that characterizes species diversity in a community. The proportion of species 'i' relative to the total number of species (pi) is calculated and squared. The squared proportions for all the species are summed, and the reciprocal is taken:

$$D = \frac{1}{\sum_{i=0}^{n} P_i^2}$$

This is followed by calculating 1/D. "The Simpson index is one of the most meaningful and robust diversity measures available." In essence it captures the variance of the species abundance distribution.

Shannon's Index

The Shannon diversity index (H) is another index that is commonly used to characterize species diversity in a community. Like Simpson's index, Shannon's index accounts for both abundance and evenness of the species present. The proportion of species i relative to the total number of species (pi) is calculated, and then multiplied by the natural logarithm of this proportion (ln Pi). The resulting product is summed across species, and multiplied by -1.

$$H = -\sum_{i=0}^{n} P_i \ln P_i$$

Methodology Results:

The different bird species observed during various visits is enlisted in Table 4.3 below. Also the density, frequency, number of species, abundance etc. have been given Table 4.4.

Table 4.3: List of Different Species Found Near the Water Body

Common Name	Scientific Name	Number observed	Approximate distance (in feet)
Visit 1			
Eurasian coot	*Fulicaatra*	1	30
Purple Moorhen	*Porphyriopoliocephaluspoliocephalus*	6	25
Little egret	*Egrettagarzetta*	9	60
Great egret	*Ardea alba*	1	60
	Dicrurusmacrocercus	4	30
Shikra	*Accipiter badius*	1	8
Wire-tailed swallow	*Hirundosmithii*	5	30
Little cormorant	*Microcarboniger*	1	30
Black kite	*Milvusmigrans*	4	30
Common sandpiper	*Actitis hypoleucos*	2	15
Visit 2			
Grey heron	*Ardeacinerea*	2	75
Common moorhen	*Gallinulachloropus*	3	30
Little cormorant	*Microcarboniger*	5	45
Long-tailed shrike or rufous-backed shrike	*Laniusschach*	2	30
Common sandpiper	*Actitis hypoleucos*	6	25
Little egret	*Egrettagarzetta*	8	30
Great egret	*Ardea alba*	1	20
Unidentified Swift		1	25

Common Name	Scientific Name	Number observed	Approximate distance (in feet)
Ashy prinia	*Priniasocialis*	3	35
Black Kite	*Milvusmigrans*	4	45
Western Marsh Harrier	*Circus aeruginosus*	1	50
Visit 3			
Glossy ibis	*Plegadisfalcinellus*	15	30
Little cormorant	*Microcarboniger*	2	30
Long-tailed shrike or rufous-backed shrike	*Laniusschach*	1	10
Common sandpiper		4	40
Little egret	*Egrettagarzetta*	5	30
Great egret	*Ardea alba*	2	60
Ashy prinia	*Priniasocialis*	4	10
Black kite	*Milvusmigrans*	6	20
Asian koel	*Eudynamysscolopaceus*	3 (2 female and 1 male)	8

Table 4.4: Statistics and Indexes of Species Found Near the Water Body

Parameter	Result	Remarks
Species Richness	18 different species in 3 visits in post-monsoon season	--
Abundance	112 individuals in 3 visits, 37.33 individual birds observed per visit	--
Density	5.32 birds/ha	Assuming total study area to be 45.73 acres
Simpson's Index (1/D)	9.72	
Simpson's Index (1-D)	0.90	Closer the value is to 1, higher is the species richness and evenness
Shannon's Index (H)	2.51	Closer the value is to 4, higher is the species richness and evenness. Usually this value is between 2.5-3.5 and rarely exceeds 4

The photographs of some of the observed bird species are provided in Figure 4.2

a) Ashy Prinia *b) Great Egret*

c) Glossy Ibis and Little Egret *d) Hoopoe*

e) Grey Heron *f) Glossy Ibis and Common Moorhen*

g) Coot *h) Female Shikra*

i) Commom Moorhen *j) Purple Moorhen*

Figure 4.2: Bird species found near the Wadala water body

4.6 Other Species of Interest

- ***Butterflies:***

The area was found to be host to fairly good avifauna biodiversity, however some other interesting species have been also observed during the study period. A rich biodiversity of butterflies has been observed which is appended in Table 4.5.

Table 4.5: List of Butterflies Found Near Wadala Water Body

Species	Numbers
Common Castor (*Ariadne merione*)	8
Plain Tiger (*Danauschrysippus)*	2
Common Crow (*Euploea core*)	1
Grey Pansy *(Junoniaatlites)*	3
Danaid Eggfly, (*Hypolimnasmisippus*)	2
Common Lime Butterfly (*Papiliodemoleus*)	6

Species	Numbers
Common Grass Yellow (*Euremahecabe*)	6
Common Emigrant (*Catopsiliapomona*)	3
Psyche (*Leptosianina*)	1

a) Common grass *b) Danaid Eggfly*

Figure 4.3: Different Butterflies Found Around Wadala Water Body

- ***Dragonflies***

  Two different species found near Wadala water body are as follows as seen in Figure 4.4:

  - Long-legged Marsh Glider (*Trithemispallidinervis*)
  - Crimson Darter (*Crocothemisservilia*)

a) Long-legged Marsh Glider *b) Crimson Darter*

Figure 4.4: Different Species of Dragonflies around Wadala Water Body

Chapter 5 : Environmental Status and Assessment

5.1 Environment status and Pollution Load

The Wadala, water body covering an approximate area of 45.73 acres is surrounded by road on east end, slums on south and west frontier, with high rise buildings on northern frontier. Situated near Bhakti Park monorail station, this water body comprise of wetlands on the verge of extinction. The water body is covered by both fresh water and marine waters. The water body area is covered by lush green flora and fauna. The natural water body has deteriorated owing to pollution from the encroaching slum dwellers, construction debris from infrastructure developing firms and continuous neglect. The different kind of waste accumulating in the water body accounting for its degradation have been discussed below and illustrated on the Google Earth Image in Figure 5.1.

5.1.1 Solid Waste

One of the major nuisance contributing to water body degradation is solid waste. It is generated from different sources which are:

- High-density slums has only two public toilets in the close vicinity, and two farther away. Hence, most of the people dwelling in slums resort to open defecation in the region.
- Solid waste from slum gets dumped at various sites along the water body boundary.

5.1.2 Marine water and Sewage intrusion

Water pollution from marine waters, sewage flow from the slums, small–scale industries is leading to degradation of water quality in the water body. Different polluting sources are:

- A few small-scale potentially polluting industries have been observed in the slums which are releasing their untreated wastewaters.
- A drain flowing on the opposite side of the Sewri-Chembur road has two arms bounding the north and the south of the study area. These arms have been indicated in the Google Earth image.
- Sea water intrusion through the south end of study area during high tide brings in more nutrients and hampers the quality of water.

Figure 5.1: Sources of Water Pollution to the Water Body

5.1.3 Construction Debris

On the northern end high rise building are under construction, the debris of construction activities has been dumped in the water body as seen in Figure 5.2, considering it to be a free open land.

Figure 5.2: Wadala Water Body Depicting the Sources of Pollution

5.2 Flow rate Measurement

Measurement of flow rate is a quantitative analysis of water flowing in a water body. Discharge is an important parameter to monitor because of its direct influence on the chemical composition of receiving water bodies. Flow rate is affected by season, region, standard of living, population, etc.

A flow-rate measurement exercise was conducted to get the information of the load of pollution entering the water body. Flow rate assessment is an essential step in analysing water quality. Fast flowing streams have higher dissolved oxygen due to better aeration, as well as it also prevents the settlement of the suspended solids as compared to slow-flowing ones. The nallah flow rates were measured from different sampling points as seen in the Figure 5.3 twice a day at 12-hr intervals during peak flow periods.

The following equation was used for calculation:

Flow = ALC / T

Where,

A = Average cross-sectional area of the stream
(stream width multiplied by average water depth).

L = Length of the stream reach measured (usually 6.1 m or 20 ft.)

C = A coefficient or correction factor
(0.8 for rocky-bottom streams or 0.9 for muddy-bottom streams).

T = Time taken in traversing the length L in min

Depth was measured using a yardstick at three locations and the average was calculated. Time was measured using a stopwatch. Colorful plastic balls were used in place of the traditional ping-pong.

Table 5.1: Flow Rate Measurement Data

Points	Flow rate (m^3/min)
Sea water intrusion point	0.276
Dumping Site	Stagnant water
Slum side mainly sewage	0.690
Slum side mainly sewage	5.160
Slum side sewage and dying effluent	0.288

Figure 5.3: Flow Rate at Various Sampling Points

The nallahs flows has been measured at locations nearer to their meeting points to the water body. Many places, nallahs are choked upstream and therefore flow data show high variation.

5.3 Water Sampling and Analysis

The condition of the water body is continuously degrading with respect to water quality mainly because of increasing population, increased encroachment on the banks of the water body and continuous discharge of sewage. The changes in the nutrient concentrations of water may lead to harmful effects to human health and aquatic life. The physico-chemical parameters of an aquatic body not only reflect the type and diversity of aquatic biota but also the water quality and level of pollution Effluents from household and small scale industries are being regularly discharged into water body without adequate treatment which results in nutrient enrichment, the accumulation of toxic compounds in water and sediments, loss of dissolved oxygen in water and other nuisances.

Wetlands are known to act as natural filters for nutrients and contaminants that originate from the catchment area, thereby protecting the water quality. Wadala wetland which was supposedly to filter contaminants and pollutants has been degraded and shrinked due to increased human intervention resulting in reduction of its cleaning potential and forming a dump yard of waste in the water body. There is an urgent need to assess the impact of wastewater from domestic and small scale industries on water quality of Wadala water body.

The study assessed the current status of water quality of Wadala water body. The results of this study will assist the relevant authorities in designing and implementing appropriate preventive measures in order to improve the quality of water of Wadala water body.

5.3.1 Water Sampling and Locations

The water sample was collected on the basis of geographical location and possible contamination and its impact on water body. The slum area is situated on its east whereas sea water exchanges in the south direction. North and West direction of water body has less chance of direct water contamination. Therefore, sampling point 1 & 2 were selected from slum area and 3 from sea water incursion end. The sampling point 4 was on the side of Sewri-Chembur road. Figure 5.4 shows all the water sampling points.

Figure 5.4: Water Sampling Points on the Wadala Water Body

5.3.2 Water Analysis and its Inference

Water samples were collected on July 15, 2014 (Monsoon) and again on November 13, 2014 (Post Monsoon) from various sampling points as illustrated in Figure 5.4. The results based on site visits, water and sediment analysis indicates that the water body pollution is mainly due to discharge of untreated domestic wastewater from slum areas. Sea water exchange on southern part adds to the TDS and high chloride values.

Table 5.2: Water Quality Analysis (Date Sampling 15 of July 2014 &13 of November 2014)

Parameters (mg/lit) (except pH)	**Sample 1**			**Sample 2**			**Sample 3**			**Sample 4**			**Methods**	**Standards***
														SWII
	Monsoon	Post	mean	Monsoon	Post	mean	Monsoon	Post	mean	Monsoon	Post	Mean	--	--
pH	8	7	8	8	7	7	8	8	8	8	8	8	IS:3025 (Part-17):1999	6.5-8.5
DO	0	0	0	2	1	1	0	1	1	3	2	2	IS:3025 (part-11-2):2002	4
BOD@27^{o}c ,3day	127	306	217	37	56	47	117	213	165	28	48	73	IS:3025 (part38):1989	3
COD	957	980	968	113	178	146	513	682	597	79	176	128	IS:3025 (Part-58):2006	-
TDS	14650	12812	13731	276	6356	3316	368	516	442	1770	821	1295	IS:3025 (Part-44):2003	-
TSS	438	684	561	192	244	218	450	488	469	48	60	54	IS:3025 (Part-16):2002	-
PO_4 -P	2	3	2	3	4	3	4	4	4	4	3	4	IS:3025 (Part31):1988	5
TKN	47	136	91	47	53	50	96	116	106	46	58	52	IS:3025 (Part34):2003	-
Chlorides as Cl	7309	6416	6863	119	4047	2083	168	300	233	476	516	496	IS:3025 (Part-322):2003	-

Table 5.3: Water Quality Analysis (Date Sampling 15 of July 2014 &13 of November 2014)

Parameters (mg/lit) (except pH)	Sample 5	Sample 6	Methods	Standards*
				SWII
pH	7.4	7.3	IS:3025 (Part-17):1999	6.5-8.5
DO	0.3	0.6	IS:3025 (part-11-2):2002	4.0
BOD@27^{o}c ,3day	258	185	IS:3025 (part38):1989	3.0
COD	856	216	IS:3025 (Part-58):2006	-
TDS	3288	1160	IS:3025 (Part-44):2003	-
TSS	312.2	140.3	IS:3025 (Part-16):2002	-
PO_4–P	2.36	3.02	IS:3025(Part31):1988	5.0
TKN	118.6	54.2	IS:3025(Part34):2003	-
Chlorides as Cl^-	1726	528	IS:3025(Part 322):2003	-

- Abbreviations:
- Sample 1: Seawater influence water
- Sample 2, 3, 5 and 6: Slum site wastewater
- Sample 4: Opposite site of the slum area
- Class SW-II: Water quality criteria for bathing, contact water sports and commercial fishing in the coastal segment.

Figure 5.5: Monsoon and Post-Monsoon Status of Water Quality

Figure 5.6: Average of Water Quality Data at Various Sampling Points

5.3.3.1 pH

The pH is a measure of the acid balance of a solution and is defined as the negative of the logarithm to the base 10 of the hydrogen ion concentration. The pH controls the chemical state of many nutrients including dissolved oxygen, phosphate, nitrate etc. It regulates most of the biological process and biochemical reactions. In waters with high algal concentrations, pH varies diurnally, reaching values as high as 10 during the day when algae are using carbon dioxide in photosynthesis. pH changes can tip the ecological balance of the aquatic system and excessive acidity can result in the release of hydrogen sulphide. It was observed as in Figure 5.7 that pH of water increases during monsoon and decreases during post monsoon. Increase in pH during

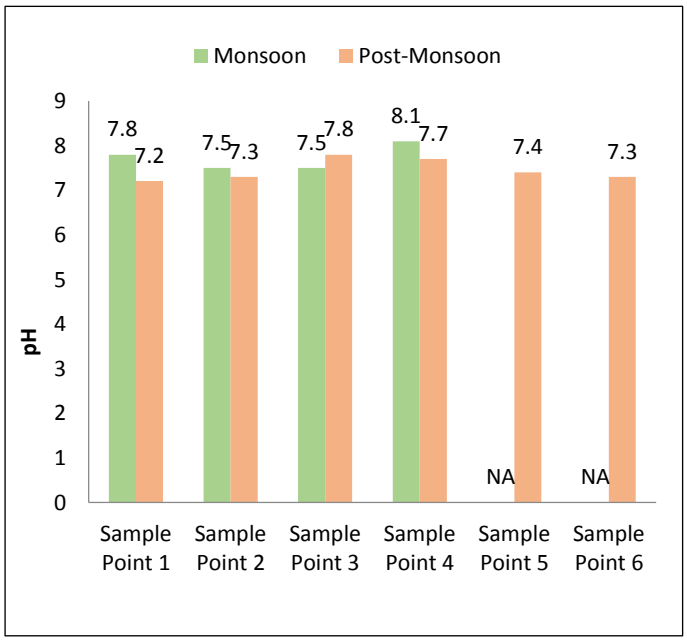


Figure 5.7: Variation in pH during Monsoon and Post-Monsoon

monsoon may be due to increased photosynthesis of the algal blooms. The decrease in pH during post monsoon may be due to decrease in photosynthesis.

The pH value of all the samples was found to be slightly alkaline in the range between 7.5 to 8.1 in monsoon and 7.1 to 7.8 in post monsoon. The lowest pH value was found in sample 5 of 7.4 and the highest mean value was found in sample 3 i.e. 7.9. The pH value of all the samples are within the limit for the discharge on land set by CPCB, Government of India i.e. 5.5 to 9.0, and SW II water standard 6.5 to 8.5.

5.3.3.2 Dissolved Oxygen (DO)

Dissolved Oxygen determines the nature of an aquatic ecosystem to a great extent. The sustenance of aquatic living organisms depends on dissolved oxygen content of the water bodies. There are two sources of oxygen for water bodies; (i) directly from the atmosphere and (ii) by the photosynthesis activity of chlorophyll bearing aquatic plants. In an aquatic ecosystem, a greater number of species of organisms are supported when the dissolved oxygen (DO) concentration is adequate.

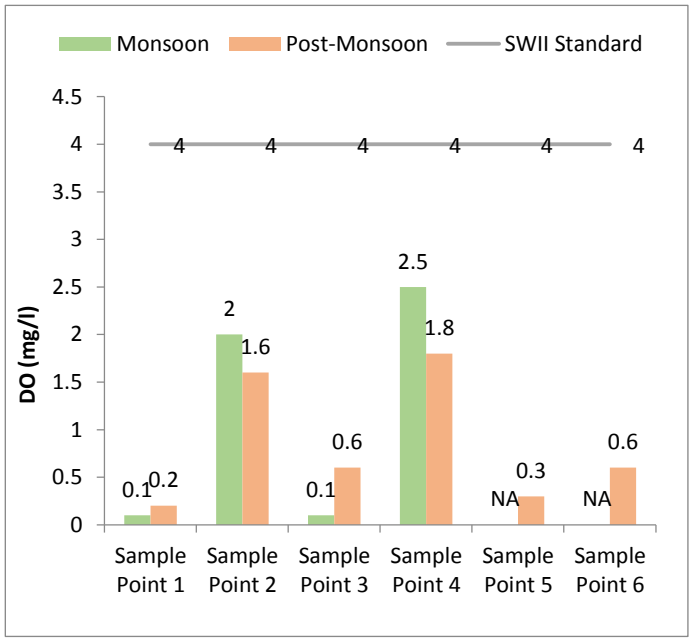


Figure 5.8 Variation in DO during Monsoon and Post-Monsoon

Depletion of oxygen is due to discharge of wastewater in to the water body that has great influence on the decomposers already present in the water stream. The DO levels are considered as the most important and commonly employed measurement of water quality and indicator of a water body's ability to support aquatic life. Inorganic reducing agents such as hydrogen sulphide, ammonia, nitrite and certain substances which readily get oxidised also tend to decrease the amount of dissolved oxygen in the water body.

DO was found to be less than SW II standard at all the sampling points clearly visible in Figure 5.8. The lowest and highest mean values were reported from sampling points 1 (0.15 mg/L) and 4 (2.15 mg/L), respectively. The value of dissolved oxygen was found to be very less not even adequate to support the aquatic life.

5.3.3.3 Chemical Oxygen Demand (COD)

The major problem of water body is pollution from nearby industries and sewage from slum areas. Several small scale industries were located in close proximity to the water body and did not have treatment facilities, therefore effluents from these industries were directly discharged in water body without adequate treatment which results in nutrient enrichment, the accumulation of toxic compounds in biomass and sediments, loss of dissolved oxygen in water, high Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD).

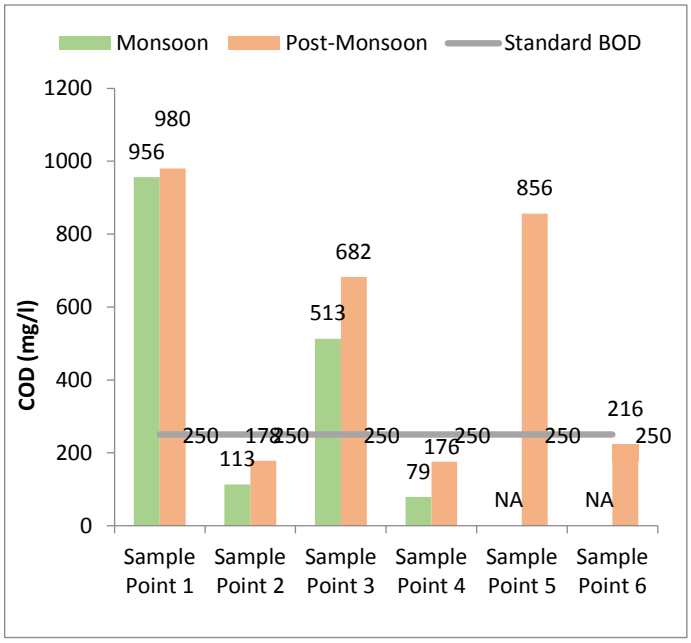


Figure 5.9: Variation in COD during Monsoon and Post-Monsoon

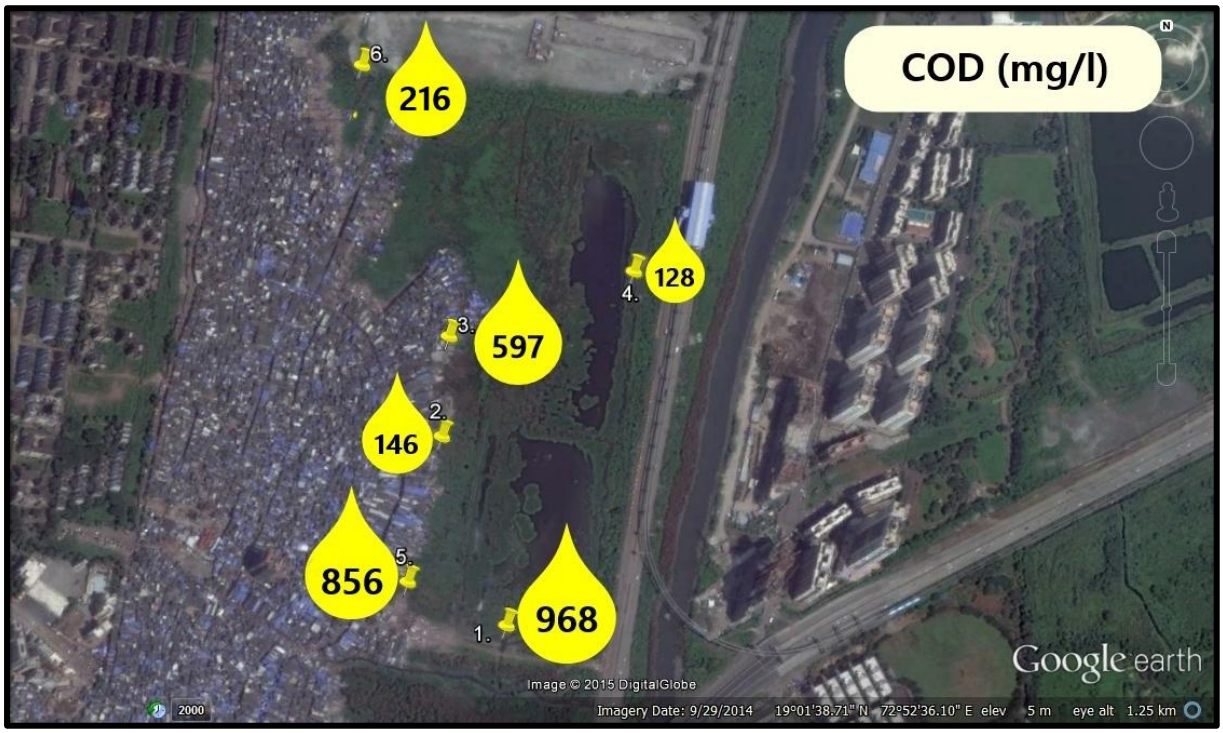


Figure 5.10: COD at Various Sampling Points

The COD values were more than limit except at sampling points 2 and 4. Figure 5.9 shows that the lowest and highest mean values were at sampling points 4(127 mg/L) and 1 (968 mg/L) respectively. The inference of data obtained from the estimation of water quality is that the sampling points 1, 3 and 5 has a COD level of approximately 900 mg/L which

indicates the influence of industrial wastewater into the main stream. Representation of the COD values at various sampling points is shown in Figure 5.10

5.3.3.4 Biological Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) is a chemical procedure for determining the amount of Dissolved Oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period. BOD can be used as a gauge of the effectiveness of wastewater treatment plants. High BOD in post monsoon might be due to high rate of organic decomposition and the entry of high concentration of dissolved and suspended solids in the water.

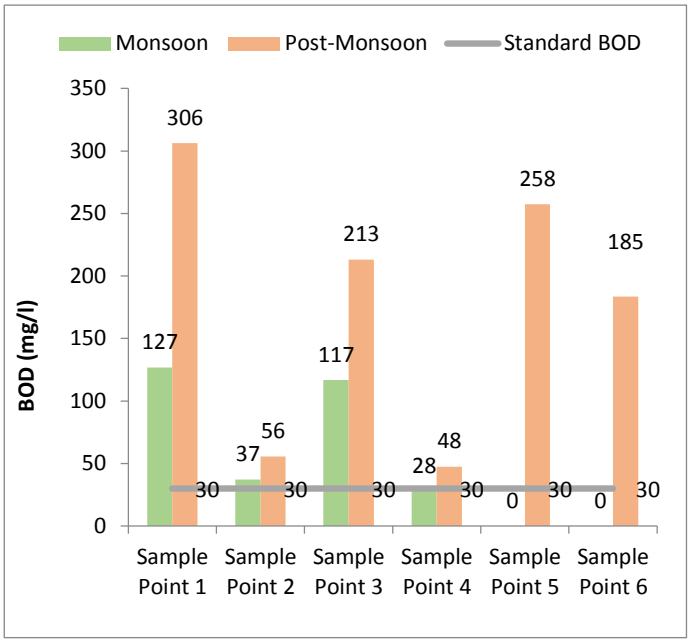


Figure 5.11: Variation in BOD during Monsoon and Post-Monsoon

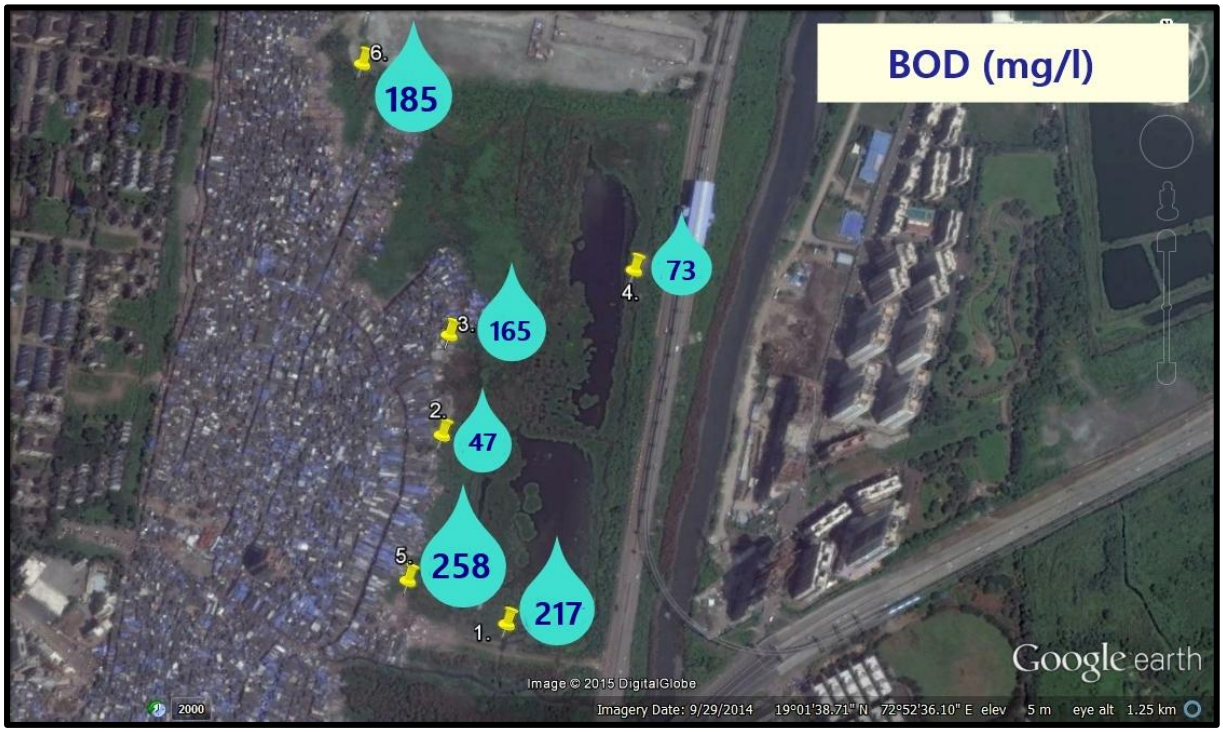


Figure 5.12: BOD Data at Various Sampling Points of Wadala Water Body

BOD was found to be higher than standard except sampling point 4 (28 mg/L) as reflected in Figure 5.11. The BOD range in the monsoon and post monsoon were found to be between 28 to 127 mg/L and 48 to 306 mg/L, respectively. The lowest and highest mean values were

reported at sampling points 4 (37.8 mg/L) and 1 (216.5 mg/l), respectively. BOD representation at the various sampling points on the map has been illustrated in Figure 5.12.

5.3.3.5 Total Dissolved Solids (TDS)

In water, total dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium, potassium and manganese, organic matter, salt and other particles. The high concentration of TDS enriches the nutrient status of water body which was resulted into eutrophication aquatic ecosystem. The dissolved solids can be estimated using total dissolved solids measures how well the water conducts an electrical current, a property that is proportional to the concentration of ions in solution.

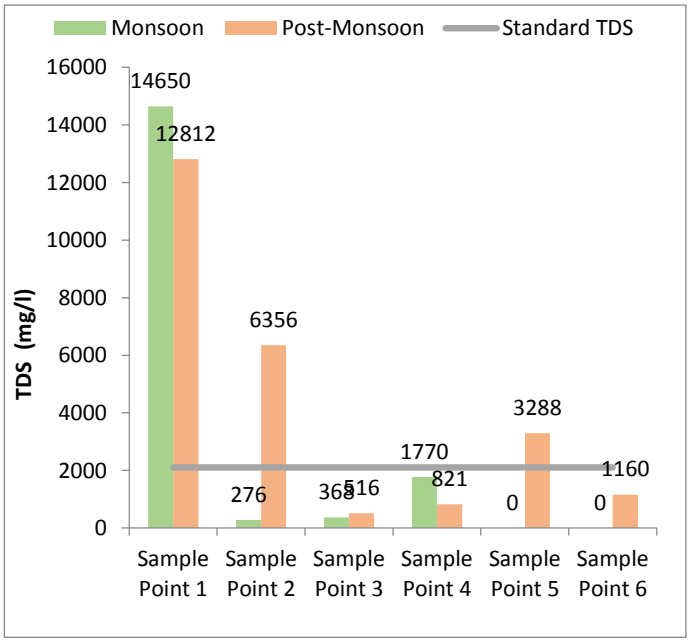


Figure 5.13: BOD Data at Various Sampling Points of Wadala Water Body

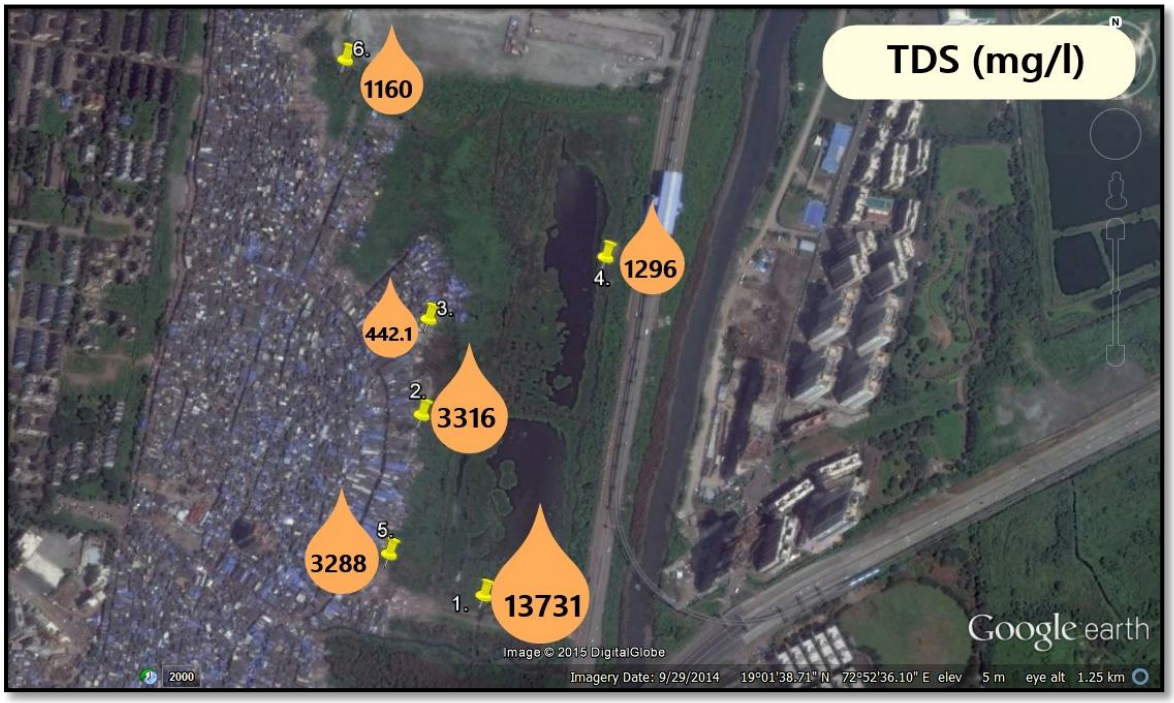


Figure 5.14: TDS Data at Various Sampling Points

The maximum total dissolved solids were observed during the monsoon season upto 14650 mg/L. The lowest and highest mean values were of sampling point 3 (442 mg/L) and 1

(13731 mg/L), respectively. Waters with high TDS value are unpalatable and potentially unhealthy. TDS levels during monsoon and post monsoon are graphically represented in Figure 5.13, while the average TDS value at various sampling points is represented in Figure 5.14

5.3.3.6 Total Suspended Solids (TSS)

Total suspended solids determination is particularly useful in the analysis of sewage and other wastewater and is as significant as BOD determination. It is used to evaluate the strength of domestic wastewaters and efficiency of treatment units. Suspended Solids containing much organic matter may cause putrefaction and consequently the water bodies may be devoid of dissolved oxygen. The source of these suspended solids includes natural and anthropogenic activities in the watershed, such as natural or excessive soil erosion from agriculture, forestry or construction, urban runoff, industrial effluents, or excess phytoplankton growth.

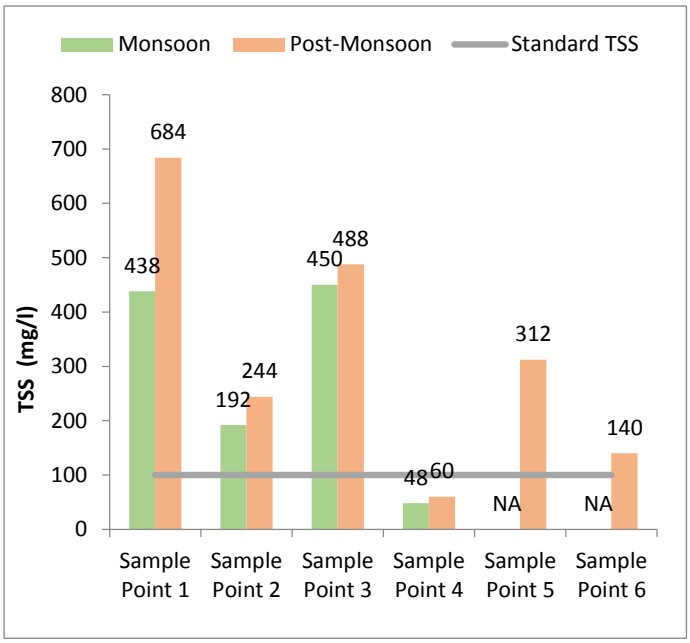


Figure 5.15: Variation in TSS during Monsoon and Post-Monsoon

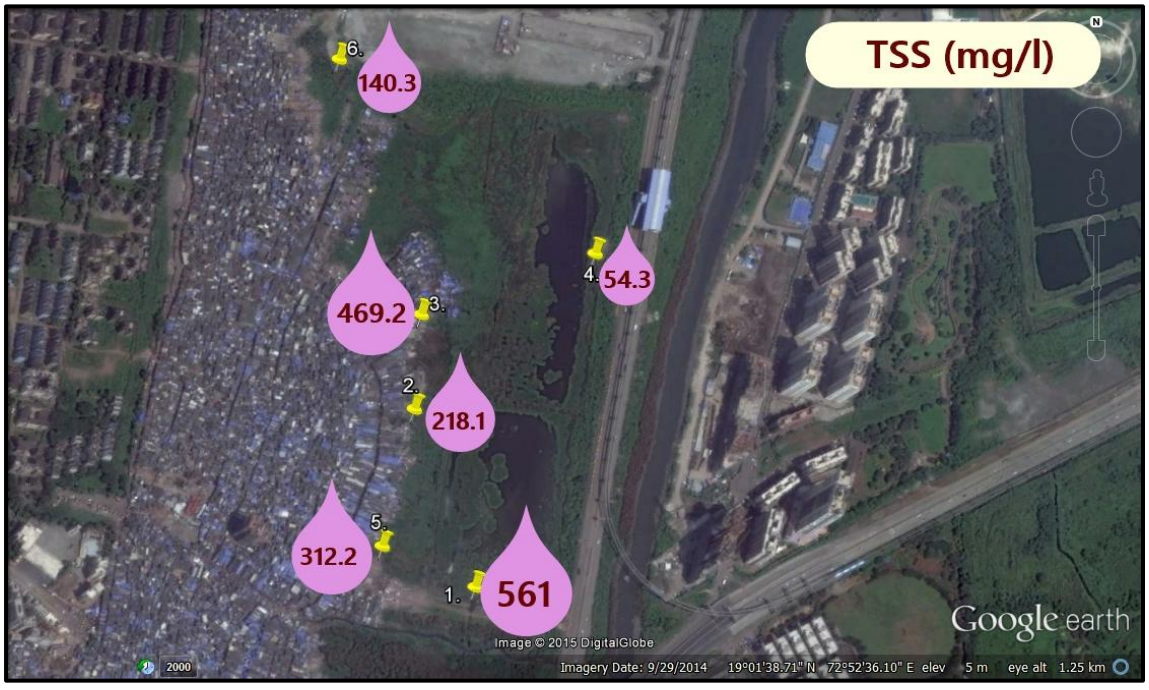


Figure 5.16: TSS Data at Various Water Sampling Points

The lowest and highest mean values were reported of sampling point 4 (54 mg/L) and 1 (561 mg/L), respectively. The sampling point 4 showed less than standard value during monsoon and post monsoon season. Waters with high Total Suspended Solids (TSS) are unpalatable and potentially unhealthy. TSS levels during monsoon and post monsoon are graphically represented in Figure 5.15, while the average TSS value at various sampling points is represented in Figure 5.16

5.3.3.7 Total Kjeldahl Nitrogen (TKN)

The result of the study showed that the value of Kjeldahl Nitrogen was exceeded the standard due to domestic wastewater discharge along the periphery of water body. The excessive TKN can cause over production of planktons and as they die and decompose they use the oxygen and therefore, the DO content of the water goes down leading to death of oxygen dependent organisms.

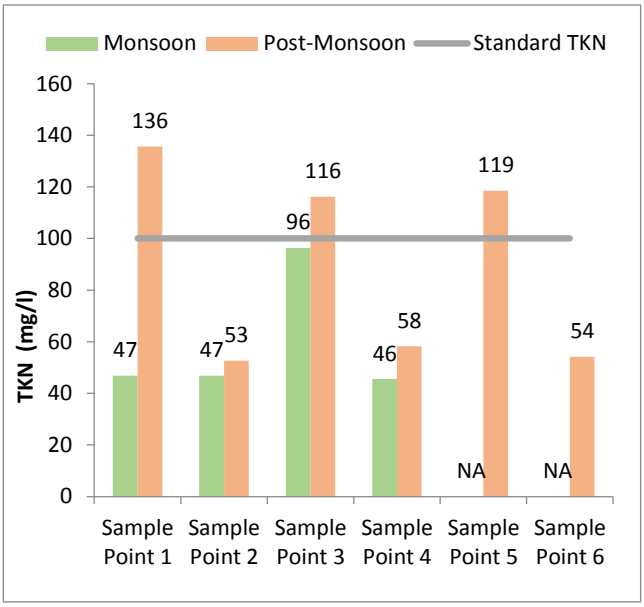


Figure 5.17: Variation in Total Kjeldahl Nitrogen during Monsoon and Post- Monsoon

All the values shown in the Figure 5.17 are within the limit except post monsoon season from sampling point 1, 3 and 5. The lowest and highest mean values were of sampling point 2 (52.7 mg/L) and 3 (106.3 mg/L), respectively. High TKN concentrations were during post monsoon season.

5.3.3.8 Chlorides

The chloride status in water is indicative of pollution, especially of anthropogenic origin. The origin of chloride in surface water is from weathering and leaching of sedimentary rocks, domestic and industrials water discharge, municipal influence etc. The chloride concentration serves as an indicator of pollution by sewage. Water with high chloride content usually has an unpleasant taste and may be objectionable for some agricultural purposes. It increases with ammonical nitrogen which also owes itself mostly to animal excreta. Chloride helps in

assessing the limits of distribution of various species of organism and it also an important factor indicating stress in a system.

The lowest and highest mean values were reported from sampling point 2 (234 mg/L) and 1 (6863 mg/L), respectively. At sampling point 1 high Cl ions concentration was reported due to influence of seawater. All values were observed above the inland surface water standard (1.0 mg/l). The high content of chloride in the water body could have resulted due to large amount of organic matter, urination, faces and wastes of animals etc. The Figure 5.18 represents the nitrogen values at various sampling points during Monsoon and Post-Monsoon

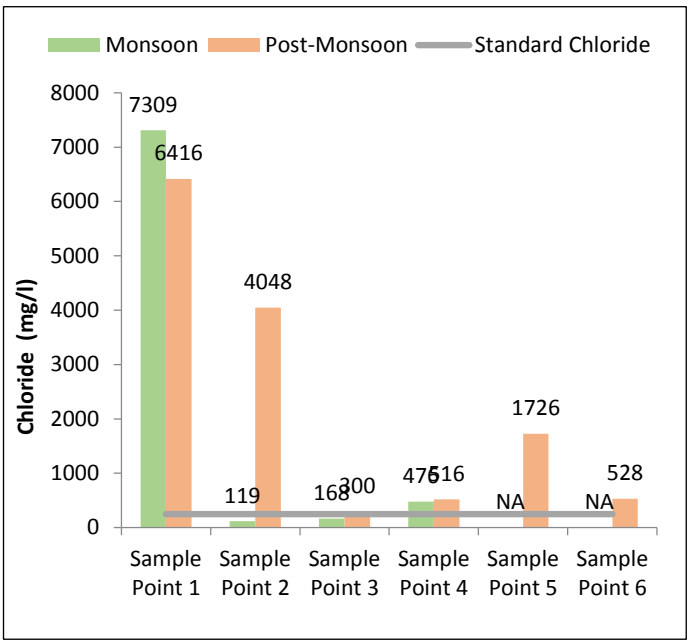


Figure 5.18: Variation in Chloride Ion during Monsoon and Post-Monsoon

5.3.3.9 Orthophosphates

Nitrogen, phosphorus or both may cause aquatic biological productivity to increase, resulting in low dissolved oxygen and eutrophication of lakes, rivers, estuaries, and marine waters. Besides adding to nutrient-content of the water, addition of some forms of nitrogen and phosphorus will increase BOD and COD. During the natural process of weathering, the rocks gradually release the phosphorus as phosphate ions which are soluble in water. Anthropogenic sources include; wastewater and septic system effluent, animal wastes, detergents, industrial discharge, fertilizers, etc. Phosphates lead to eutrophication which could also lead to unpleasant taste and odour of the water when algae die decomposed thus deteriorating the quality of the water.

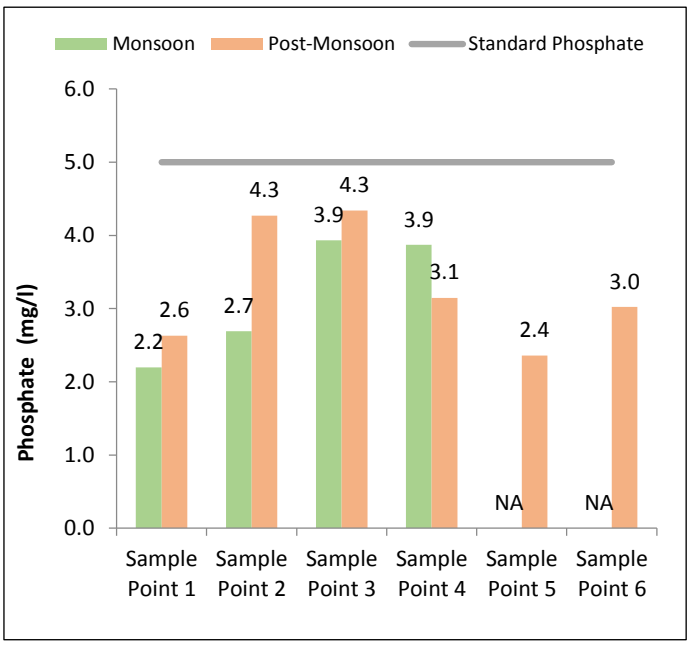


Figure 5.19: Variation in PO4 during Monsoon and Post-Monsoon

The lowest and highest mean values were reported from sampling point 1 (2.4 mg/L) and sampling point 3 (4.1 mg/L) respectively. The PO_4 values of different samples as seen in the figure 5.19 were within the desirable and suitable range of inland surface water standard (5.0 mg/L). The high concentrations of phosphate during post monsoon were observed probably due to the presence and decomposition of aquatic vegetation which release phosphate. Any amount in the excess of 0.5 ppm of phosphate is an indicator of pollution.

5.3.3.10 Correlation Coefficient

Statistical study of correlation coefficients of the water quality parameters not only helps to assess the overall water quality but also quantify relative concentration of various pollutants in water and provide necessary cue for the implementation of rapid water quality management programs. The correlations among the physicochemical properties were studied and results presented below in. Table 5.4

Table 5.4: Correlation Coefficient between Environmental Variables in Water Body

	pH	DO	BOD	COD	TDS	TSS	TKN	Cl
pH	1							
DO	0.59	1.00						
BOD	-0.30	**-0.94**	1.00					
COD	-0.40	**-0.95**	**0.98**	1.00				
TDS	-0.18	**-0.53**	**0.65**	0.75	1.00			
TSS	-0.68	**-0.98**	**0.90**	**0.94**	0.61	1.00		
TKN	-0.48	**-0.94**	**0.88**	**0.82**	0.24	**0.88**	1.00	
Cl	-0.24	-0.52	0.61	0.73	1.00	0.60	0.22	1.00

* strong correlation are shown in bold

The pH showed positive correlation with DO (r=0.59) indicating probable organic contamination which produce organic acids and their oxidation reduce the DO value in the water body. There was moderate correlation observed between pH and DO (r = 0.59). But pH with other parameters exhibited a negative correlation. The DO and BOD, COD showed negative and positive correlation with all the other parameters, respectively. The TDS showed positive relation with BOD. Whereas, TSS showed strong positive and negative correlation with BOD, COD and DO, respectively. The BOD is inversely correlated (r = -0.94) with DO suggesting its consumption during aerobic degradation of organic wastes and also with pH (r = -0.30).

This will help to understand the nature of these physicochemical variables and their specification in the effluent and receiving watershed. It is generally known that an increase in concentration of pollutants will occur during low flows when point sources dominate.

5.3.3.11 Water Quality Index

One of the most effective ways to communicate water quality is Water Quality Index (WQI), where the water quality is assessed on the basis of calculated water quality indices. Quality of water is defined in terms of its physical, chemical, and biological parameters. However, the quality is difficult to evaluate from a large number of samples, each containing concentrations for many parameters. WQI is a mathematical instrument used to transform large quantities of water quality data into a single number which represents the water quality level while eliminating the subjective assessments of water quality and biases of individual water quality experts.

NSF WQI is an excellent management and general administrative tool in communicating water quality information. This index has been widely field tested and applied to data from a number of different geographical areas all over the world in order to calculate Water Quality Index (WQI) of various water bodies critical pollution parameters were considered. The mathematical expression for NSF WQI is given by

$$NSF\ WQI = \sum_{i=1}^{p} W_i\, I_i$$

Where:

I_i is the sub-index for i_{th} water quality parameters

W_i is the weight (in terms of importance) associated with i^{th} water quality parameter

p is the number of water quality parameters The classification criteria standards based on NSF WQI are given in Table 5.5.

Table 5.5: Classification Criteria Standards Based on NSF- WQI

NSF-WQI	Descriptor	Category
91-100	Excellent	A
71-90	Good	B
51-70	Medium	C
26-50	Bad	D
0-25	Very Bad	E

The following observations were made based on the National Sanitation Foundation-Water Quality Index of various water bodies in the study area.

This water quality rating as seen in Figure 5.20 clearly shows that, the status of the water body is eutrophic and it is unsuitable for human uses. The WQI was observed highest and lowest WQI values at sampling station 2 and 3, respectively as in Figure 5.20.

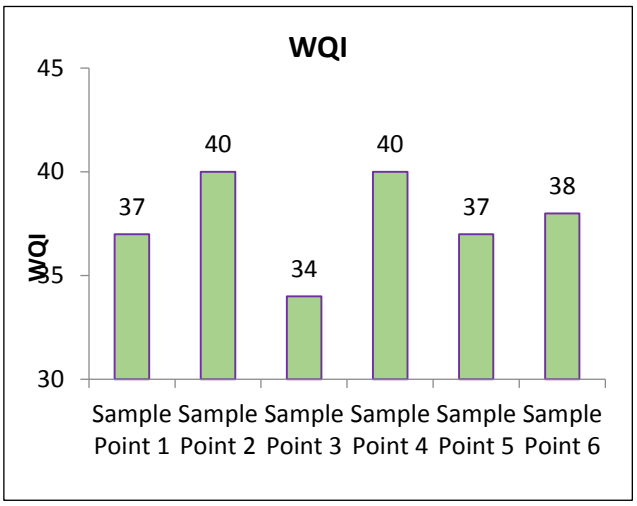


Figure 5.20: Spatial Variation in WQI of Wadala Water Body

5.4 Sediment Sampling and Analysis

Sediment analysis is another important factor for evaluating ecosystem state of a water body, in addition to the water sample analysis. Sediment serves both as reservoirs and also a potential source of contaminants to water. Elements usually found in traces in the water body may accumulate slowly to higher levels within the sediment. The sediment nurtures and harbours high populations of benthic and epi-benthic organisms. Sediment quality assessment gives a significant insight on water and ecosystem quality.

5.4.1 Sediment Sampling and Location

Sediment was collected from 5 locations along the water body as illustrated in Figure 5.21. Sampling locations and results have been elaborated in Figure 5.22. This study was aimed at examining the impact of pollution on sediment quality, and to identify the parameters involved in degraded sediment quality.

Figure 5.21: Sediment Sampling Locations Located on the Wadala Water Body Map

5.4.3 Sampling Analysis

Sediment analysis is a highly significant factor in evaluating qualities of the total ecosystem of a water body in addition to the water sample analysis. Sediment serves both as reservoirs and as potential sources of contaminants to the water column. It is the ultimate sink of contaminants in aquatic systems. It plays an extremely crucial role in retaining and releasing elements, as a result of which it is essential for biogeochemical cycles. Also, elements found in the water column in traces may accumulate to higher levels in the sediment. Also, the sediment nurtures and harbours high populations of benthic and epi-benthic organisms. Sediment quality assessment is, hence, likely to have significant ramifications on over-all water and ecosystem quality. Organic matter, Polycyclic Organic Matter gives information about natural and anthropogenic activities within the drainage basin. The concentration of organic carbon gives information about the amount of organic matter in the sediment.

The impact of pollution on sediment quality can be analysed using various parameters of sediment analysis which are mentioned in Table 5.6

Table 5.6: Sediment Analysis Results

Sampling Location	pH	Organic Carbon (%)	Total Nitrogen (mg/kg)
Reference point	**5.0**	**0.4**	**19.6**
1	7.3	3.68	512.3
2	7.2	2.67	246.6
3	7.1	4.82	496.3
4	7.4	2.81	283.5
5	7.5	2.93	332.3

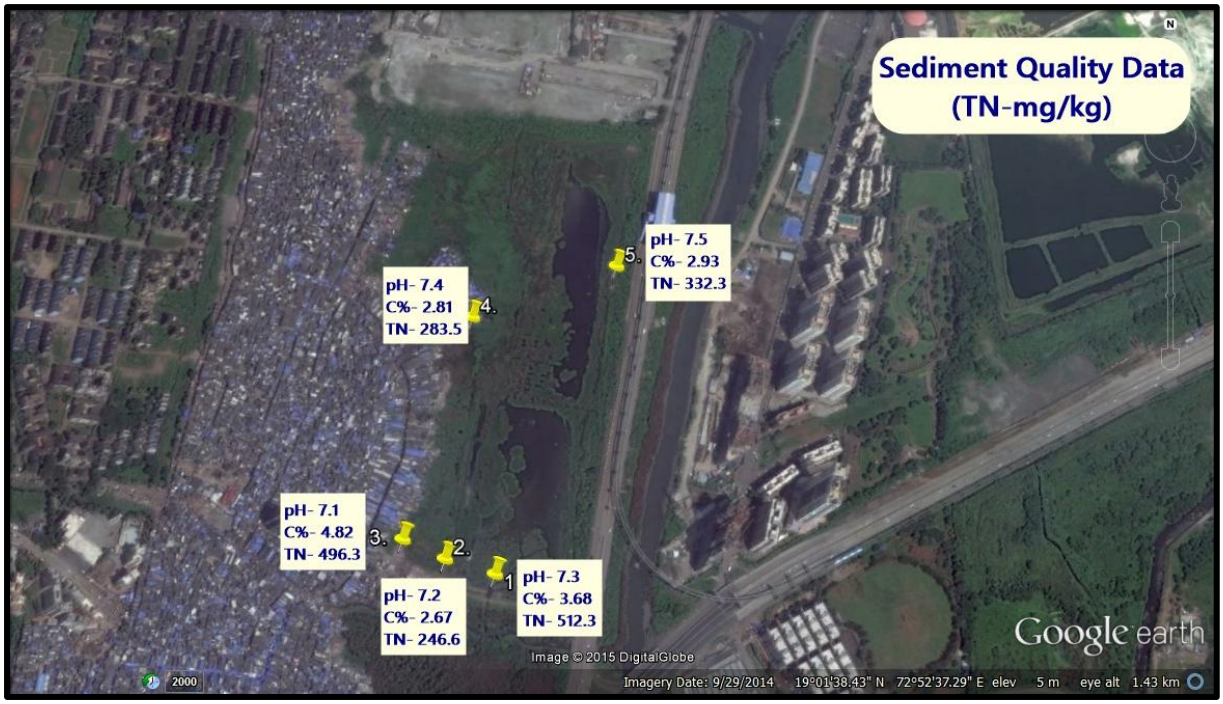


Figure 5.22: Sediment Quality Analysis Data at the Various Sampling Point

The reference point was denoted to sea sediment off Mahim bay. The pH values observed were in the range of 7.1 - 7.5 as seen in Figure 5.24. Organic carbon enters the sediments through the decomposition of plant and animal residues, living and dead micro-organisms and soil-biota. Sewage effluents rich in decomposable organic matter, is the primary cause of organic pollution. Reference point showed low organic carbon, total nitrogen whereas, high C/N ratio compared with other sampling locations. The lowest and highest organic carbon values were observed at the sampling stations 2 and 3, respectively as seen in Figure 5.23. Whereas Figure 5.25 shows lowest and highest total nitrogen values were reported at the sampling stations 4 and 1, respectively.

Results and Discussion:

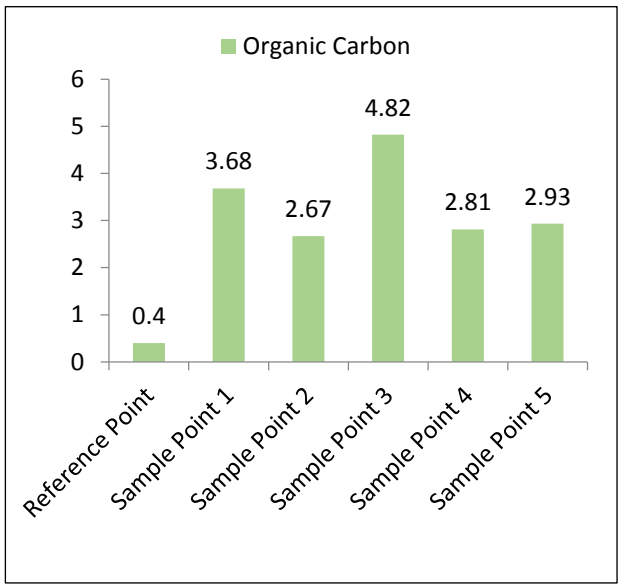


Figure 5.23: Variation in Organic Carbon

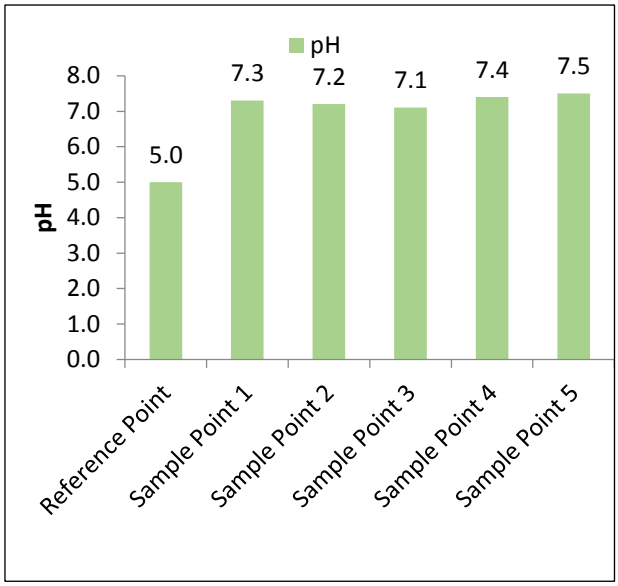


Figure 5.24: Variation of pH

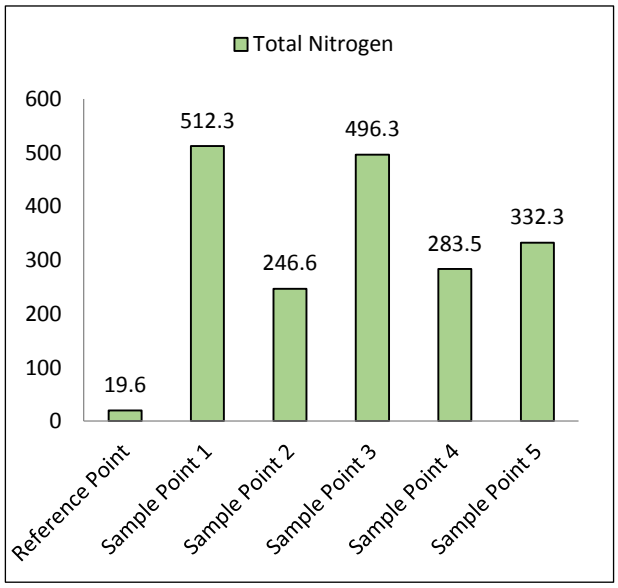


Figure 5.25: Variation in Total Nitrogen

Water sample collection was carried out on July 15, 2014 and Nov 13, 2014 during monsoon and post monsoon season, respectively. Sea water exchange on southern part adds to TDS and high chlorides. Dumping of construction material is reducing footprint of the lake. The main points during monsoon and post monsoon season are as below:

1. The pH was observed within the standard limits during both the seasons at all the sampling locations.
2. The D.O. concentrations were reported below the standard limit during both the season at all the sampling locations.
3. The Sample 4 showed low BOD during monsoon season due to dilution from rainwater.
4. The COD were observed below than standard limits at sample 2 and 4 due to dilution and less influence from slum wastewater, respectively.

5. The Sample 3 showed higher value of COD and orthophosphate concentrations due to small scale industries inflows.
6. On the basis of WQI samples 2 and 3 showed better water quality compared to other samples.
7. On the basis of sediment analysis sample 3 showed high organic carbon and total nitrogen concentrations.

Chapter 6 : Design of Proposed Treatment System

Proposed treatment system for the wastewater from different sources leading to varying levels of pollution have been explained on the basis of following parameters: process variables that includes hydrology and hydraulics of the system, volume of system, plant used, flow pattern as well as flow rate and type of wastewater treated.

6.1 Process Variables

Proposed treatment systems are considered as attached growth biological reactor. Performance of the treatment system can be described with first-order plug flow kinetics. Design process of the treatment system is based on the study of hydrology and hydraulics, it includes the flow of the overall system, their aspect ratio, retention time and organic loading rate.

6.1.1 Hydrology

Hydrologic consideration is one of the important parameter for designing the treatment system, it includes the characterization of surface water and groundwater along with the water that may enter into a proposed treatment system from various pathways such as precipitation, surface flow, groundwater flow and wastewater influent.

6.1.2 Hydraulics

Hydraulic study is one of the important factors to consider while designing the treatment system. Hydraulics study plays a major role in the determination of retention time, loading rate and control structure equipment. Above mentioned parameter plays a major role in the successful design of the treatment system.

6.1.3 Flow Rate

Flow pattern is horizontal and from the flow measurement data it seems to be laminar in nature. The maximum mean volumetric flow rate is 2.046 m^3/min.

6.1.4 Aspect Ratio

Aspect ratio is derived from Darcy's law and it is one of the critical parameter to design the treatment system. Aspect ratio of any treatment system should be in the range of three to five to make sure the proper flow of water in the treatment system. If it is lesser or more than the standard value then it leads to the short circuiting of the system.

$$Ac = \frac{Qs}{[Kf(dH/d_s)]}$$

Where:

Ac is cross-sectional area of the bed (m^2);

Qs is the average flow ($m\ s^{-1}$);

Kf is hydraulic conductivity of the media ($m\ s^{-1}$);

dH /ds is slope ($m\ m^{-1}$).

The significance of the aspect ratio is to know about the distribution of the wastewater in the bed, if the bed has a low aspect ratio i.e. in the range of three to four then there will be proper distribution of wastewater in the treatment system and no clogging at the inlet zone. In proposed design aspect ratio assumed is three.

6.1.5 Hydraulic Retention Time

Hydraulic residence time is the time that it takes for the wastewater to pass through the system. A hydraulic residence time ensures proper interaction between the physical, chemical and biological factor of the treatment system to achieve the desired efficiency. Hydraulic residence time is defined as:

t (second) = L W n d / Q

Where:

L = Length of system -parallel to flow direction (m)
W = Width of system (m)
n = porosity of the bed.
d = depth of submergence (m)
Q= average flow through the system (m^3/day)

6.1.6 Organic Loading Rate

Organic loading rate is defined as the application of soluble and particulate organic matter. It is typically expressed on an area basis as kg of BOD_5 per unit area per unit time, such as kg of BOD_5 per square meter per day (kg/m^2/day). It depends on the concentration of BOD as well as flow rate. Mathematical Significance of organic load in a system is for denitrification purpose as well overall nitrogen removal. Organic load of a system estimate the oxygen

requirement of the wetland vegetation. Oxygen required of the system is 1.5 times of the total organic load on the system.

6.1.7 Hydraulic Loading Rate (HLR)

Hydraulic loading rate is commonly accepted concept that ensures the particle capture capacity of the treatment system. It is expressed as the ratio of flow, in cubic meter per second, divided the surface area square meter. This is expressed as:

HLR = Q / LW

Hydraulic loading rate of the treatment system closely depends on the hydrological factor, factors are site specific.

6.1.8 Media

Use of filtration media in constructed wetland is for achieving the following objectives:

- *Facilitate macrophyte growth,*
- *Provide sustainable filtration effect,*
- *Maintain high hydraulic conductivity.*

In 1970s and early 1980s system used mostly soil based media which fulfilled the first two requirements but failed to maintain high hydraulic conductivity. Lower hydraulic conductivity resulted in surface flow and lower treatment efficiency

In the proposed treatment system, fresh gravel is used as media, it is a constant parameter in treatment system.

6.1.9 Vegetation

Plants are the most important components of the proposed treatment system. The proposed wastewater treatment is accomplished through an integrated combination of biological, physical and chemical interactions between the plants, the substrata and the microbial community. Functional property of macrophytes is explained in **Error! Reference source not found.**. The most frequently used plant in treatment system is Canna indica, reeds (Phragmites), cattails (Typha) and elephant grass (Pennisetum).

Table 6.1: Wetland Plant and Their Roles

Wetland Plant Part	Role
Aerial plant tissues	Light attenuation → reduced growth of phytoplankton's
	Influences on microorganism → insulation during winter
	Reduced wind velocity → reduced risk of re-suspension of solids
	Aesthetic appearance
	Nutrient storage
Plant tissue in water	Filtering effect → filter out large debris
	Reduced current velocity → increased rate of sedimentation reduced risk of re-suspension
	Surface area for attached microorganisms
	Nutrient uptake
	Excretion of photosynthetic oxygen
Roots and rhizomes	Stabilizing the sediment surface → less soil erosion
	Prevents the medium from clogging in vertical flow systems
	Release of oxygen increase organic degradation and nitrification
	Nutrient uptake
	Secretion of antibiotics for detoxification of root zone → pathogen removal

6.1.10 Porosity

Porosity is a measure of the void spaces in a material, and is a fraction of the volume of voids over the total volume.

$$\emptyset = \frac{V_V}{V_T}$$

Where:

V_V is the volume of void-space and V_T is the total or bulk volume of system, including the solid and void components.

Both the symbols Ǿ and are used to denote porosity. By the above mentioned formula void volume of the system is 70% and vertical subsurface system has 40% porosity.

6.2 Physical Design

Physical design basically consists of system configuration, screening chamber and flow channelization system to ensure the plug flow condition with the help of proper aspect ratio.

6.2.1 Screening Unit

In order to prevent the entry of floating material in to the treatment zone screening unit should be placed at the initial point of treatment system. In order to achieve this, a trough can be created inside the water body before the screening unit. The solids would settle under the influence of gravity and they must be removed periodically. After this, a screening unit will remove all the floating material. The screening unit must be cleaned at periodic interval for better efficiency of the system.

6.12.2 System Configuration

Configuration of the floating treatment system consist of dimension of the system based on the calculation of the volumetric flow rate, aspect ratio and cross sectional area of the water body.

Hydraulic Retention Time = 24 hours

Hydraulic loading: 1.2 MLD

Total no. of bed = 6 (each having two parallel units)

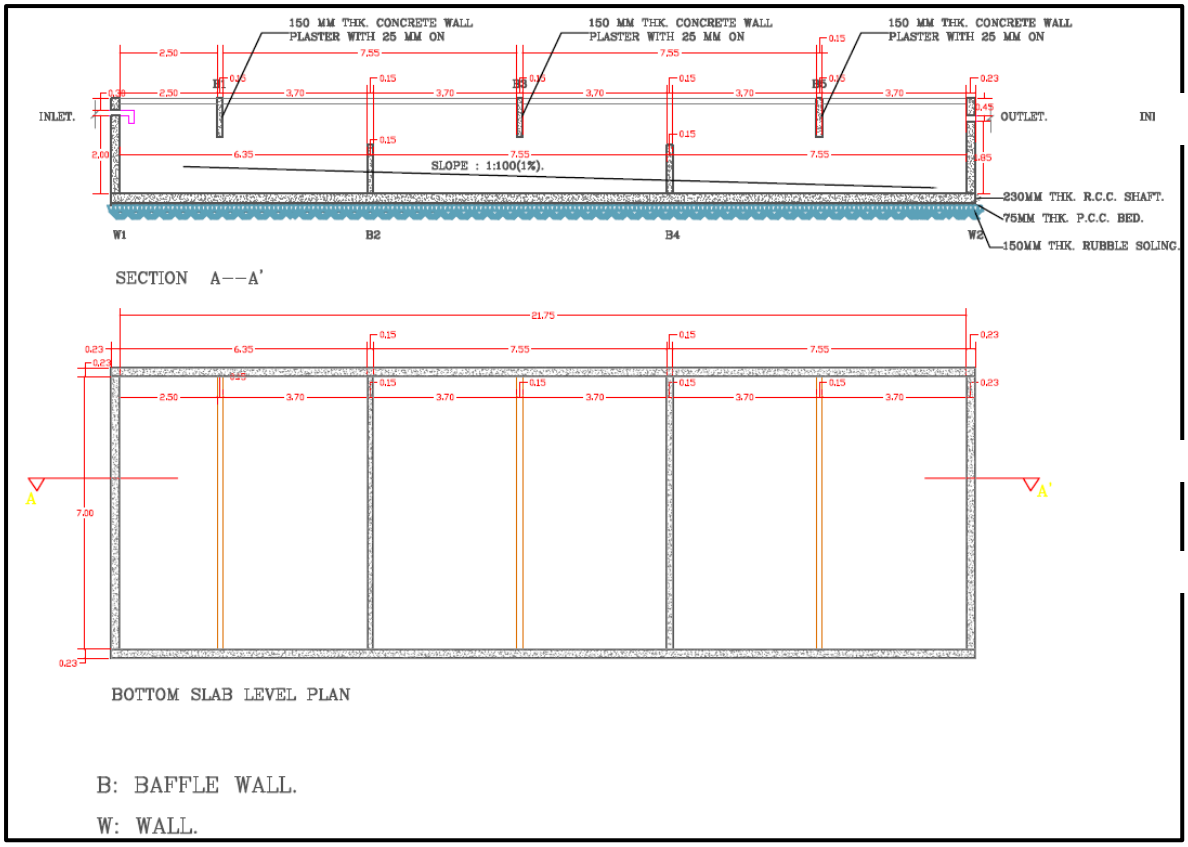


Figure 6.1: Schematic Design of IWT for Wastewater Treatment

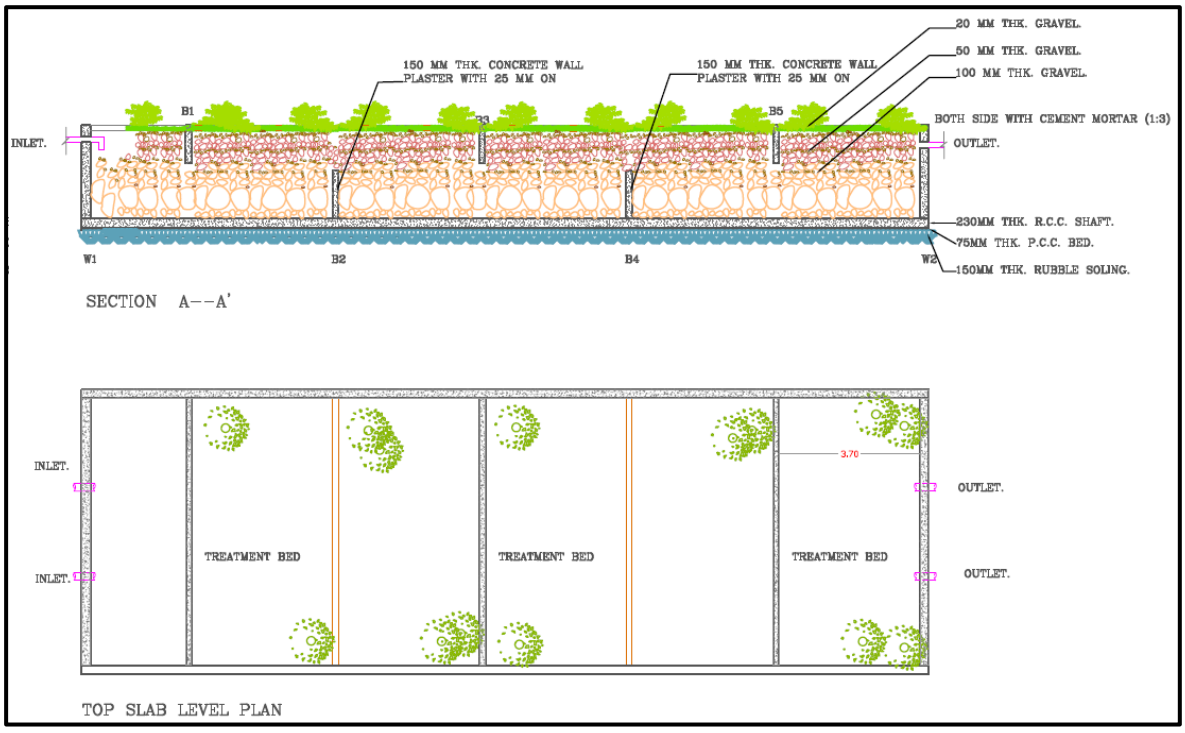


Figure 6.2: Sectional View and Top view of the IWT Plant

Schematic diagram for wastewater treatment technology is illustrated in Figure 6.1 and Figure 6.2. The top view, sectional view also the construction of schematic design for civil work has been described in it. The proposed design for treatment plant will be implemented mainly on the eastern boundary to treat the wastewater from the slums.

Chapter 7 : Socio-economic Survey

7.1 Introduction

Stakeholder involvement in environmental management is an acclaimed step used popularly in the western countries. This is probably because of the dynamic and complex nature of environmental issues, which requires relevant decisions to be flexible and based on as broad a knowledge base as possible. However, public attitude towards the environment is seldom ideal, it is either one of apathy or that of active antagonism. Especially, there is a general misbelief that ecosystems such as wetlands and mangroves do not serve any purpose and are, indeed, wastelands.

Keeping this in mind the importance of involving stakeholders in environmental management and also the aspect of creating a positive awareness regarding ecosystem goods and services, the tool of a questionnaire-based socio-economic survey becomes an obvious answer.

7.1.1 Methodology

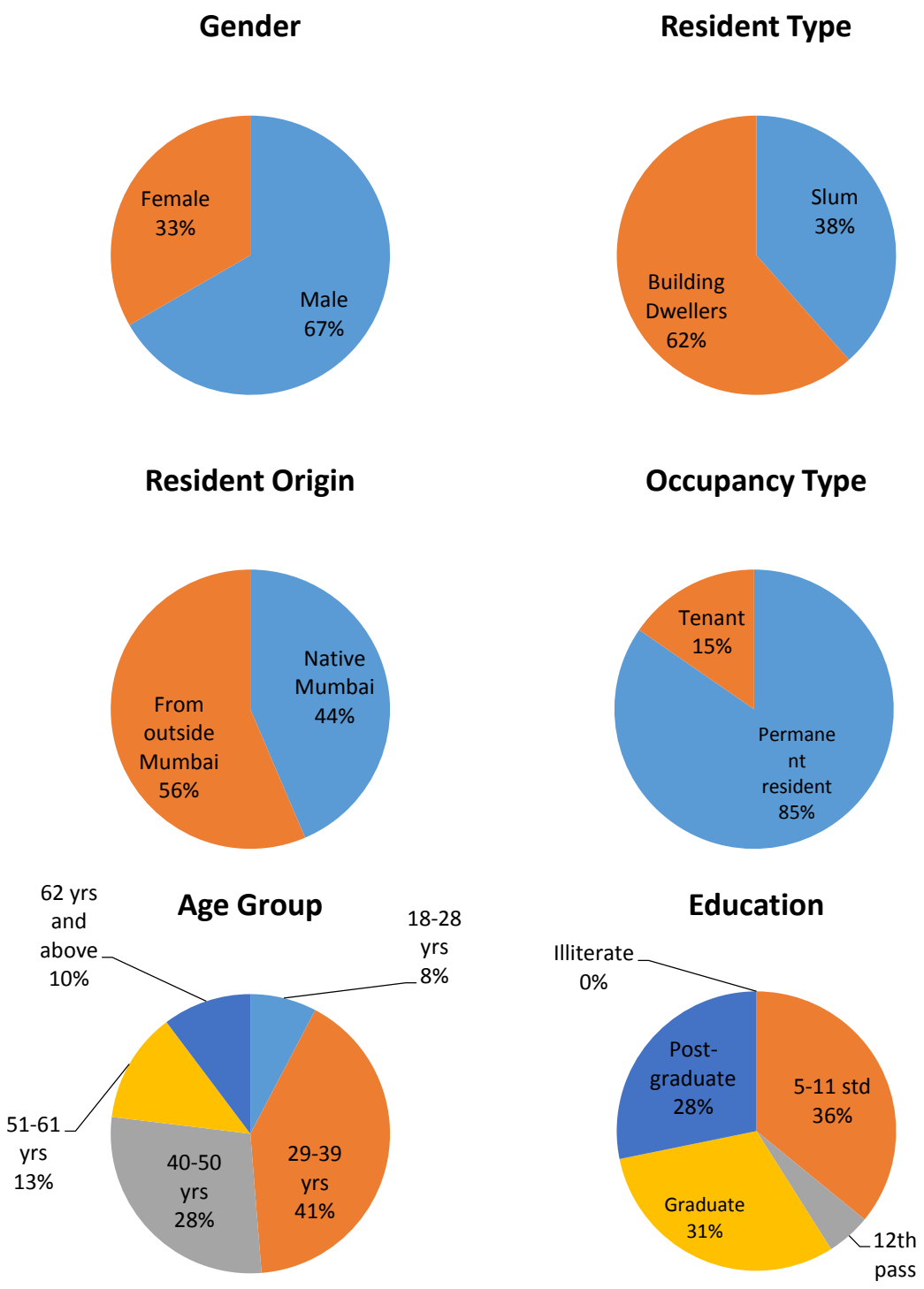
A questionnaire-based voluntary survey was conducted among the local stakeholders. The same was a structured questionnaire. It was a mix of open-ended and close-ended questions. Open-ended questions invite the opinion of the interviewee while close-ended ones restrict him/her to the alternatives mentioned in the questionnaire. Hence, a mix of the two types is considered ideal for social research as they can be used to expand the scope of either method and offset the weakness of each method if used alone.

The purpose of the questionnaire was to ascertain their current level of awareness and attitude towards the wetland. The stakeholders were also invited to submit their ideas as to how the wetland should be improved for future use. A total of 39 individuals were approached for the survey – of these 24 were residents of housing societies on the opposite side of the Sewri-Chembur Road with a view of the wetland. These housing societies were: Orchid, Hilton, Venus and Mount Alps. The questionnaire was prepared in English and distributed among volunteers for perusal and filling-up. Several questionnaires were filled in by our representative after verbally asking the questions of the respondents (in English, Hindi and Marathi, as required) and filling up the questionnaire in front of them.

A copy of the questionnaire used for survey has been provided as Annexure VI.

7.2 Analysis of Responses

Detailed analysis of the survey data has been given in the Figure 7.1. All data is in percentage.



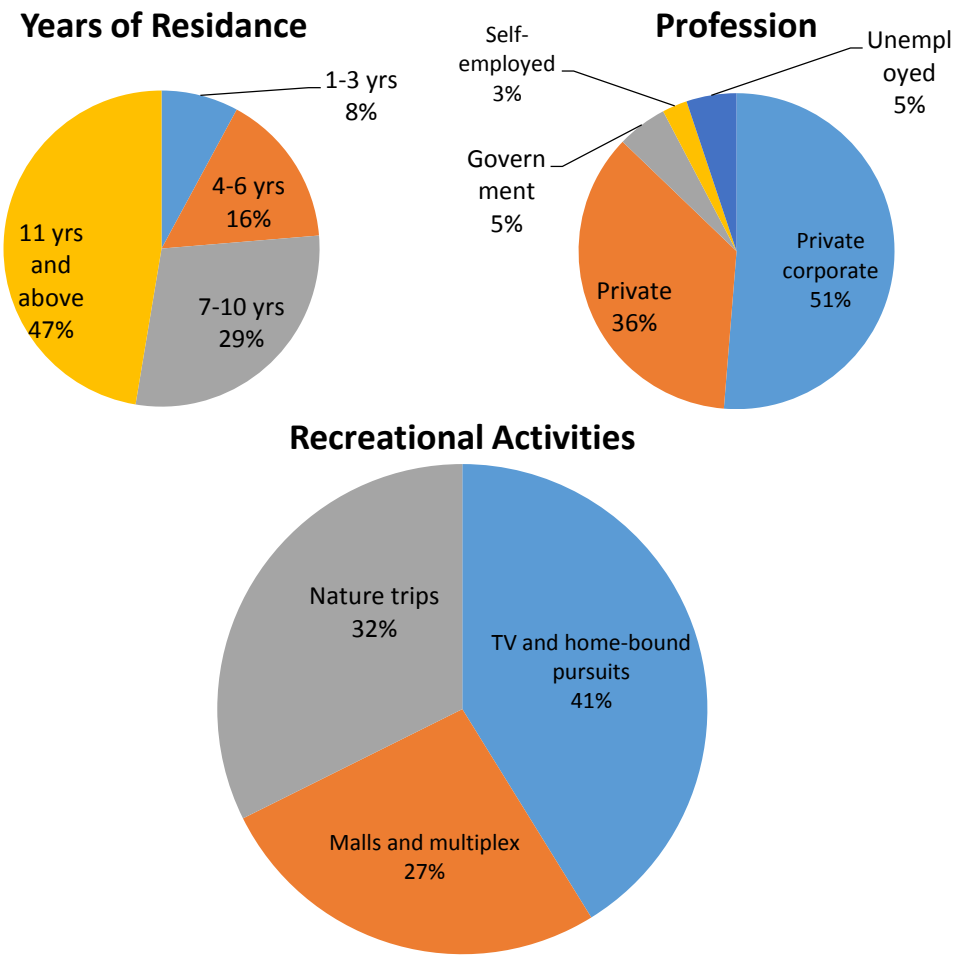


Figure 7.1: Analysis of Responses on Various Parameters

About 38% of the surveyed population (n= 15) was from the slum-dwellers, while the rest were residents of buildings on the opposite side of the Sewri-Chembur Road. Residents of these buildings had a view of the wetland from their buildings. However, it may be noted here that new buildings were coming up between the existent buildings and the Sewri-Chembur Road and the surveyed buildings will probably lose their direct view of the proposed water body. The surveyed population had the following features:

1. Were males (66.7%, n = 26)
2. Were permanent residents (86.4%, n = 33)
3. Natives of regions outside Mumbai, and at times Maharashtra (56.4%, n = 22)
4. Were in the age-group of 29-39 years (41.0%, n= 16)
5. Had resided in the area for more than 11 years (46.2%, n = 18)
6. Were educated up to 5^{th} -11^{th} grade (35.9%, n = 14)
7. Were privately employed (35.9%, n = 14)
8. Preferred television and other homebound pursuits as recreational activity (35.9%,

n =14).

Interestingly, 28.2 % of the surveyed residents (n = 11) claimed to prefer nature trips as a pastime.

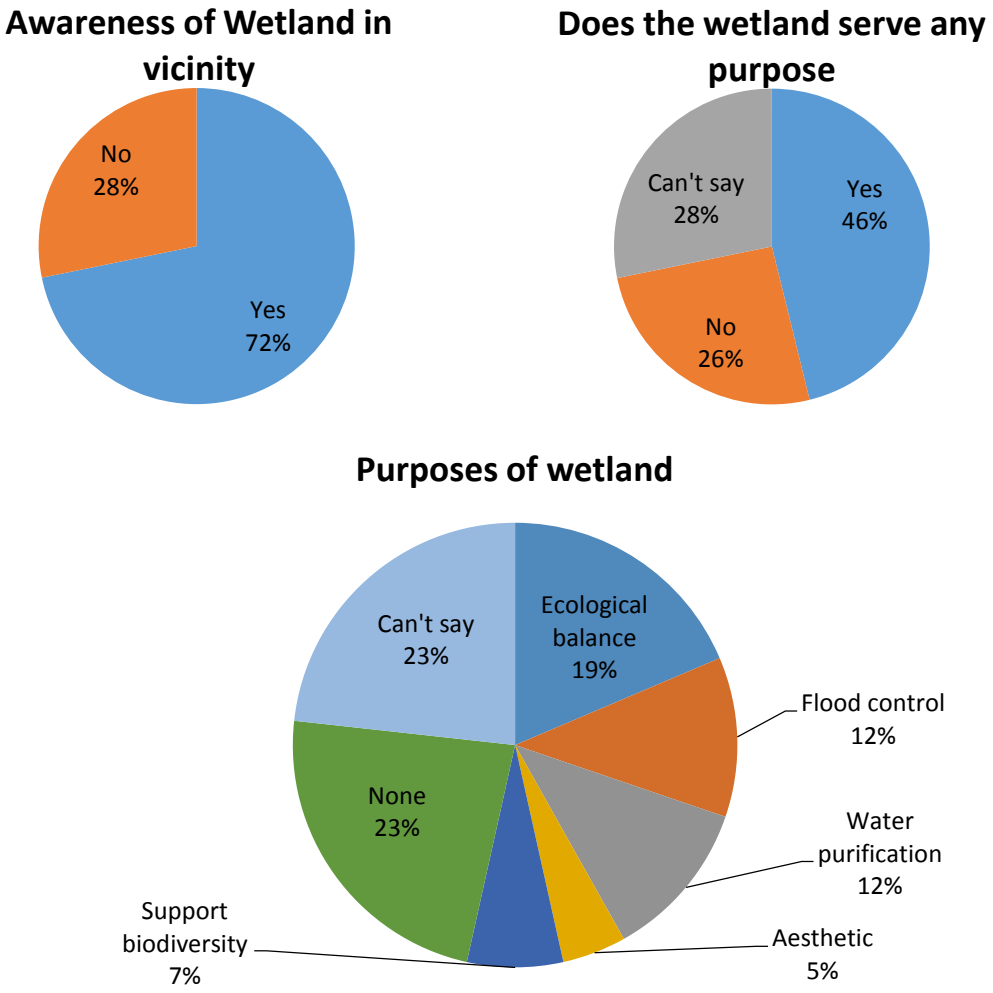


Figure 7.2: Results of the Survey Based on the Questions Asked

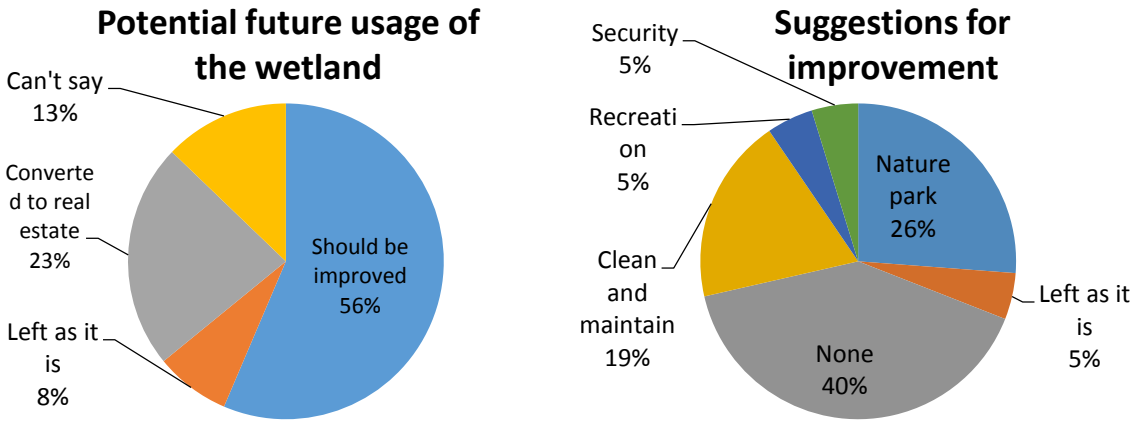


Figure 7.3 Results of the Survey Based on Questions Asked (contd.)

The responses of all the stakeholders with respect to questions specific for the wetland (Questions results given in Figure 7.3) were analysed and found to be similar irrespective of gender, age-group, place of origin, years of residence and permanency/tenancy. However, education and profession were factors on the basis of which the attitude and response towards the wetland were found to vary. Deeper analysis revealed that these two factors were in turn dependent on whether the questioned individual lived in a slum or a building. In short, a wide disparity was observed between the responses of the slum-dwellers and the residents of buildings.

Hence, the responses of the two groups were separated and then analysed. Results have been provided in the Table 7.1:

Table 7.1: Responses from Different Localities

Question??	Most Popular Answer	
	In Slums (% answered)	In Buildings (% answered)
Education	5^{th} -11^{th}std (93.3%)	Graduate (50%); Post-graduate (45.8%)
Profession	Private (93.3%)	Private corporate (83.3%)
Preferred pastime	TV and other homebound pursuits (100%)	Nature trips (54.2%)
Aware that a wetland exists in the vicinity?	Yes (73.3%)	Yes (70.8%)
Does this wetland serve any purpose?	No (66.7%)	Yes (66.7%)
If yes, what?	None (93.3%)	Ecological balance (29.1%)
Future potential usage of the wetland?	Convert it to real estate (46.7%)	Improve it (83.3%)
Suggestions for improvement?	None (100%)	Develop it as a Nature park (37.5%)

Findings:

The Table 7.1 indicates that slums will have to be especially targeted with respect to making their attitudes more amenable towards the development of the ecological infrastructure. At the same time, the population residing in the buildings must also be made more aware regarding the science behind nature.

Residents from both housing societies and slums will benefit from the wetland water body in terms of open space, aesthetical values and spiritual freedom, rich flora and fauna shall be a source of recreation. As of present scenario there is no open space available for the people

residing in the area. Seemingly, it is a concrete jungle with lots of traffic, pollution and dust and waste all around. Due to the lack of open space, the residents does not have a recreational facility in their close vicinity. Even children lack the opportunity to observe nature and learn from it along which would enhance their development and skills.

In the current context it would be best to develop the water body based on nature ideology, with natural resources used and innovative technology which is nature friendly to mitigate the effects of pollution shall be commissioned. Not only the residents of Mumbai but also visiting tourists would be appealed by the wetland ecosystem and find this as a place of attraction among all other places to visit.

Additionally, the city of Mumbai does not have places where the nature is at its best and at the same time is friendly to the humans too. An opportunity is presented here for the people to connect with nature among the crowded Mumbai.

Chapter 8 : Revival of Wadala Water Body- Recommendation

Wadala water body after human interference is in a vulnerable state and needs a renewed intervention to revive the wetland ecosystem that once used to thrive there. As of now, wetland is a dumping ground subjected to solid waste dumping, construction debris from neighbouring construction activities; a bank for sewage and sea water intrusion. The challenge that lies ahead is to revive the water body which can be fulfilled only when different problems associated with its deterioration is dealt individually. The solution for each defined problem should be of minimum concretisation and glass use; it should go the nature's way in the nature's arena.

Development of the wetland system into an **ECO-PARK** is recommended here, not only for its revival but also to build a healthy ecosystem which supports the diverse flora and fauna. For achieving the same, a stepwise outline to tackle each problem has been dealt with great care and final recommendations for the revival of the water body are made. These recommendation are described below.

8.1 Bottlenecks and Solutions

Various bottlenecks for the development of the Wadala water body exists and each of them should be dealt with utmost precision and care for comprehensive development of the water body.

8.1.1 Sanitation

The people dwelling in the slums lack proper sanitation facilities and resort to open defecation around the water body. The water body thus, is filthy and also gives unpleasant odour. Majorly, the road sides and the western boundary of water body touching the slums are resorted to open defecation.

Solutions:

- A proper and convenient sanitation facility for the slum dwellers.
- The facility should be made either free or on a charge nominally (pay and use).
- Awareness campaign for the slum dwellers to be carried out, in order to educate them about the consequences of open defecation

8.1.2 Wastewater treatment

The wastewater from the slums and small industries around is being continuously discharged into the water body. The water flows and gets accumulated in the water body due to its land gradient. Consequently, the water body is rendered unfit for the aquatic flora and fauna, simultaneously also affecting the population of migratory birds and the ecosystem. In order to treat the wastewater, a design of natural wastewater treatment systems (IWT/Phytorid) have been proposed earlier. The position for the wastewater treatment units at Wadala water body site is showed in Figure 8.1.

Solutions:

- The collection trench with 24 hours HRT shall be installed for wastewater collection.
- The complete stretch towards the slum of the water body on the western end shall be provided with a treatment bed, each comprising of two parallel treatment units for wastewater.
- The treated water from the units will be safe to discharge in the water body

Figure 8.1: Representative Positioning of the Wastewater Treatment Plants

8.1.3 Municipal Solid Waste Management

The slum dwellers on the western frontier of the water body are dumping solid waste into and near the water body area. The current condition stands compromised where the water body is

full of all sort of wastes and also effluents from the both small industries and slums. Even the construction debris is dumped on the northern end.

Solutions:

- Proper waste disposal system by the municipal corporation for the slum dwellers.
- Regular collection of solid waste by suitable vehicles.
- Provision for dustbin should be made after the rejuvenation of Wadala eco-park.
- Regular maintenance of these dustbins made a mandate.
- Monitoring systems in the eco-park like CCTV camera provided to keep a check on unwanted activities.
- Awareness programs for slum dwellers and residents of housing societies to be organised for topics:
    - Municipal Solid Waste
    - Segregation of solid waste, process and its benefits
    - Benefits and ill-effects of proper and improper disposal of waste

8.1.4 Biodiversity enrichment

Flora and fauna diversity is affected in the area due to pollution and encroachment. Migratory birds which were once an attraction of the area is reduced on a large scale.

Solutions:

- No further disturbance for indigenous flora and fauna.
- Cleaning of the water body.
- New plants to support the ecosystem can be planted.

Security

Continuous encroachment in the water body is due to the open area available and no demarcation of the water body boundary. Consequently, the area under water coverage is reducing and also hampers the flora and fauna of the ecosystem.

Solutions:

- Prevent encroachment around the water body by building a restriction boundary.
- Monitoring system such as CCTV camera should be installed to prevent unlawful activities

- Provision for lighting facilities.
- Periodic visits by authorities to regulate the upkeep.

After rejuvenation of the water body the various bottlenecks would have been completely overcome. Sustained maintenance of all the solutions provided is mandatory for the upkeep of the health of the water body.

8.2 Concept Design- Wadala Water Body

At the current pace of development the existence of natural ecosystem is dwindling. Additionally, the human life is moving at a running pace such that it seldom gets time to venture into the lap of nature. An approach is needed to provide an ecosystem within the jungle of concrete buildings, where humans can acknowledge nature and enjoy in the lap of nature. An existing wetland ecosystem at Wadala is slowly deteriorating at a fast pace, hence, it is proposed here to develop it as an Eco-Park with various facilities to allow humans to experience nature.

The concept proposal includes various breakthroughs to allow for interaction of people with the ecosystem without disturbing it. Holistic approach for the development of the Wadala ecosystem as an Eco-park will be adopted. Beneficiaries arising from this approach would include the nature as well as people. Adaptation of ecological engineering to maintain an overall development of the ecosystem. Environment awareness centre will also be incorporated along with suitable other recreational plans; redefining the meaning of “recreation”. Sustainable development of the complete area under concern as well as its neighbourhoods would be taken up along with suggestions for management and sustained maintenance.

Site development and rejuvenation would include several sub-level projects to counter several environmental issues. Commissioning of all the small projects would lead to the development of an **ECO-PARK** at the Wadala wetland site.

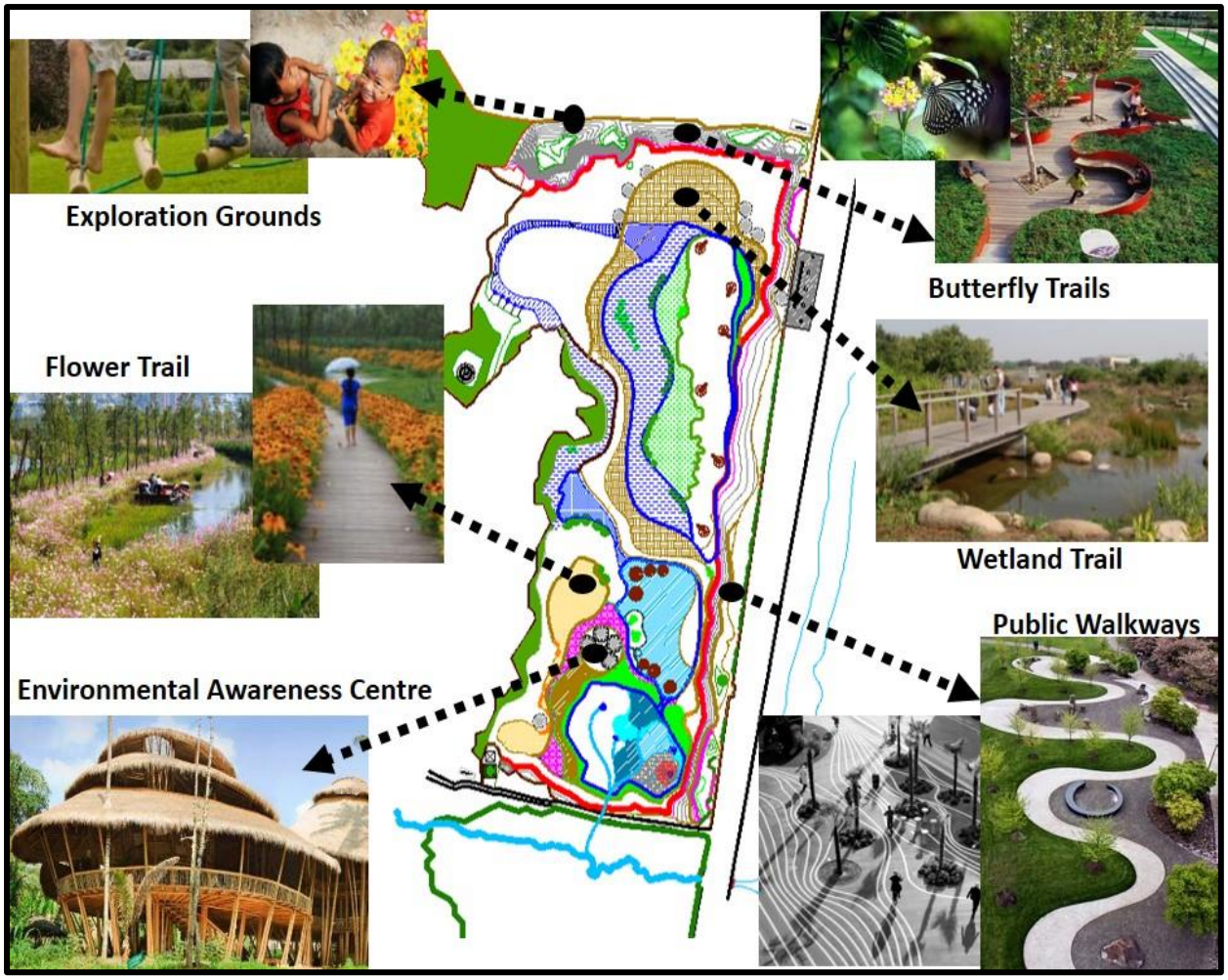


Figure 8.2: Proposed Design Concept of Wadala Eco-Park

All round development for the Wadala water body is conceptualized as represented in the Figure 8.2. Environmental awareness centre, public walkways, wetland trail, flower trail, butterfly trail, exploration grounds are all means to connect public with the nature and the ecosystem. This provides recreation along with education and awareness to the common bout the ecosystem and nature.

8.2.1 Indulge-in Activities at Wadala Eco-Park

Environment enthusiast as well as common man all get an equal opportunity to connect to the nature and the wetland ecosystem. They observe the ecosystem closely as well as become a part of it while being in the Eco-park. Recreation in the eco-park comes with no disturbance to the natural trail.

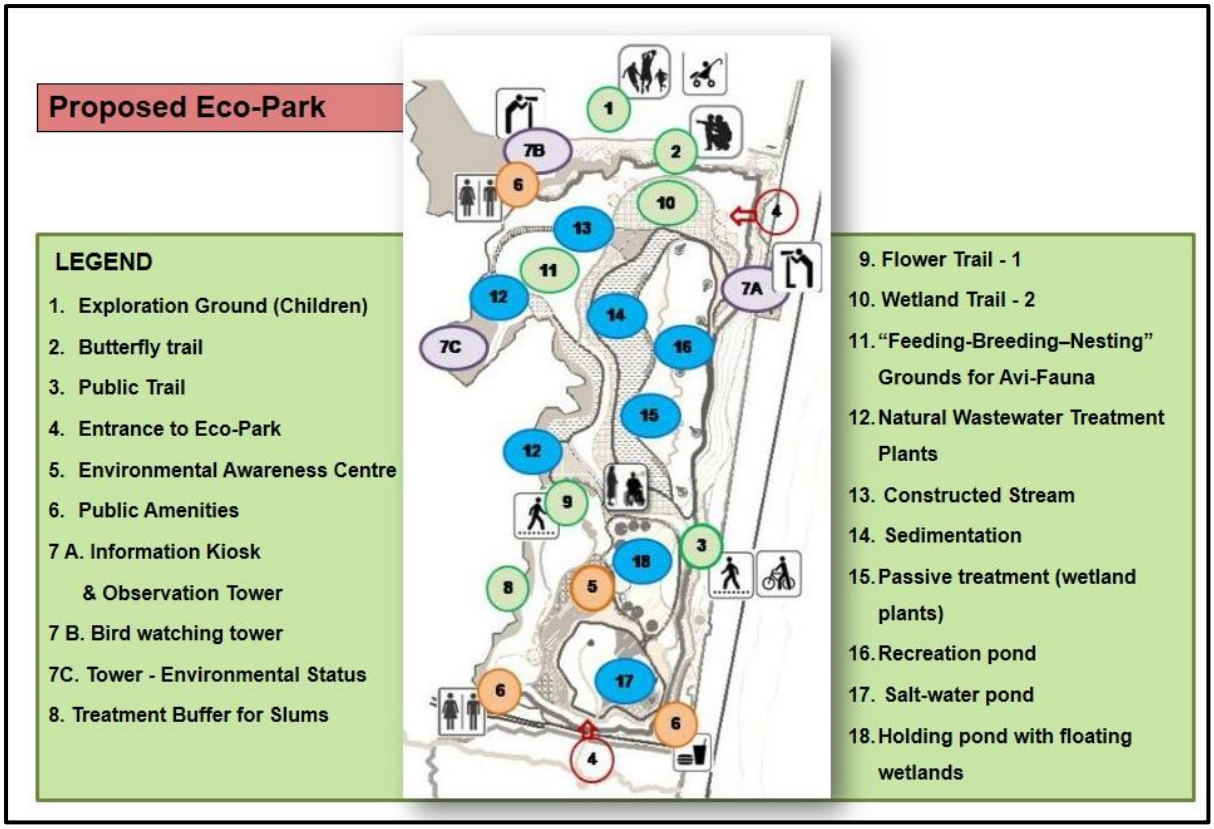


Figure 8.3: Schematic Location of Various Indulge-in Activities for Public

Figure 8.3 shows possible options to be developed at Wadala water body which will be available for the public to explore and connect with the nature. Recreation for all walks of life has been taken care of and each get an equal opportunity to connect with the nature and enjoy with it.

Annexure I

Monsoon Images

Sea Water intrusion point

Sea Water intrusion point

Eutrophication of water body

Flow of Nallah during rain

Condition of water body during rain

Condition of place during rains

Pollution of water body because of waste coming from slums

Annexure II

Water sampling Images Post Monsoon

Water sampling after monsoon is over

Annexure III

Soil Sampling

Soil sampling being carried out at Wadala water body

Annexure IV

Flow rate measurements

Flow rate measurement at source 1

Flow rate measurement at source 2

Flow rate measurement at source 3

Flow rate measurement at source 4

Annexure V

Central Pollution Control Board (CPCB) Standards

GENERAL STANDARDS FOR DISCHARGE OF ENVIRONMENTAL POLLUTANTS PART-A : EFFLUENTS

S. No.	Parameter	Standards			
		Inland surface water	Public Sewers	Land for irrigation	Marine coastal areas
1	2			3	
		(a)	(b)	(c)	(d)
1.	Colour and odour	See 6 of Annexure-I	--	See 6 of Annexure -I	See 6 of Annexure-I
2.	Suspended solids mg/l, Max.	100	600	200	(a) For process waste water- 100 (b) For cooling water effluent 10 percent above total suspended matter of influent.
3.	Particulate size of suspended solids	Shall pass 850 micron IS Sieve	--	--	(a) Floatable solids, max. 3 mm. (b) Settleable solids, max. 850 microns.
[2]4.	***	*	--	***	--
5.	pH Value	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0	5.5 to 9.0
6.	Temperature	shall not exceed $5^{o}C$ above the receiving water temperature	--	--	shall not exceed $5^{o}C$ above the receiving water temperature

[1] Schedule VI inserted by Rule 2(d) of the Environment (Protection) Second Amendment Rules, 1993 notified vide G.S.R. 422(E) dated 19.05.1993, published in the Gazette No. 174 dated 19.05.1993.

[2] Omitted by Rule 2(d)(i) of the Environment (Protection) Third Amendment Rules, 1993 vide Notification No.G.S.R.801(E), dated 31.12.1993.

S. No.	Parameter	Standards			
		Inland surface water	Public Sewers	Land for irrigation	Marine coastal areas
1	2			3	
		(a)	(b)	(c)	(d)
7.	Oil and grease mg/l Max.	10	20	10	20
8.	Total residual chlorin mg/l Max.	1.0	--	--	1.0
9.	Ammonical nitrogen (as N), mg/l Max.	50	50	--	50
10.	Total Kjeldahl Nitrogen (as NH_3) mg/l, Max.	100	--	--	100
11.	Free ammonia (as NH_3) mg/l, Max.	5.0	--	--	5.0
12.	Biochemical Oxygen demand [1][3 days at 27^oC] mg/l max.	30	350	100	100
13.	Chemical Oxygen Demand, mg/l, max.	250	--	--	250
14.	Arsenic (as As), mg/l, max.	0.2	0.2	0.2	0.2
15.	Mercury (as Hg), mg/l, Max.	0.01	0.01	--	0.01
16.	Lead (as Pb) mg/l, Max.	0.1	1.0	--	2.0
17.	Cadmium (as Cd) mg/l, Max.	2.0	1.0	--	2.0
18.	Hexavalent Chromium (as Cr+6), mg/l max.	0.1	2.0	--	1.0

[1] Substituted by Rule2 of the Environment (Protection) Amendment Rules, 1996 notified by G.S.R.176, dated 2.4.1996 may be read as BOD (3 days at 27^oC) wherever BOD 5 days 20^oC occurred.

S. No.	Parameter	Standards			
		Inland surface water	Public Sewers	Land for irrigation	Marine coastal areas
1	2			3	
		(a)	(b)	(c)	(d)
19.	Total chromium (as Cr.) mg/l, Max.	2.0	2.0	--	2.0
20.	Copper (as Cu) mg/l, Max.	3.0	3.0	--	3.0
21.	Zinc (As Zn.) mg/l, Max.	5.0	15	--	15
22.	Selenium (as Se.) mg/l, Max.	0.05	0.05	--	0.05
23.	Nickel (as Ni) mg/l, Max.	3.0	3.0	--	5.0
[1]24.	* * *	*	*	*	*
[1]25.	* * *	*	*	*	*
[1]26.	* * *	*	*	*	*
27.	Cyanide (as CN) mg/l Max.	0.2	2.0	0.2	0.2
[1]28.	* * *	*	*	*	*
29.	Fluoride (as F) mg/l Max.	2.0	15	--	15
30.	Dissolved Phosphates (as P), mg/l Max.	5.0	--	--	--
[2]31.	* * *	*	*	*	*
32.	Sulphide (as S) mg/l Max.	2.0	--	--	5.0
33.	Phenoile compounds (as C_6H_5OH) mg/l, Max.	1.0	5.0	--	5.0

[1] Omitted by Rule 2(d)(i) of the Environment (Protection) Third Amendment Rules, 1993 vide Notification No.G.S.R.801(E), dated 31.12.1993.

S. No.	Parameter	Standards			
		Inland surface water	Public Sewers	Land for irrigation	Marine coastal areas
1	2	3			
		(a)	(b)	(c)	(d)
34.	Radioactive materials :				
	(a) Alpha emitter micro curie/ml.	10^{-7}	10^{-7}	10^{-8}	10^{-7}
	(b) Beta emitter micro curie/ml.	10^{-6}	10^{-6}	10^{-7}	10^{-6}
35.	Bio-assay test	90% survival of fish after 96 hours in 100% effluent	90% survival of fish after 96 hours in 100% effluent	90% survival of fish after 96 hours in 100% effluent	90% survival of fish after 96 hours in 100% effluent
36.	Manganese (as Mn)	2 mg/l	2 mg/l	--	2 mg/l
37.	Iron (as Fe)	3 mg/l	3 mg/l	--	3 mg/l
38.	Vanadium (as V)	0.2 mg/l	0.2 mg/l	--	0.2 mg/l
39.	Nitrate Nitrogen	10 mg/l	--	--	20 mg/l
[1]40.	* * *	*	*	*	*

[1] Omitted by Rule 2(d)(i) of the Environment (Protection) Third Amendment Rules, 1993 vide Notification No. G.S.R. 801(E) dated 31.12.1993

PRIMARY WATER QUALITY CRITERIA FOR CLASS SW-II WATERS			
(For Bathing, Contact Water Sports and Commercial Fishing)			
S.No.	Parameter	Standards	Rationale/Remarks
1	pH range	6.5-8.5	Range does not cause skin or eye irritation and is also conducive for propagation of aquatic lives.
2	Dissolved Oxygen	4.0 mg/I or 50 per cent saturation value whichever is higher.	Not less than 3.5 mg/1 at anytime for protection of aquatic lives.
3	Color and Odor	No noticeable color or offensive odor	Specially caused by chemical compound like creosols phenols, naptha, benzene, pyridine toluene etc. causing visible coloration of water and tainting of and odor in fish flesh.
4	Floating Matters	Nothing obnoxious or detrimental for use purposes.	None in such concentration that would impair usages specially assigned to this class.
5	Turbidity	30 NTU (Nephelo Turbidity Unit)	Measured at 0.9 depth
6	Fecal Coliform	100/100 ml(MPN)	The average value not exceeding 200/100 ml in 20 per cent of samples in the year and in 3 consecutive samples in monsoon months.
7	Biochemical Oxygen Demand (BOD) (3 days at 27°C)	3 mg/I	Restricted for bathing (aesthetic quality of water). Also prescribed by IS:22961974.

Annexure VI

QUESTIONNAIRE USED FOR THE SURVEY

Date:_____ ***Place:_____*** ***Survey no.:_____***

GENERAL INFORMATION

1) Name: - _____

2) Gender: - Male / Female

3) Age group: - 1) 18 – 28 years
2) 29 – 39 years
3) 40 – 50 years
4) 51 – 61 years
5) 62 years and above

4) Education: - 1) Illiterate
2)5 – 11 standard
3)12th pass
4) Graduate
5) Post Graduate

5) Native Place:-_____

6) How long you have been living here? :-
1) 1 to 3 years
2) 4 to 6 years
3) 7 to 10 years
5) 11 years and above

8) Resident: -
1) Permanent
2) tenant

9) Profession: -
1) Govt
2) Private (Corporate)
3) Private
4) Self-employed
5) Unemployed

WETLAND-SPECIFIC INFORMATION

9) Are you aware that there is a wetland area near your home/place of commute?
1) Yes
2) No

10) Do you feel this wetland serves any purpose?

1) Yes
2) No

11) If Yes, What?

_____

_____

10) What is your perception about the potential future use of this wetland?

1) It should be retained as it is

2) It should be improved
2) It should be destroyed and converted to other uses
3) I am neutral as to whether it is there or not

12) MMRDA is planning to develop it as an ecological infrastructure centre for urban recreation and biodiversity. What's your opinion about it? What do you think should be done?

_____

_____

_____

This is a unique exercise of Ecological Infrastructure creation. We solicit your interest in your surrounding nature and biodiversity and help conserve it.

N.B. Slum-dwellers were asked two additional questions:

10) What is your source of water supply? : -

1) Own piped water supply
2) Common municipality tap

11) Do you use public toilet? : -

1) Yes
2) No (Hence, open defecation)