Assessing and Improving Urban Sanitation - a Case study approach of Odisha Integrated Sanitation Improvement Project

by

Sankalp Swastik Sahoo,

M.Tech, Environmental Engineering,
Delhi Technological University, Delhi, 2015

SUBMITTED TO THE DEPARTMENT OF ENVIRONMENTAL ENGINEERING,
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CERTIFICATE

This is to certify that the thesis entitled **Assessing and Improving Urban Sanitation - a Case study approach of Odisha Integrated Sanitation Improvement Project** submitted by Mr. Sankalp Swastik Sahoo, in partial requirement for the award of Master of Technology in Environmental Engineering at the Delhi Technological University, Delhi, is an authentic work carried out by him under my supervision and guidance. To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the award of any Degree or Diploma.

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Dedicated to my Parents, Mentor, Friends

and

the Almighty…

List of Abbreviations and Symbols

Sl No.	Abbreviation/Symbol	Expansion/Meaning of the Abbreviation/Symbol
1	AFBR	Anaerobic Fluidized Bed Reactor
2	ASP	Activated Sludge Process
3	AWWA	American Water Works Association
4	BAF	Biological Aerated Filters
5	BBSR	Bhubaneswar
6	BDA	Bhubaneswar Development Authority
7	BIS	Bureau of Indian Standards
8	BMC	Bhubaneswar Municipal Corporation
9	BOD_5	5 days Biochemical Oxygen Demand
10	CDP	City Development Plan
11	COD	Chemical Oxygen Demand
12	CPCB	Central Pollution Control Board, Ministry of Environment and Forests
13	CPHEEO	Central Public Health and Environmental Engineering Organisation
14	CPM	Critical Path Method
15	DO	Dissolved Oxygen
16	EIA	Environmental Impact Assessment
17	EMP	Environmental Management Plan
18	EPA	Environmental Protection Agency
19	FC	Fecal Coliform
20	GIS	Geographical Information System
21	GOI	Government of India
22	GOO	Government of Orissa
23	GPS	Global Positioning System
24	HUDD	Housing and Urban development Department
25	JBIC	Japanese Bank for International Co-operation
26	JICA	Japan International Cooperation Agency
27	JNNURM	Jawaharlal Nehru National Urban Renewal Mission
28	JPY	Japanese Yen

29	LPCD, l/c/d	Litres per Capita per Day
30	MBR	Membrane Bioreactor
31	MCD	Municipal Corporation of Delhi
32	mg/l	Milligram/ Litre
33	mld	Million Litres per day
34	MoF	Ministry of Finance
35	MoUD	Ministry of Urban Development
36	MPN	Most Probable Numbers
37	NHAI	National Highway Authority of India
38	NRCD	National River Conservation Directorate
39	NRW	Non-Revenue Water
40	O&M	Operation and Maintenance
41	OP	Oxidation Pond
42	OREDA	Orissa Renewal Energy Development Agency
43	OSPCB	Orissa State Pollution Control Board
44	OWSSB	Orissa Water Supply and Sewerage Board
45	PERT	Program Evaluation Review Technique
46	PHEO	Public Health and Engineering Organisation
47	PMU	Project Management Unit
48	R&R	Rehabilitation & Resettlement
49	RL	Reduced Level
50	RS	Remote Sensing
51	SAPROF	Special Assistance for Project Formation
52	SASP	Standard Activated Sludge Process
53	SBR	Sequence Batch Reactor
54	SPCB	State Pollution Control Board
55	SS	Suspended Solids
56	STP	Sewerage Treatment Plant
57	TC	Total Coliform
58	TSS	Total Suspended Solids
59	UASB	Up flow Anaerobic Sludge Blanket
60	ULBs	Urban Local Bodies
61	WHO	World Health Organization
62	WWTP	Waste Water Treatment Plant

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Submitted to the Department of Environmental Engineering, Delhi Technological University, Delhi, India on 8th July 2015 in partial fulfilment of the requirements of the degree of Master of Technology in Environmental Engineering

Abstract

The present rate of techno-economic advancement has outpaced our ability to conform to many facets in our daily life. The development in the sanitation system, particularly, urban sanitation, has remained, mostly, sluggish. Behavioural change coupled with technological metamorphosis are the most important factors towards overhauling the present urban sanitation system in India. The Odisha Integrated Sanitation Improvement Project funded by JICA, aims at improving the sanitation system in the capital city of Bhubaneswar. Though the city is the capital of the state with a copious supply of water, it has no conventional Wastewater Treatment facility or any centralized sewerage system. Even though the project report was prepared in 2005, rapid development of the city due to an unforeseen increase in immigrants and the extension of the city limits saw a strain on the city's supplies. At the same time, the waste generation, in the area under consideration increased by almost 55% - an increase unforeseen within such a short span of time. Since the project work is still going on, there is a possibility to change some of the design criteria to account for the newer trends in population. But before that specific studies have to be undertaken to know the degree or extent of the change and in what aspects. This dissertation aims at doing the same. The waste water quality in District-VI - the project area, has been carefully analysed for any changes with respect to the earlier data obtained in 2005. The data shows a huge difference in the quality of waste water owing to the socio-economic transition in the city. Further, an abnormal increase in the coliform levels and a rapid

deterioration in the DO levels show the alarming nature of the change within a few years. Subsequent design changes have to be done in the sewerage network. Further, the process identification for STP has also been recommended to be changed from SBR to one of activated sludge with recent research regarding electricity generation from the process being also given secondary priority. Lastly, in the areas where the project is going on, a study of the sustainability indicators was done and relevant public opinion was solicited, documented, analysed and solutions recommended. Amalgamating all the above aims so as to ensure sustainability, efficiency and acceptability of the project has been the focus of this dissertation.

Contents

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Aims of the Project

Today, urban sanitation is one of the prime focus areas in countries worldwide. Inadequate sanitation had cost India USD 54 billion in 2006, which by then estimates were almost equal to 6 % of the national GDP (~1/16th of national GDP). This amount today, is sure to increase, promoted by a still-under-developed sanitary system and the slow pace of public awareness tending towards a change for the better. Most of the above accrual has come in the health sector. It has been theorized that as per recent trends in population increase, the urban population is all set to touch the half-way mark i.e. 50% of the total population by 2025. It is a matter of fact that, the urban sanitary conditions are still insufficient to meet the growing sectoral demands of its economy. Although there have been recent changes brought in by the Government regarding this, yet, it remains that the pace of population growth will fast outpace this pace of development.

This project aims at looking at the recent changes in the urban sanitation scenario in India, particularly in the city of Bhubaneswar, the capital of Odisha. Rapidly growing as a neo-urban city, it has seen a balancing between socio-economic strains on infrastructural problems and efforts being made to counteract that. One such project is the Odisha Integrated Sanitation Improvement Project (OISIP).

The broad aims of the dissertation are as follows-

1. To carry out a review of some major sewage treatment processes presently in use in different parts of the world.
2. To justify which STP process would be suitable for the project area.
3. To review the change in demography since 2005 and its impact on waste water generation.
4. To examine other technical aspects of the project. This include the sewer design criteria, the sewerage collection network design, pumping house design so as to get first-hand knowledge about an urban sanitation network.

5. Collection of waste water quality data inside the project area since the start of the project.
6. To examine whether this increase in demography can be effectively sustained by the designed network for the future i.e. 2045.
7. To get an idea whether there is public acceptability of the project – during the construction phase of the project.
8. To know whether the sustainability of the project with regards to the sustainability indicators is acceptable or not.

Cohesively merging all the above aims, we find that the essential objective of the project is to **assess the viability of the project with regards to the present changed scenario, get a brief idea on the ability of the project to select a scientifically chosen STP process and also examine whether the project is being carried out in a sustainable manner, thus ensuring that the future manageability of the project becomes efficient and effective**.

The project being JICA (Japan International Co-operation Agency)-funded, the State Govt. is aware of the need to ascertain the mid-term effectiveness of the project inorder to maintain continuous liquidity in funding. This dissertation was prepared by the full co-operation of the Govt. agencies involved.

This dissertation has been divided into 10 chapters (the references and the appendix have been appended at the end of the project).

The first chapter provides a brief introduction to the aims and aspirations of the project.

The second chapter accounts for the motivation that persuaded me to study the project.

The third chapter stitches all the relevant sources of literature that went into the fruitful completion of the project. All sources – articles, journals, research papers, books, website references etc – are too vast to mention within the confines of the project. Therefore a selective study of the important sources of information and knowledge with respect to the project have only been mentioned. However, all the sources of information have been specifically mentioned in the references section.

The fourth chapter gives a brief idea about Bhubaneswar – the study area of the project. It also mentions the current conditions of the project in Bhubaneswar. Other conditions relevant to the project inorder to get a brief idea about the project has also been explained.

The fifth chapter provides an insight into the population projections of the area. Since population is an important deciding factor affecting its viability with regards to its scope, economic considerations etc, a brief summary of the population calculations done have been recreated for a better understanding of the project and the people affected.

The sixth chapter describes the methodology adopted for the project. Since the project comprises of three parts, they have been individually accounted for.

The seventh chapter goes deeper into the waste water testing part of the project, while the eighth and ninth chapters go into the details of the STP process selection analysis and sustainability analysis part of the project respectively.

The tenth and final chapter of the project mentions the results obtained by the various tests and their inferences. It also gives an account of the recommendations for the project with respect to the study undertaken.

The dissertation ends with the list of references attached at the end as well as the appended list of persons involved in the sustainability survey and 2 examples of the survey attached at the end.

1.2 Project background

The Odisha Integrated Sanitation Improvement project (OISIP) is being implemented by the Odisha Water Supply & Sewerage Board (OWSSB) under the Housing & Urban Development (H&UD) Department of the Government of Odisha. The project aims at improving wastewater collection and treatment in Bhubaneswar.

Odisha, a culturally rich state is located in the south-eastern part of India. It is a littoral state of India with a long coastline and a storehouse of mineral wealth. Because of its mineral wealth, availability of adequate water and strategic location it attracts huge foreign investment in steel, aluminium, power, refineries, and infrastructure. Cuttack and Bhubaneswar are the prime business and political urban hubs which have significant roles to play in development of the state. Bhubaneswar, being the capital of the state has been the epitome of development in the state, ever since its inception in 1948.

In parallel with the urbanisation and population increase, water consumption and wastewater generation is also increasing. However the provision of sewerage treatment and disposal facilities has not been able to keep pace with the development needs. Wastewater generated by unregulated, unplanned and ill monitored urban localities passes on to water bodies and the rivers. This causes pollution with hazardous consequence to public health and environment.

In order to address the above problems, Housing and Urban Development Department of the State Government of Odisha through Government of India requested JICA (Japan International Cooperation Agency), formerly known as JBIC, to assist in improving water quality of rivers and sanitary conditions of people in Bhubaneswar. Detailed Project Reports for Bhubaneswar was prepared in November and December 2005 respectively and sanitation improvement works in the two cities were prioritized for JICA loan.

Chapter 2 : Motivation

As the global population continues to grow at a steady pace, more and more people are moving to cities every single day. With experts predicting that the world's urban population shall double by 2050 – meaning an addition of seven New Delhi like-cities to the planet every single year, there is an urgent need for providing better services to the people in these areas, in different areas like water, sanitation, transportation, proper environment etc.

In India, the urban population is currently 31% of the total population and it contributes over 60% of India's GDP. It is projected that urban India will contribute nearly 75% of the national GDP in the next 15 years. Cities are accordingly referred to as the engines of economic growth.

We, in India, are at a critical juncture in history in our endeavour to be recognised as a developed country. We are on the cusp of an 'infrastructural revolution' aiming at providing the citizens with means to develop themselves and the country. Programmes such as 'Smart Cities' mission and 'Swachh Bharat' *abhiyan* are testaments to this fact.

The complex intersection among capital, competitiveness and sustainability are the hallmarks of an efficient smart city. The city should be smart enough to keep up with the pace of development and this is only possible by creating a reference framework – a plan well enough to meet the present challenges and at the same time be ready to overcome other future ones. Effective planning of such infrastructure projects therefore becomes key to the sustainability of the cities themselves and therefore for its residents.

After the selection of Bhubaneswar as one of the six smart cities prioritised for development into a smart city, smarter ways to treat/recycle waste water are being proposed. The facilitation of the development of the OISIP is one such step, which would help provide the basis for further development of the sewerage network in the state. According to a McKinsey India report (McKinsey Global Institute 2010), proper planned development of urban centres in India can reap the benefit of demographic dividend and provide jobs which can contribute to around 70% of the Indian GDP in 2030.

Cleanliness has to remain an integral part in our way of living. Starting from our homes and extending to the whole country, cleanliness or *Swachh Bharat* would remain an utopian dream without the participation of the masses. But that doesn't absolve the Govt. of its duties towards the people. Improvement in sanitation projects in ULBs has been an important node in the process of urban development.

The common characteristic of these two 'mega' projects/schemes is sanitation. More specifically, urban sanitation. Urban sanitation, has captured the attention of governments around the world. With the time period of MDG (Millennium Development Goals) coming to a close in 2015, and a new framework to be discussed among the countries at the Paris Summit later this year, urban sanitation has been one important point of concern. Therefore, development of an integrated urban sewerage network plays a critical role in facilitating India's standing among the global diaspora.

Bhubaneswar, as has been seen earlier, has always played a vital role in the development of the State as a whole by creating a base model for future development. Urban sanitation in Bhubaneswar, in light of the growing population, faces a lot of constraints. In order to achieve the twin objectives of urban sustainable development and effective unburdening of the waste waters of the city, the JICA project was started. The JICA project began as a part of the Total Sanitation Campaign (previously also known as the Nirmal Bharat campaign) way back in 2006. Presently, no review of its scope has been undertaken by the concerned agency or the department concerned. The project report was prepared and submitted then.

But, the city has undergone rapid changes in the last few years. Starting from the development of techno-educational clusters like IIT-Bhubaneswar, AIIMS-Bhubaneswar, NISER-Bhubaneswar, IIIT-Bhubaneswar, NIFT-Bhubaneswar, XIMB and several other universities, along with economic hubs like Infocity (1 &2) which cater to the interests of several MNCs like Infosys, Wipro, TCS, Mindtree, HCL etc. and a gradual expansion of the city's boundaries, Bhubaneswar is projected to be the next Bangalore albeit accompanied by a rapid rise in population and other associated impacts. Concurrently, there needs to be a revision of the project's aims, identities and scope and align it with the changing demography.

This project is a small endeavour towards achieving that. It aims at highlighting the aspects which require attention and action. The amount of generation of waste water has increased manifold and is also supposed to rise quite steeply in the forthcoming couple of years. Its estimation and its contrast with that designed has been undertaken with a view to acknowledge the rate of growth and to further assimilate it in the future design criteria.

Chapter 3 : Literature Review

The Literature Review regarding this dissertation can be divided into four parts.

The first part involves review of the method of population calculation using new modified methods of regression analysis. **(Tayman et al. 2011)** have shown that regression models based on data for individual places provide powerful but under-utilized tools for investigating the determinants of population forecast accuracy. Using decennial census data from 1900 to 2000 for 2,482 counties in the US, they have constructed a large number of county population forecasts and calculated forecast errors for 10- and 20-year horizons. Then, they developed and evaluated several alternative functional forms of regression models relating to population size and growth rate to forecast accuracy; investigated the impact of adding several other explanatory variables; and estimated the relative contributions of each variable to the discriminatory power of the models. **(Larry & Winship 1994)** have argued in favour of the shortcomings regarding the practice of estimating ordinary least squares models with weighted data. The use of common incorrect formulae to estimate coefficient standard errors during the use of sampling weighted data – if so decided after analysis. **(Ding 2006)** has beautifully presented the applications of regression mixture models, also known as latent class regression analysis, in educational research. Conventional regression analysis is found to be more rigid than regression mixture analysis in that latent classes in the data can be identified and regression parameter estimates can vary within each latent class. He has also provided an example of the regression analysis by using authentic data sets of an empirical study. **(Guangqing & Voss 2000)** have, in their paper titled '*Small-Area Population Forecasting Using a Spatial Regression Approach'* have introduced a revised regression specification that has brought into the regression forecasting approach, explicit "neighbourhood" influences through spatial regression (spatial econometric) techniques.

The second part i.e. waste water testing, mostly involved the use of CPCB's literature and material available publicly with occasional references to some other standard industry methods.

The penultimate part of the dissertation involves a comprehensive review of various sewage treatment processes being researched upon and practically being implemented in many parts of the world. (Torretta et al. 2013) have discussed about membrane fouling in membrane bio-reactors. They have written about the use of powdered charcoal to mitigate that and have calculated its efficiency in removing membrane fouling.**(Bitton 2005)** has given a very comprehensive description about the activated sludge process. **(Leon S. Downing 2011), (H & M 1994), (Shahzad et al. 2015), (Nuhoglu et al. 2005)** have also shown various aspects of the activated sludge process and discussed about certain process management measures to increase the efficiency of the process. **(Fang & Chui 1993), (Lettinga et al. 1983), (de Graaff et al. 2010), (Chowdhury & Mehrotra 2004)** and (**Sandhu & Pandey 2014**) have discussed in detail about other sewage treatment processes like the UASB. **(Zhang et al. 2006)** and (**Ahmed et al. 2007**) have described in detail about the membrane bio-reactors (MBR) process. Apart from them, several other research papers were referred to which have been mentioned during the course of the thesis.

The final part of the thesis deals with the sustainability part. **(Todd Litman 2009)**, has mentioned that the Planning measures rely on indicators (i.e. standardized information suitable for analysis) for guidance, such as people rely on their senses i.e. sight, hearing and touch. Indicators let us analyze the trends and model their impacts. Decision-making increasingly include sustainability concepts, for example consideration of long-term social, economic and environmental impacts. Numerous approaches, models etc towards sustainability

Chapter 4 : About the Project

4.1 Project Area details

1. Bhubaneswar City Profile

Bhubaneswar is the capital and largest city of the Indian state of Odisha, India. Being the dream-child of the great French architect, Le Corbusier, the city takes pride in being the 2nd planned city in all of India, after Chandigarh. Once the capital of the erstwhile Kalinga Empire, the city has a long history and is today a centre for commerce and religious activity. Rising among its contemporaries as yet another well managed city, it has earned the tag of 'the best city for doing business in India'. Culturally, with its vast variety of Hindu temples, Bhubaneswar is often referred to as "*the temple city of India*".

Table 4.1: General Information: Bhubaneswar

Items	Feature
Municipal Area	146.60 Km^2
No of Wards	60
Population	8,37,737 (as per 2011 Census)
Languages	Oriya, Hindi, English, Bengali and Telugu
Climate	Tropical (Temperature- Max-46^0 C and Min- 10^0 C)
Average Rain Fall	1,470 mm/year

Source: OWSSB

Figure 4A : The map of Bhubaneswar showing different sewerage districts

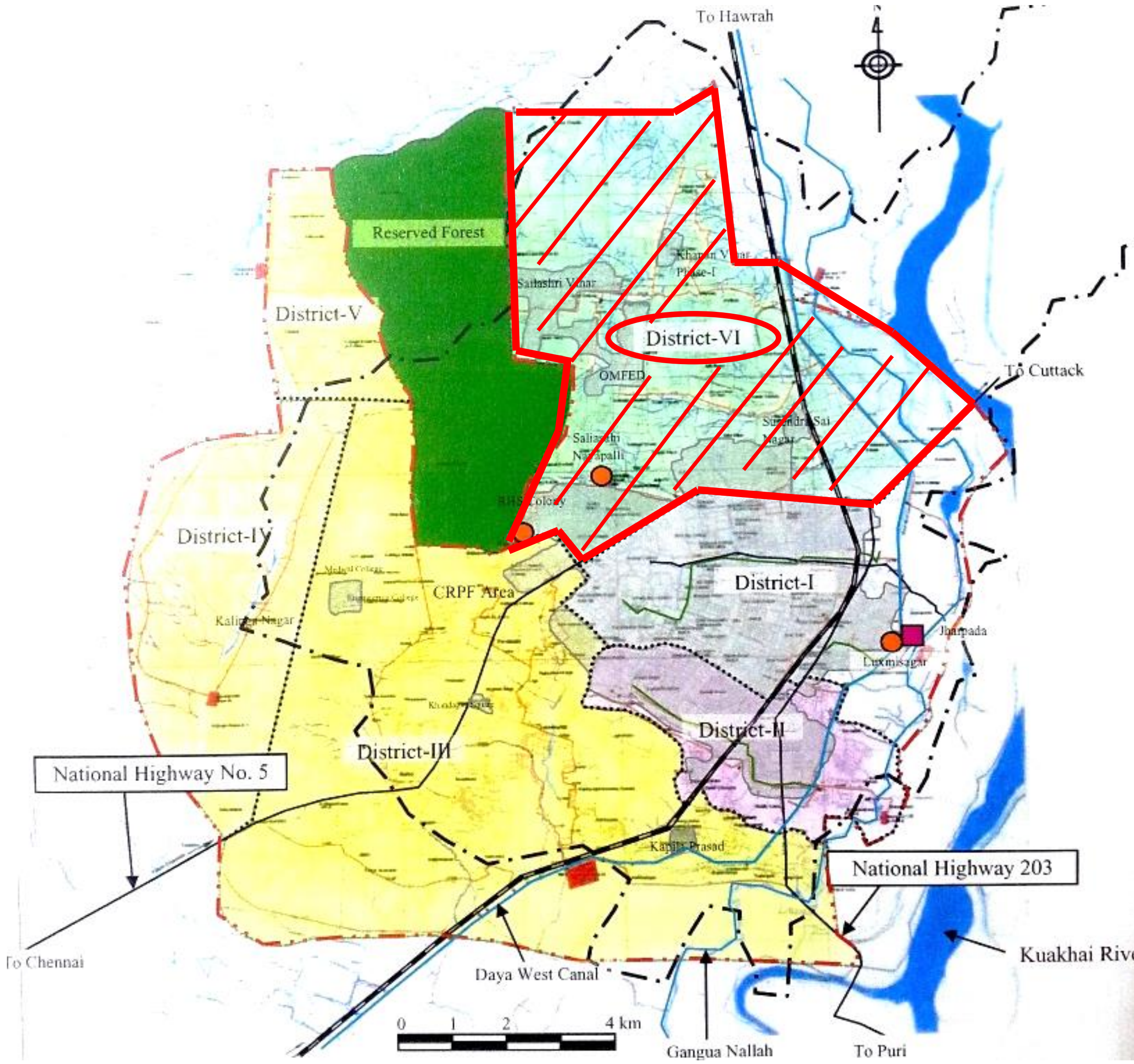
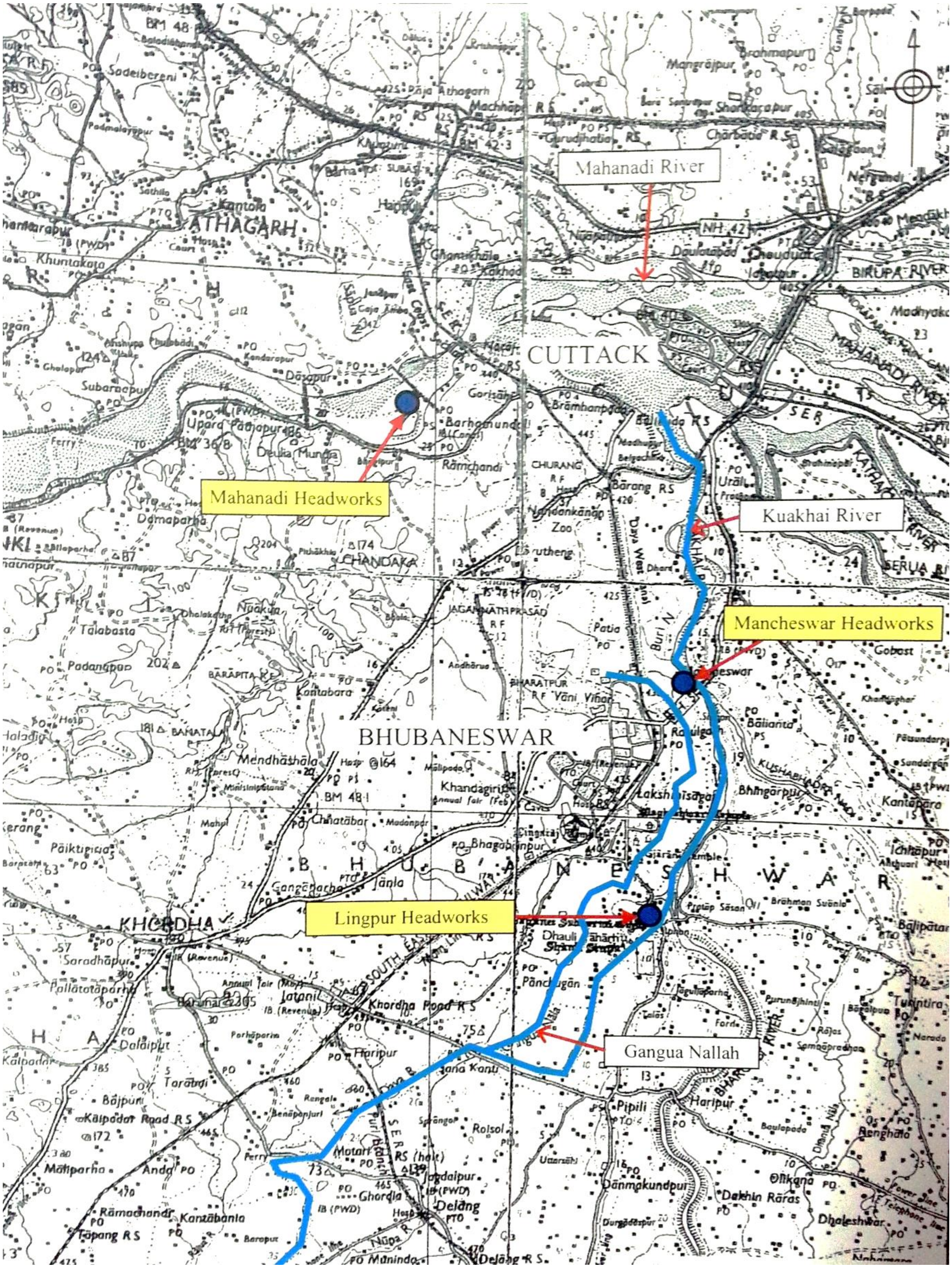


Figure 4B : Map showing headworks and confluence points of the sewers



2. Location

The city lies in the Mahanadi Delta, on the west bank of river Kuakhai, which is a distributary of river Kathajori, a branch of Mahanadi River, 30 kms south east of Cuttack. The river Daya branches off from Kuakhai and flows along the south-eastern part of the city. Bhubaneswar lies on the western fringe of the mid-coastal plain of Odisha with an average elevation of 45 meters above mean sea level. Bhubaneswar is located in Khurda district of coastal Odisha, between Latitude 20°12' N to 20°25' N and Longitude 85°44'E to 85°55' E on the western fringe of the coastal plain across the main axis of the Eastern Ghats.

The city has been built along the corridors of East-Coast Railway and National High Way No.16 (according to the old numbering system, it was NH 5) with about 146 km^2 municipal corporation area and forms the apex of the "Golden Triangle" with Konark and Puri being the other two points.

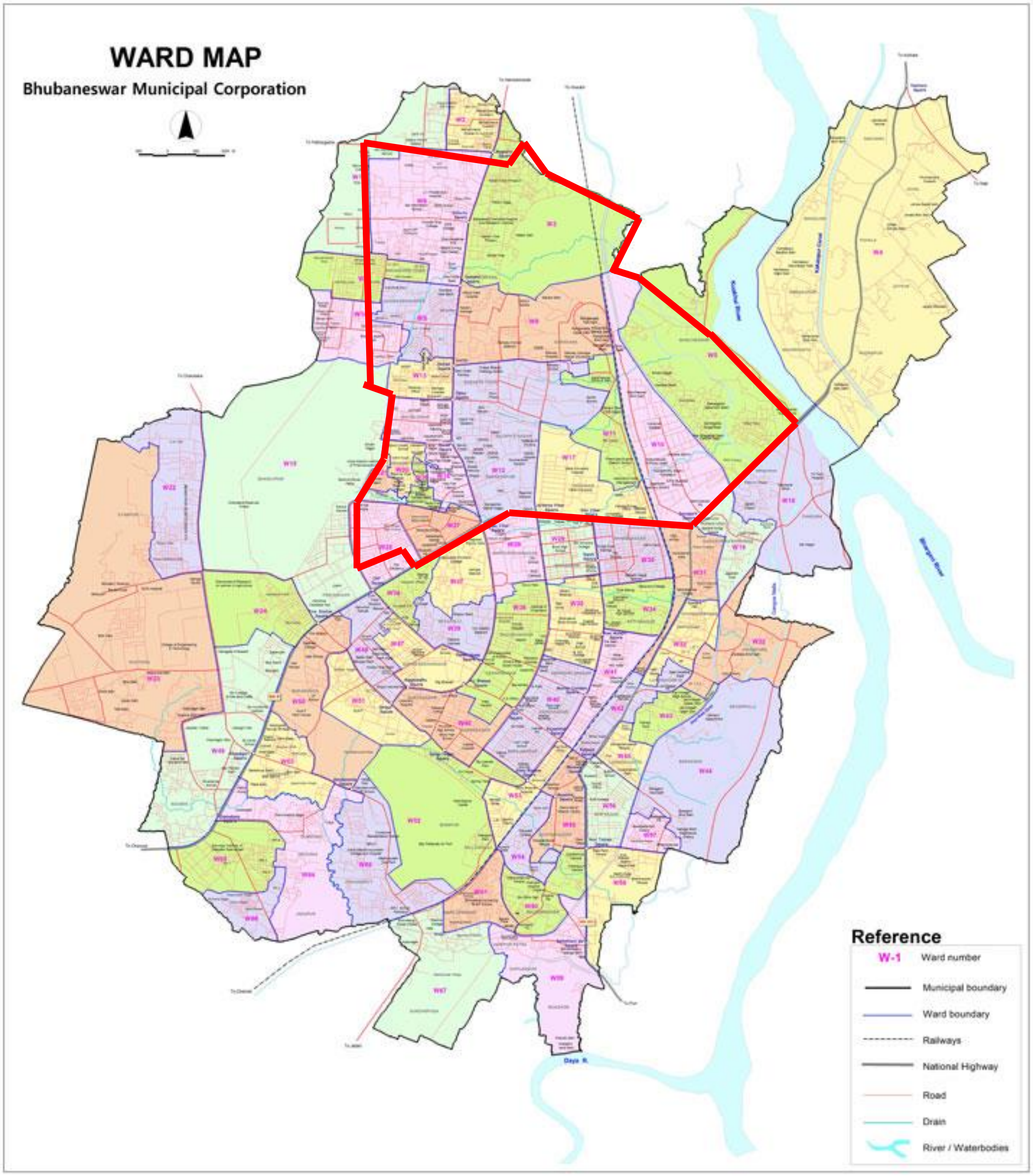
The city is situated just 60 kms from the town of Puri, one of the '*chaar dhaams* ' which has been religiously revered over the ages. It is this proximity to the sea (via international major ports at Paradip, Gopalpur and Dhamra in the Bay of Bengal and defence establishments of DRDO such as the Interim test Range (ITR) at Chandipur, Balasore – a few kilometres away from it) which gives it a premium advantage over other cities and makes it a critical nerve centre in global geo-politics.

Coming to the internal divisions within the city, it is subdivided into a number of townships and housings. The City is divided into 60 municipal Wards. A group of wards make up a 'cluster unit' or simply 'Unit'. Demographically, its population has increased from 16,512 in 1951 to 6,48,032 in 2001 and 8,37,737 in 2011 – a growth of 30% in just 10 years (or roughly 3% per year hypothetically considering a uniform growth rate per year). Bhubaneswar has four industrial estates.

As per the Master plan area of BDA, the core areas in Bhubaneswar have been declared as "air pollution control area" where there is strict restriction on the use of fossil fuel. As such, there has not been much industrial activity in the vicinity.

Fig. 4.1 & 4.2 shows the location of project area and Index map of Project area and Fig 4.3 shows the municipal area along with the project area.

Figure 4C : Municipal map showing District – VI – the project area



3. Historical Overview:

The city has a recorded history of 2500 years starting with the Chedi dynasty (around 2nd century BCE) that had Sisupalgarh near present-day Bhubaneswar as their capital. Historically, Bhubaneswar has been known by different names such as Toshali, Kalinga Nagari, Nagar Kalinga, Ekamra Kanan, Ekamra Kshetra and Mandira Malini Nagari "city of temples" otherwise known as the temple city of India (with its large number of Hindu temples - over 600 in number). Bhubaneswar, today is a centre of economic and religious importance in the region.

Bhubaneswar's proud possession of magnificent sculptures and architectural heritage, coupled with the sanctity as Ekamra Kshetra make this one of the great religious centres of Odisha since early medieval days.

Kalinga empire, of which present day Odisha forms a part, was ruled by the dynasty of Nanda kings between the period 370 B.C. to 322 B.C. “Tosali”, known today as Bhubaneswar, was the capital of Kalinga empire.

Odisha was constituted as a separate province in the year 1936 with its capital in Cuttack. Subsequently Cuttack could not continue to be the capital of the state due to various physical constraints and Bhubaneswar was chosen as suitable for the new capital of Odisha due to several reasons like its location on major transport routes, availability of vast stretches of government land, excellent soil conditions, healthy climate, and availability of water and natural drainage conditions.

Construction of the capital started in the year 1948. After completion of the secretariat building in 1956, different departments of the state secretariat were shifted from Cuttack to Bhubaneswar. Gradually a stream of offices and institutions like the Assembly, Raj Bhawan, Utkal University and other state level government and semi-government offices followed.

The salubrious climate, proximity to the administrative centre, availability of suitable land and other attendant facilities led to residential development in the private sector to a considerable extent. In keeping with administrative, institutional and construction activities commercial activities also developed. All this contributed to a rapidly increasing trend of migration of people from the hinterland, which to some extent covers the entire state.

4. Climate

Bhubaneswar enjoys a humid tropical climate. Average rainfall is about 1470 mm falling from June to September (76%) and from October to December (13%). Temperature and humidity are high throughout the year. The mean maximum humidity ranges from 71% to 83%.

5. Topography

Bhubaneswar lies on the western fringe of the mid-coastal plain of Odisha with an average elevation of 45 metres above mean sea-level. It is located on a low lateritic plateau and continuous erosion has shaped the topography into a valley and ridges. The Rivers Kuakhai, Bhargavi and Daya flow on south-eastern fringe of the town. Enormous hillock and forests exist in the northern, western and southern parts. Topographically, the city can be divided into two major parts, namely; western upland and the eastern lowland with the south-eastern railways forming the boundary between these two broad units.

4.2 Existing Conditions of the project in Bhubaneswar

1. City Management

The following departments / agencies are responsible for water, sanitation related Operational and developmental responsibilities for the City.

a. **BMC:** Bhubaneswar Municipality was formed on 14^{th} April 1979. Bhubaneswar was declared as Municipal Corporation in 1994. The Urban Local Body (ULB) in accordance with the Municipal Act is vested with the responsibility of Solid Waste Management apart from other duties and responsibilities embodied in the Act. The Municipality area has been divided in to 14 zones and 60 wards.

b. **BDA:** Under the Odisha Development Authorities Act enacted in 1982 the Bhubaneswar Development Authority was constituted. It is responsible for development of Bhubaneswar Master Plan Area and has as principal objectives creation of housing stock, creation of commercial complexes, improvement of city level infrastructure, environmental improvement, parks and plantations in colonies, blocks, institutions and roadsides and prepares development plans.

c. **PHEO:** Public Health Engineering Organization is a state level organization under the Housing and urban Development Department of Govt. of Odisha with a mandate of providing drinking water. The department has three Public Health Divisions in Bhubaneswar, through which the water supply and sewerage services are currently operated and maintained.

d. **OWSSB:** Odisha Water Supply Sewerage Board under the Housing and Urban Development Department, Govt. of Odisha is a state level organization with a mandate to plan and execute water and sanitation projects throughout the state. OWSSB is the Executive Agency for implementation of the JICA Assisted Odisha Integrated Sanitation Improvement project in Bhubaneswar and Cuttack City.

2. Population Trend

There was a 131 % growth between in 1951 and 1961. The shifting of the Capital in 1954 is believed to be the primary reason. The population further increased by 176 % from 1961-71 and was 108% between 1971-81. The high population growth during these two decades was mainly due to inward migration of rural population. In 2001, the population was 648,032. During 1991-2001, the growth was 57.40%. In 2011, the population was 8,37,737, during 2001-11 the growth rate was 29.27%. Such growth in past decades can be ascribed to following reasons:

- Natural growth
- Large number of rural immigrants to the city.
- Establishment of more government, public sector and private sector offices
- Addition of fewer adjoining areas into the ambit of the municipality.

More analysis regarding this has been done in the fifth chapter.

3. Water Supply

The Kuakhai headworks are located on river Kuakhai which is downstream of the outfall point of Drain No.1 into river Kuakhai and Daya headworks are located on river Daya upstream of the outfall point of Gangua nala into river Daya.

Table 4.2: Source of Water Supply to Bhubaneswar City

Sl.	Sources of water Supply	Quantity			
1	River Kuakhai, River Daya, River Mahanadi	211.70 MLD			
3	Ground Water Production	49.08 MLD			
4	Total quantity of water generated	260.78 MLD			
5	Number of Tube wells	2873 Nos.			
6	Number of Stand posts	563 Nos.			
6	Population (2010) Covered	9,37,500			
7	Per Capita Water Supply	278 lpcd			
8	Ward wise Coverage	Total No. Of Wards	Wards Fully Covered	Wards Partly Covered	Uncovered Wards
		60	25	31	4

4. Strom Water Drains:

The City slopes from west to east, hence has a natural advantage for drainage. Ten major drainage channels are there in the City. There are four drainage channels in sewerage District-VI as tabulated below.

Table 4.3: Drainage Channels in Sewerage District VI, Bhubaneswar

Drain No.	Drain name	Starting Point	Outfall Point	Major areas	Ward nos
1	Patia	Forest Lake, Chandrasekharpur	Daya West Canal crossing	ChandraShekharpur, Damana, Garkhana, Patia,Rokata, Mancheswar	1
2	Sainik School	Sainik School Road Culvert	Railway Bridge (Confluence with drain no. 3)	Garkhana	2
3	OAP area	Field near Sainik School	Railway Bridge (Confluence with drain no. 2)	Samanta Vihar, Vani Vihar, Garkana	2,3,5, 6,7,8
4	Vani Vihar	Culvert near Reserve Forest Bharatpur	Daya West Canal, CD	Nayapalli, Madhusudan Nagar, Vani Vihar, Pandar, Garkana, Bhoi Nagar	4,6,7, 17

The drains in the area are maintained by the Bhubaneswar Municipal Corporation (BMC).

5. Solid Waste Management:

The BMC is responsible for solid waste management in the City. The BMC is having a conventional and primitive system of Solid Waste management system. The BMC have a health Wing with a city medical officer, sanitary inspectors (12Nos), sweepers (1277 Nos), loading staff (175 Nos), and assistant unit officers etc, .The Total Solid Waste generation in Bhubaneswar Municipal area is estimated as 432 MT/Day. The City is divided into different sanitation Wards and each sanitation wards are further divided into sub-units. The normal frequency of collection of wastes is at least one in a day in busy commercial areas and in others areas once in 3-7 days. The collected waste is dumped into 8 designated dumping sites located throughout the city. Segregation of wastes is almost absent in the system.
Following is a brief summary of present Solid Waste Management scenario in Bhubaneswar City.

- Absence of scientific & systematic method of collection, segregation, transportation and treatment of wastes.
- Solid wastes dumped into the drains results in clogging and choking of drains, mosquito breeding etc.
- Crude methods of open dumping, unsanitary land filling and open incineration are practiced, which may result sub-soil and ground water pollution.
- Biomedical & hazardous waste collection and treatment are not properly addressed.

6. Sewerage System

Presently, Bhubaneswar is partially covered with an underground sewerage collection and conveyance system with glazed stoneware and reinforced cement concrete pipes. Around 50% of the Municipal Area and 30 % of the population are covered under the present sewerage system. Sewage collected at the intermediate pumping stations is pumped by primary sewage pumps to the influent distribution chamber of the sewage treatment plants (Oxidation ponds and aerated lagoons) at different locations for treatment and disposal.

About 80 % of the existing sewer are inadequate or in dilapidated conditions and need repair or replacement. Out of existing approximate 20000 manholes, 80 % are in damaged condition. Wastewater is discharged through storm drain outfalls to Gangua nallah and finally to Daya river. The Drain No. 1 opens into the river Kuakhai and the remaining 9 drains open into Gangua nallah which in turn transfers the volume and load to River Daya near Barimula village about one kilometer D/S of Kakudia Bridge.

Only a part of generated sewage flows through closed conduits leading to treatment systems, and major quantity flows through the 10 Nos. of open storm drains. At present 23 community septic tanks, 10 aerated lagoons and 7 Oxidation ponds exist. Out of all, only one aerated lagoon at Laxmi Sagar is functioning.

The sewage collection system is neither adequate nor functioning properly. The open drains of the city are severely polluted by sewage and garbage being dumped into it.

7. Water and Waste Water Quality of Rivers and Drains

The results of monitoring of water quality of river Kuakhai and Daya, as conducted by the State Pollution Control Board (*Jan 2009 – Jan 2014*) are presented here. Table 4.4 gives water quality of river Kuakhai and Daya and clearly depicts the degradation in water quality of the river from U/S to D/S. Table 4.5 gives wastewater characteristics of different drains.

Table 4.4: Water Quality of R. Kuakhai and R. Daya (Designated Best Use – C)

Parameters	Result					
	Upstream of Bhubaneswar on River Kuakhai			Downstream of Bhubaneswar on River Daya		
	Avg.	Variation	Limits	Avg.	Variation	Limits
pH	7.8	7.8-8.4	6.5 – 8.5	7.6	7.0-8.4	6.5 – 8.5
TS (mg/l)	201	156 - 243	500 – 2000	162	128-192	500 - 2000
DO (mg/l)	7.8	5.8-9.3	> 4	5.5	1.4 – 7.2	>4
BOD (mg/l)	1.5	0.7-2.7	< 4	3.6	2.2 – 4.7	<4
TC (MPN/100ml)	31218	2400-92000	5000-10000	52909	22000 - 160000	5000-10000

Table 4.5: Waste water characteristics of different drains

Parameters	Monitoring Sites									
	Limits	1	2	3	4	5	6	7	8	9
PH	5.5 - 9	7.4	6.1	7.5	7.6	6.9	7.2	7.2	5.9	6.9
TDS (mg/l)	500	520	510	660	505	340	280	560	650	600
TSS (mg/l)	100	180	200	200	200	400	300	400	200	400
BOD (mg/l)	30	100	160	120	60	140	120	140	24	100
COD (mg/l)	250	130	208	160	120	208	176	176	52	160
Tot Cl (mg/l)	1	3.6	5.0	6.6	3.4	7.2	6.4	8.8	2.5	7.2
Tot. N (mg/l)	100	112	98	78	85	103	150	110	69	76

Source: OSPCB, 2014

Due to disposal of untreated wastewater, the water pollution in Storm drains and rivers is further increasing. It is imperative to control and prevent the pollution in order to improve the river water quality.

4.3 Need of the Project

As inferred above, the major environmental and public health problems in Bhubaneswar City (which can be intra-polated to Sewerage Dist-VI) are due to:

1) Insufficient capacity and deteriorated and/or lack of treatment facilities.
2) Storm drains which are used as sewage collection facilities.
3) Absence of systematic solid waste collection and open dumping without leachate treatment and soil cover, resulting in choking of drains and groundwater contamination,
4) Lack of financial resources and human capacity in institutions responsible for sewerage, drainage and solid waste management.

Since at present there is no proper sewerage system or treatment plant in the city, the discharge of domestic waste through storm water drains goes to the river. In the existing reports of Odisha State Pollution Control Board, the water quality of Kuakhai River shows general increase of pollution with time. Downstream of Bhubaneswar, there is a higher degree of pollution with higher values of organic matter, bacteria and chemicals. The pollution in the river is due to the direct flow of sewage into the river.

Apart from the health risk to the city population, damage and dislocation from flooding, the lack of sanitation in the city results in a similar risk to the health of downstream villagers in the Mahanadi Delta. The natural environment of the delta and the bay of Bengal are affected as the generally polluted drains and discharges to the surrounding Mahanadi and Kothajori, Kuakhai and Daya Rivers.

Therefore a major improvement to the sanitation of Bhubaneswar requires a comprehensive sewage collection, treatment and disposal system

4.4 Existing sewerage system

The Project Area of Bhubaneswar city has been divided in to 6 nos. of Sewerage Districts namely District-I, District-II, District-III, District-IV, District-V and District-VI.

The Sewerage District VI covers 16 wards out of 60 nos. Municipal wards of the city. The main areas coming under this Sewerage district are IRC Village, Nayapalli, Jaydev Vihar, Salia Sahi, Rental Housing Colony, Chandrasekharpur, Niladrivihar, Sailashree vihar, Maitri Vihar, Patia, Kanan vihar, Damana, Gadakana, Kalarahang,Satya Vihar, Sainik School, Gajapati Nagar, Utkal University area, Veer Surendra Sai Nagar & Mancheswar Industrial estate area etc. The list has been mentioned in Table 4.6.

A part of the district –VI area mainly Government and Semi Government colonies, BDA & Housing Board constructed colonies has been provided with sewerage system and in the rest part of the district the house owners are having individual Septic tanks.

The existing collection system consists of Stone ware and RCC pipe sewers and brick masonry Man holes Chambers. The sizes of sewers are from 100mm to 500mm diameter. Most of the brick masonry man hole Chambers are in damaged condition and at many places the sewer lines are either damaged or choked, and hence sewage is allowed to flow in to nearby by surface drains.

No Centralized Treatment facility is available for treatment of generated sewage. Few treatment plants have been provided locally. These are Oxidation ponds, Aerated lagoons, Root zone treatment or common septic tanks. Some of them are incomplete in construction, some of them have become defunct and some are of inadequate capacity, and hence serving no purpose. At some places no treatment is provided. The sewage generated from almost all the areas is discharged to nearby valleys or storm water drains which ultimately goes to Gangua Nallah and finally discharged to river Daya away from the town in south.

Table 4.6 : Spatial distribution of the units and areas covered with sewerage system (on NEXT PAGE)

Sl. No.	Ward No.	Area Covered	Areas having sewerage system
1	1	Patia Industrial Area, Mula Sahi, Chandaka Industrial Area, Maruti Vihar, Chandrasekharpur, Saileshree Vihar (Phase- VII and Duplex)	Chandrasekharpur, Sailashree Viihar
2	2	Patia Village, Kanan Vihar (Phase- II), Sree Vihar & Damana Village	NONE
3	3	Chakei Siani, Samai Gadia, Kalaspur, Mancheswar, Vatapada & PHED Water Works Colony	Mancheswar
4	6	IDCO Colony, Mancheswar Industrial Area, Rasulgarh & Sabara Sahi	Mancheswar Industrial Area
5	7	Gadakana, Rangamatia, Mancheswar Railway Coach Factory Area and nearby Slum, Omfed Center, Kanchanjangha Apartment Area	NONE
6	8	Damana Hata Area, Arya Vihar, Apolo Vihar, Nilamadhaba Basti (Slum), Omfed Centre, C. S. Pur, OSHB Housing Colony Phase- I.	OSHB Housing Colony
7	9	Saileshree Vihar (VIM & GA), Niladri Vihar (Slum), Niladri Vihar(Sector 1 to 5 GA Plots), Defense Plots, Army Housing & Lumbini Vihar	Sailashree Vihar, Niladri Vihar
8	10 (half)	Half of Udyan Vihar Area, VIP Area, Rental Housing Colony, Ekamra Villa, Private Plot Area.	
9	11	Nalco Colony, C. S. Pur BDA Colony (Phase- 1 & 2), Rail Vihar, Nalco Colony Phase- II, Nilamadhab Basti (Slum.)	CSPur BDA Colony
10	12	Gajpati Nagar, IMMT, Survey of India Office, 7th Batalion, Durdarshana Kendra, Institute of Physics, CMPDI Colony, Text Book Press, GA Quarters, Sainik School, Laxmi Vihar & Samanta Vihar.	IMMT, Gajapatai Nagar, Sainik school, IoP, IoM
11	13	V S S Nagar Housing Board Colony, Gaheswal Hata, V S S Nagar Private Plots, Hotel Management Institution, Pathara Khani Basti (Slum)	VSS Nagar
12	14	Vani Vihar Area, Pathar Kata Basti (Slum), Income Tax Colony, (Revenue Colony), Bajapeyi Nagar, Mangala Basti (Slum), P & T Colony.	Vani Vihar Area
13	15	Kalinga Hospital Area, Maitri Vihar, Xavier Area, Bajpeyi Nagar, Mangala Basti (Slum), Sarala Vihar, Salia Sahi, Nilachakra Nagar, Mayfair Basti (Slum), Tarini Nagar, Bishnu Priya Apartment.	XIMB, Kalinga Hospital area
14	16	Adivasi Area, Nilachakra Nagar, Beddy Sahi, Janata Nagar, Maitri Nagar, Salia Sahi, Loyala School.	Maitri Nagar
15	19	N-1, N-2, N-3, N-4 blocks of Nayapalli, RBI Colony & Iscon Area.	Nayapalli, RBI Colony
16	20	Jaydev Vihar,, N-5& N-6 blocks of Nayapalli, Indradhanu Market Area, Biju Patnaik College Area.	Nayapalli

Table- 4.7 : Existing Status of Sewerage System Treatment Disposal in Sewerage District- VI, Bhubaneswar

SI. No.	Area Covered	Sewer Network System	Type of Sewage Treatment Proposed in the system	Present Status of existing Treatment Plant	Remark
1	Chandra Sekhar Pur, BDA, Phase-I	Sewer Line laid prior to 1986	Aerated lagoon	Construction of lagoon is left in incomplete stage	The sewage is directly discharged to the nearest valley
2	Chandra Sekhar Pur, OSHB, Phase- I	Sewer Line laid prior to 1986	Aerated lagoon	2 nos. of laggons are left incomplete in construction stage	-Do-
3	Chandra Sekhar Pur OSHB Phase- II-V	Sewer Line laid prior to 1990	No Treatment	-	-Do-
4	Chandra Sekhar Pur, OSHB, Phase- VI	Sewer Line laid prior to 1992	No Treatment	-	-Do-
5	Chandra Sekhar Pur, OSHB, Phase- VII	Sewer Line laid prior to 1992	No Treatment	-	-Do-
6	District Centre BDA	Sewer Line laid prior to 1996	No Treatment	-	-Do-
7	Chandra Sekhar Pur, BDA, Phase- II	Internal Sewer Line laid prior to 1994	No Treatment	-	-Do-
8	Kanan Vihar Phase- I	Sewer Line laid prior to 1992	Aerated Lagoon	Construction of lagoon is left in incomplete stage	-Do-

SI. No.	Area Covered	Sewer Network System	Type of Sewage Treatment Proposed in the system	Present Status of existing Treatment Plant	Remark
9	Kanan Vihar, Phase-II	No Sewerage System	Individual Septic tank	Septic tanks are functioning	-
10	Rail Vihar	Sewer line laid	Aerated lagoon	The lagoon has been damaged and has become defunct	The sewage is directly discharged to nearest valley
11	Maitri Vihar	No Sewer System	Individual Septic tank	Septic Tanks are functioning	
12	Lumbini Vihar	Sewer line laid	No Treatment	-	The Sewage is flowing to a nearby Storm Water Drain.
13	Gift Press	Internal Sewer Line laid prior to 1973	Oxidation Pond	Oxidation Pond is over loaded	-
14	Sainik School	Internal Sewer Line laid prior to 1970	Oxidation Pond & Root Zone System	The capacity is inadequate and not functioning properly	The treated effluent of OP & RZ will be connected to Trunk Sewer
15	VSS Nagar	Internal Sewer Line laid prior to 1980	Partial Treatment by ST (20%) and path ally by Oxidation Pond (80% by Oxidation pond)	The Capacity is inadequate	The effluent is discharge to storm water drain
16	Utkal University Vani Vihar	Internal Sewer Line laid prior to 1957	Common Septic tanks	Capacity inadequate	Septic Tank over loaded and sewage is overflowing to drainr

SI. No.	Area Covered	Sewer Network System	Type of Sewage Treatment Proposed in the system	Present Status of existing Treatment Plant	Remark
17	Regional Research Laboratory Campus	Internal Sewer Line laid prior to 1970	Septic Tank	×	
18	IRC Village Nayapalli Jaydev Vihar	Internal Sewer Line laid prior to 1986	Aerated lagoon	The capacity of lagoon is inadequate and also not functioning properly	The sewage is directly discharged to storm water drain
19	Rental Colony Nayapalli	Internal Sewer Line laid prior to 1989	Aerated lagoon	The lagoon is not functioning properly	The sewage is discharged to nearby valley
20	Subash Chandra Bose Enclave Gadakana	Sewer line laid	Package Treatment plant	The Treatment plant is new and put in to operation recently	Sewage Treatment Plan is new and functioning
21	Prachi Enclave	Sewer line laid	Not Treated	-	The Sewage is flowing to a nearby Storm Water Drain.
22	GA Plots at C. S. Pur	Sewer line laid	Not Treated	-	The Sewage is flowing to a nearby Storm Water Drain.
23	GA Quarters near Adimata Colony	Sewer line laid	Common Septic Tank	Soak pits are not functioning properly	The effluent is discharged to nearby drain
24	Adimata Colony	Sewer line laid	Common Septic Tank	Soak pits are not functioning properly	The effluent is discharged to nearby drain

4.5 About the project

In order to address the above problems in Bhubaneswar city, the Housing and Urban Development Department of the State Government of Odisha through Government of India requested JICA (Japan International Cooperation Agency), formerly known as JBIC, to assist in improving water quality of rivers and sanitary conditions of people in four cities including Bhubaneswar, Cuttack, Berhampur and Sambalpur. The JICA project which started in 2008, has since, been going on successfully.

The objectives of the undertaking are to enhance the water quality in encompassing rivers and overhaul the sanitary condition for the individuals in urban and peri-urban ranges. This will be done through sewerage and seepage change incorporated with institutional change that will bolster effective execution of the facilities in a sustainable manner.

As per conditional assessment survey made by OWSSB, 85.225km of sewer pipeline is existing in Sewerage District VI with 8826 house connections. As of 2012, out of 85.225kms sewer lines, about 23.225km sewer line were reported damaged and needed replacement. (Source: OWSSB, Bhubaneswar).

1. Project Finances

The President of India / Government of India has received an official development assistance (ODA) loan from JICA in the amount of 19061 million YEN towards the cost of implementation of Odisha Integrated Sanitation Improvement Project.

The Total project cost in Bhubaneswar is estimated at Rs. 332.70 crores, of which the Government of Japan will fund Rs. 117 crores through Japan International Cooperation Agency (JICA) as loan assistance and the balance will be borne by the State Government. The loan will be repaid by the State Government in 40 years with a moratorium period of 10 years with an interest rate of 0.75 percent per annum. Training and capacity building is also scheduled to be provided to the local authorities during the implementation stage to ensure sustainable operation and maintenance of the assets during the post-construction period.

2. Other ongoing projects

In addition to the JICA project in District-VI, there are two other projects under implementation for improvement of sewerage system in remaining sewerage districts of Bhubaneswar.

a. 12th Finance Commission Grant.

- The Sewerage laying Works in sewerage District – I & II of Bhubaneswar city are covered under the scheme and the project is under execution by OWSSB.

b. JNNURM Fund.

- The Sewerage improvement works in sewerage Districts – I, II, III, IV, V & VI shall be met from JNNURM funds excluding cost of sewer laying in sewerage District – I & II.
- The Sewerage Treatment plants of the five sewerage Districts (except for sewerage district-VI) are provisioned under JNNURM funded scheme, which is under execution by OWSSB. The scope of the works under JNNURM funds for sewerage district-VI is limited to rehabilitation of existing sewerage system only.
- The development of new sewerage system along with treatment plant is provisioned under the JICA project.

Due care has been taken to ensure that there is no overlapping of project scope and boundaries thus limiting delay and subsequent judicial intervention.

Chapter 5 : Population Projections

5.1 Introduction

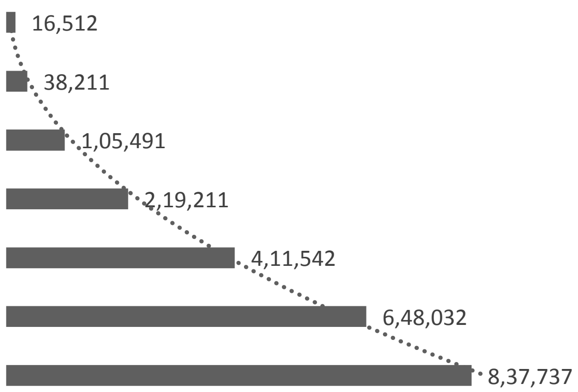
The projections of the populations for the city and Sewer District VI to the design year of 2045 are based on the most recent Comprehensive Development Plans for the city. Because the Comprehensive Development Plans are the most recent government approved population projections they will form the basis for projecting future sewage flows in the city, as per CPHEEO guidelines. Finally the recommended populations are interpolated for District VI for use in the sewer design for 2045 conditions.

5.2 Historic Populations

The population history for Bhubaneswar is given in Table 4.1 decade-wise from 1901 to 2001. These data were taken from the SAPROF Report and are based on the Census of India taken every ten years.

Table 5.1: Historic Population Data of Bhubaneswar

Census Year	Bhubaneswar Population	Trend Analysis
1941	-Not available-	
1951	16,512	
1961	38,211	
1971	105,491	
1981	219,211	
1991	411,542	
2001	648,032	
2011	8,37,737	



5.3 Population Projections, SAPROF

According to the CPHEEO Manual on Sewerage and Sewage Treatment published by the Ministry of Urban Development (MoUD), Government of India, there are several methods for calculating population. These are:

- Arithmetic Increase Method
- Incremental Increase Method
- Geometric Increase Method
- Graphical Methods

Based on the graphical method a new projection was calculated using a regression (curve fitting) analysis. This is a more rigorous statistical analysis than those typically recommended by the MoUD and is judged to be the most accurate of the statistical methods. In addition, and consistent with MoUD guidelines, this work also considered the previous population projections done by local Development Authorities based on land use & demographics.

The results of the different approaches are summarized in Table 4.2 (A). Also included in Table 4.2 (A) is the population projection for sewerage District VI as identified in the SAPROF.

Table 5.2 (A) - **Population Projections**

Method of Analysis	Bhubaneswar Projected Population to Design Year 2041
Arithmetic Increase	11’53,000
Incremental Increase	16,90,000
Geometric Increase	1,13,76,000
Regression Analysis (*)	24,60,000
Earlier City-wide Recommendation (2007) - **Population of Sewer District VI**	21,13,000 (an increase of 3.47 lakhs) 5,91,000

* Curve fitting method

Table 5.2 (B) - **Population Projections of Bhubaneswar as per BDPA (in Lakhs)**

Year	2001	2008	2011	2015	2021	2030	2041
Bhubaneswar City	6.582	10.80	12.054	13.727	16.236	20.00	24.60

The standard CPHEEO methods are statistical and therefore the projections done by these methods are based on historical trends and by nature are ‘backward’ looking. This included the regression analysis. On the other hand the projections done by local Development

Authorities are based on population allocations using land uses and demographics and are by nature 'forward' looking.

Because of this distinction, previous reports have recommended using projections based on land use and demographics done by the local Development Authorities. To be consistent with this approach, the Bhubaneswar Development Authority was contacted and the most recent population projections were obtained (used in their Comprehensive Development Plans - Comprehensive Development Plan for Bhubaneswar Development Plan Area (BDPA)).

5.4 Population Projection, BDPA

The population projections in the Comprehensive Development Plans are based on recent data and the planning experience of the Development Authority. The projections were made till 2030 and breakdown of the population by planning zones were different from the previous reports noted above. Therefore in order to compare the old and new projections, the newer BDPA projections needed to be disaggregated for Sewer District VI and further projected to 2045.

The first step was to define the Sewer District VI boundary in Bhubaneswar, since there are two maps in the SAPROF report with slightly different boundaries (SAPROF Report, Drawings, November 2006, DRWG S1 and DRWG S5). Based on a review of the report and the apparent accuracy of the two maps, DRWG S5 will be used for comparison purposes.

The BDPA population data were developed by planning zones and portions of three Zones (12-Bharatpur, 13-Chandrasekharpur and 14-Sribantapur) are in SAPROF Sewer District VI. An overlay of the BDPA and the SAPROF maps is shown in Figure 4.1, map pocket. Based on area calculations using AutoCAD software and population densities given in the BDPA Comprehensive Plan, the population for District VI was computed for 2030. BDPA data represents a straight line projection from 2011 to 2030. Therefore, the population was increased to 2045 by continuing the BDPA's straight line projection. The results are summarized in Table 4.3 along with the SAPROF projections for 2011 and 2041.

Table 5.3 – Bhubaneswar Population Projections

Year	2011		% Difference	2041		% Difference
	SAPROF	BDPA		SAPROF	BDPA	
Dist. VI	2,60,000	2,90,000	14% (+)	5,91,000	7,41,667	25% (+)
City (BMC)	10,26,000	12,61,000	23% (+)	21,13,000	24,60,000	16% (+)

The comparison of population projections in Table 4.3 shows that more recent BDPA projection is higher than the SAPROF projection in Bhubaneswar Sewer District VI. This difference appears reasonable given the available land uses, infrastructure and growth potential as described in the BDPA Comprehensive plans. It is the PMC's opinion that the BDPA's most recent and 'forward looking' projections best represent future conditions in Bhubaneswar District VI. As such these populations should be used in projecting future sewage flows in these areas.

The population projections and distribution in the preceding Tables include estimates of slum populations, but do not include floating populations. For the purpose of estimating sewage flows, a floating population of 5% will be used in Bhubaneswar District VI. This is consistent with the SAPROF Report.

Table 4.4 summarizes the land areas and population densities that will be used in the sewer design for 2045 conditions while Figure 4.2 illustrates the areas and densities.

Table 5.4 – Bhubaneswar Sewer District VI

Area	2045			
	Total Area	**Habitable Area**	**Density**	**Population**
	Sq.KM	Sq.KM	Persons/Sq.KM	
Zone - 12 (Bharatpur)	11.27	5.01	1,427	7,148
Zone - 13 (Chandrasekharpur)	38.33	38.33	19,003	7,28,961

Zone -14 (Sribantpur)	6.60	5.55	2,210	12,266
	Sewer District VI			**7,48,375 Say 7,48,400**

5.5 Population Projections by Various Methods

1. Arithmetical Increase Method: Bhubaneswar

Table 5.5 Arithematic Increase method calculation

Year	Event	Population	Population Difference
(X)	x	(Y)	(dy)
1951	1	16512	
1961	2	38211	21699
1971	3	105491	67280
1981	4	219211	113720
1991	5	411542	192331
2001	6	648032	236490
2011	7	837737	189705
2015	8	892485	
2021	9	974608	
2025	10	1029356	
2031	11	1111479	
2041	12	1248350	
2045	13	1303098	
2051	14	1385221	
Total (1951 to 2001) dy =			8,21,225
Average increase dy			**1,36,871**

The increment in arithmetic increase is determined from past decades and the average of that increment is added to the average increase.

2. Incremental Increase Method: Bhubaneswar

Table 5.6 : Incremental Increase method calculation

Year	Event	Population	Increment	Incremental	
(X)	X	(Y)	(a) x	Increase (b) y	
1951	1	16512	0		
1961	2	38211	21699	45581	
1971	3	105491	67280	46440	
1981	4	219211	113720	78611	
1991	5	411542	192331	44159	
2001	6	648032	236490	-46785	
2011	7	837737	189705		n
2015	8	901894			0.4
2021	9	1008209			1
2025	10	1085806			1.4
2031	11	1212282			2
2041	12	1449957			3
2045	13	1554435			3.4
2051	14	1721232			4
Total (1951 to 2011) dy		=	136871	33601.2	
		USE: 1,691,000 capita, Year 2041			

3. Geometric Increase Method: Bhubaneswar

Table 5.7 : Geometric Increase Method calculation

Year	Event	Population (capita)	Increment	Increase
(X)	x	(Y)		
1951	1	16512	0	
1961	2	38211	21699	1.31
1971	3	105491	67280	1.76
1981	4	219211	113720	1.08
1991	5	411542	192331	0.88
2001	6	648032	236490	0.57
2011	7	837737	189705	0.29
2015	8	1070670		
2021	9	1546954		

2025	10	1977084		
2031	11	2856583		
2041	12	5274927		
2045	13	8616129		
2051	14	9740606		
	USE: 7,33,800 capita, Year 1941			
(A) Geometric Mean (5 positive elements)=				1.05

4. Population Projection by Regression Method: Bhubaneswar

Figure 5-A - Graph of population projection by Regression method

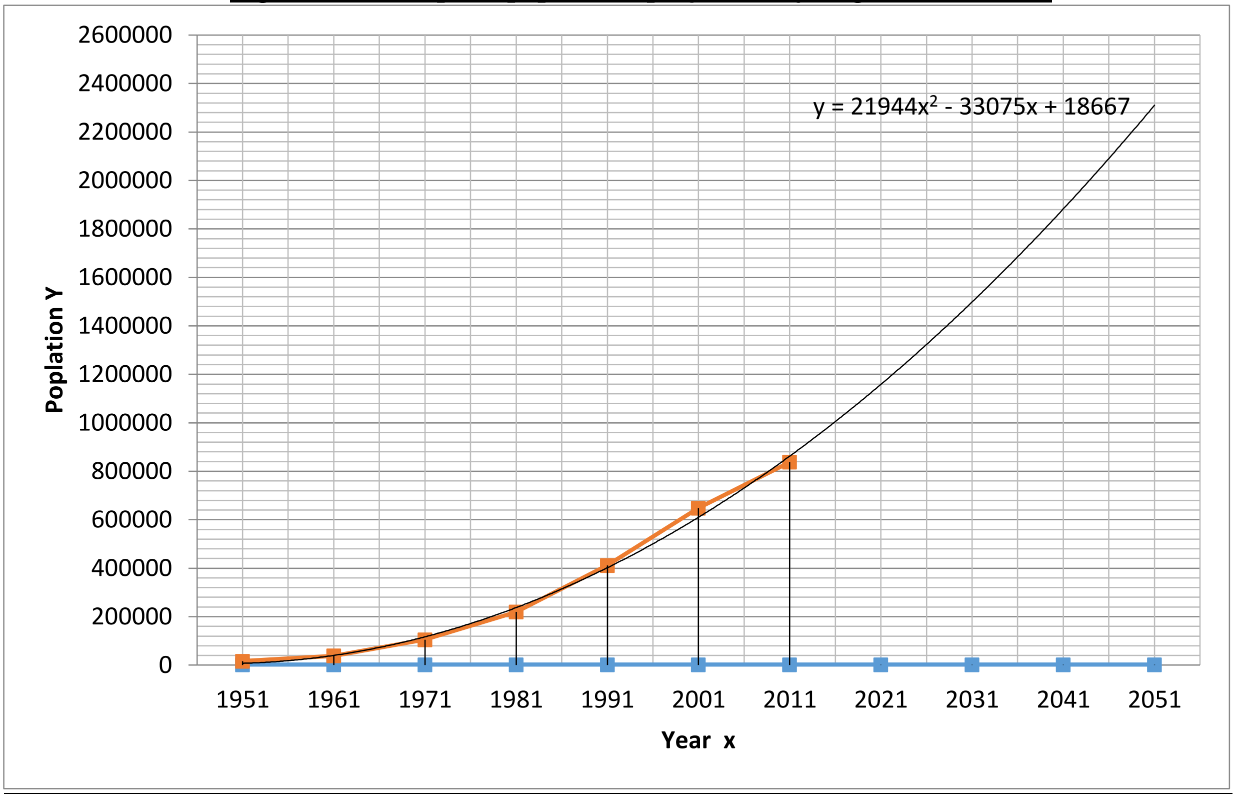
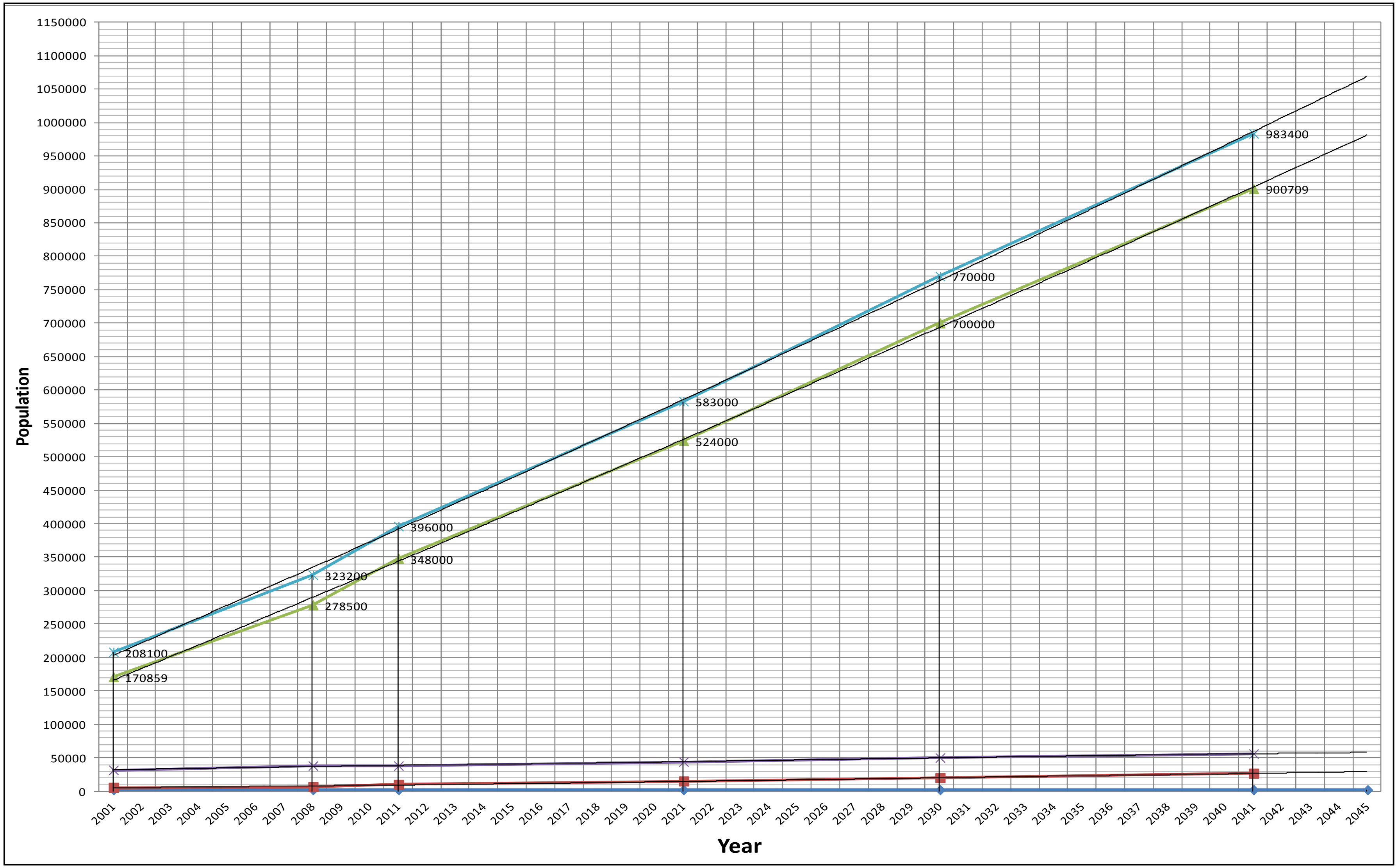


Table 5.8 : Estimated Bhubaneswar Population (by regression method)

Year	Bhubaneswar Population
1951	16,512
1961	38,211
1971	1,05,491
1981	2,19,211
1991	4,11,542
2001	6,48,032
2011	8,37,737

Year	Population	Year	Population
1951	19,868	**2001**	6,47,198
1961	32,894	**2011**	8,37,737
1971	1,02,140	**2021**	12,91,670
1981	2,27,606	**2031**	16,98,236
1991	4,09,292	**2041**	21,60,000

Figure 5-B : Bhubaneswar District VI Population 2001 -2045



5.6 BDPA Planning Zone Population and Density Perspective

Table 5.9 : District VI – project area population data

Area	BDPA Area	Populations							Sewer District VI			
Population	**Area Sq.KM**	**2001**	**2011**	**2015**	**2021**	**2030**	**2041**	**2045**	**2015**	**2030**	**2041**	**2045**
Bharatpur	40.86	5601	12925	14831	17585	21716	26682	28601	4083	5506	6550	7148
Chandrasekharpur	47.81	170859	449790	509914	600100	735379	900709	960844	408790	556213	667989	728961
Sribantpur	30.95	31647	44115	45703	48085	51658	56020	57613	8196	9952	11240	12266
Total		208107	506830	570448	665770	808753	983411	1047058	421069	571671	685779	748375
Density	Area Sq.KM	2001	2011	2015	2021	2030	2041	2045				
Bharatpur	40.86	137	316	363	430	532	653	700				
Chandrasekhar pur	47.81	3574	9408	10665	12552	15381	18839	20097				
Sribantpur	30.95	1023	1425	1479	1554	1669	1810	1861				

Source: BDPA data (*Note – Population data for Chandrasekharpur in 2008 was adjusted to reflect a continuous growth trend between 2001 and 2011).

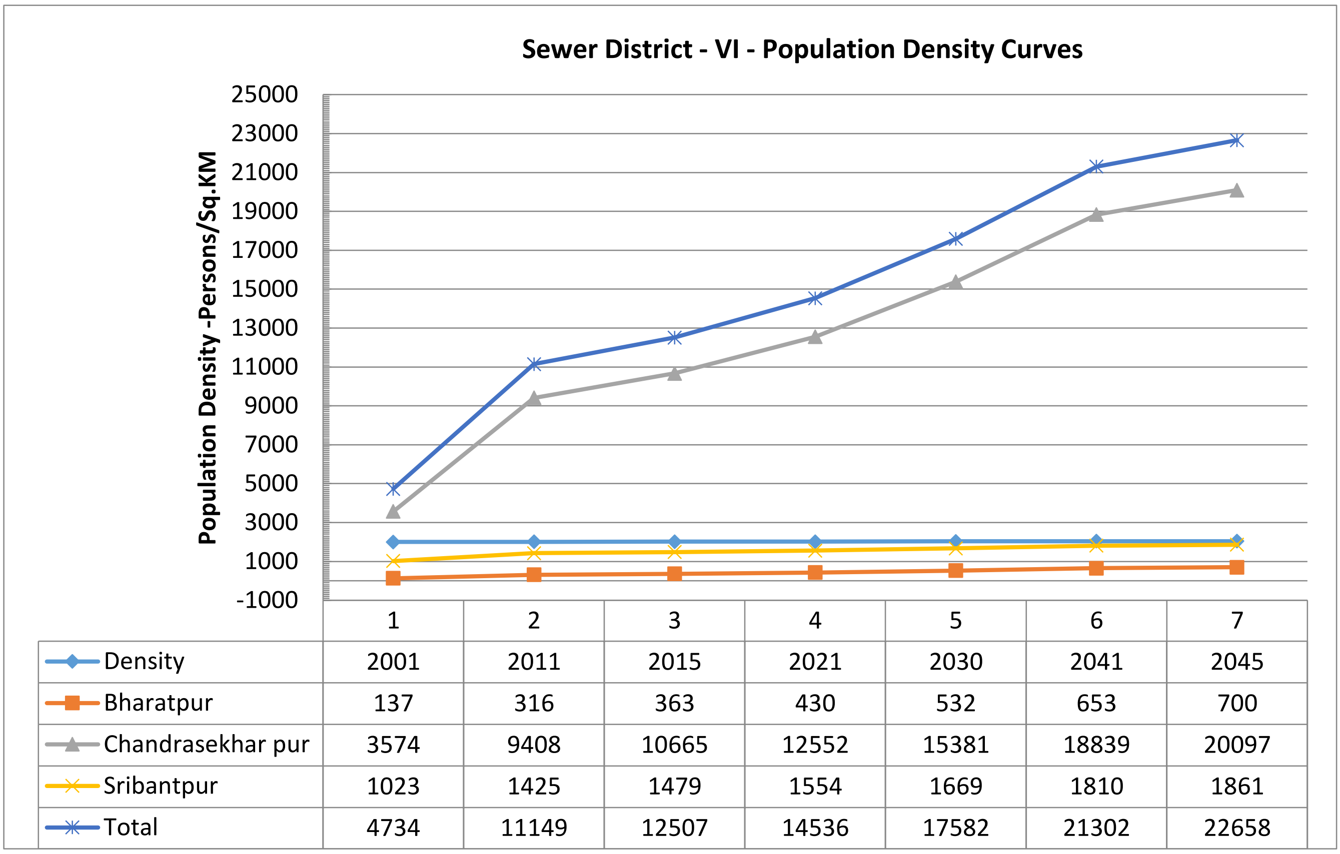


Figure 5-C : Zone wise relation of population density wrt historical population

Table 5.10 : Zone wise division of population inside the project area (BDPA)

Location	2001	2011	2015	2021	2030	2041	2045
Zone - 12 (Bharatpur)	137	316	363	430	532	653	700
Zone - 13 (Chandrasekharpur)	3574	9408	10665	12552	15381	18839	20097
Zone -14 (Sribantpur)	1023	1425	1479	1554	1669	1810	1861

5.7 Sewer District VI Area Calculation

Table 5.11 : Ratio of Zone wise area to total area of District-VI i.e. project area

Sr. No	Area	BDPA Area #	% of District VI included	District VI population	
				2041	2045
1	Bharatpur	26682	28 %	6550	7148
2	Chandrasekharpur	900709	80 %	667989	728961
3	Sribantpur	56020	21 %	11240	12266
Total				685779	748375

Chapter 6 : Methodology

One of the foremost aims of this project has been about finding out the amount of efficiency in areas where this project is going on and in some areas where it is envisioned to be done.

An analysis of the choice of process selection has been done here. A comparison of the processes which are feasible given the constraints present has also been done.

The success of a project depends on many factors involving the pre-construction phase (involving planning, staffing, co-ordination etc), construction phase (observation, supervision etc) and post-construction phase (maintenance and supervision etc). Public acceptance goes a long way in ensuring proper maintenance of the project.

Therefore, generating an analysis of the sensitivity associated with the project and its impact upon the local residents and workers, directly or indirectly affected, is one of the additionalities of the project and aims at giving us an idea about whether the project implementation is giving the desired benefits or not and whether sustainability in the long run is encroaching upon the benefits of the present. Moreover, an idea about the acceptability of the project among the public can also be ascertained.

The methodology followed during the completion of each part of the project is being described.

6.1 For Waste Water analysis

1. Samples were collected from 4 places –
    a. Chandrasekharpur, BDA Colony Phase-I, at Nilamadhav Basti.
    b. Sailashree Chowk, Near Sailahsree Vihar Area – a traditional urban area.
    c. Kanan Vihar Phase-I, Near Nandan Kanan Road – An area of rapid urbanization.
    d. VSS Nagar – one of the many industrial estates in Bhubaneswar.
    e. Salia Sahi area – the largest slum in Odisha.

    In 2 phases –

    A. Phase 1 : 10.01.2015 till 18.021.2015 (on weekends)
    B. Phase 2 : 10.03.2015 till 20.03.2015 (on weekdays)

2. Maps showing locations of sampling and flow measurement points are presented in Figure-10.1 and 10.2.
3. Two 24 hour composite samples were taken at each location, one on a weekend (Phase 1) and one on a weekday (Phase 2). The areas tributaries to the sampling locations are primarily

residential with some mixed commercial uses. The results are summarized in Tables 10.2 and 10.3.

4. Due care was followed while experimenting on the samples and sufficient precautions were taken.
5. The samples were experimented upon at the Central Laboratory of the OSPCB, Sachivalaya marg, Bhubaneswar and the Environmental Engineering laboratory at the College of Engineering and Technology, Bhubaneswar.
6. The results obtained from the experiments were tabulated.

Figure 6-A : Testing of Waste Water at Central laboratory, Bhubaneswar

6.2 For STP Process Selection Analysis

1. Several sources of literature such as reports, case studies – both in India and abroad were collected. Special emphasis was given to case studies inside the Indian sub-continent because of the similarity of climate and other geographical factors which would make it easy for correlation.
2. Relevant details were obtained from several sources like the BDA (topographical maps, land-use maps), OWSSB (design maps, drawings, project reports etc). They were studied in great detail, analysed with reference to the available literature on the subjects.
3. With reference to the area under consideration and several parameters like – area required, cost for setting up of a particular facility, cost for operations and maintenance and other turn-key factors were analysed. During this process, help was sought from various sources like the institutions involved in the project, some experts in this field (including teachers from nearby institutions).
4. Individual procedures were studied and they were marked for their benefits in tabular form as is available in the results.

6.3 For Sustainability Analysis

1. Since, the project covers a large area (District-VI) of Bhubaneswar, it was important to select appropriate areas for the analysis i.e. a targeted sample space. It should include all kinds of people inorder to present a coherent approach towards the analysis. At the same time, care should be taken to ensure that the people understand fully the aim of the survey, the impact the project can have on the population and the benefits of the study being conducted.

2. As soon as the segments were finalized as the location for the case study, data was collected. The initial step was to identify the data requirements and the sources from where the data could be collected. Hence, a table was developed listing all the data sources and the individual data requirement from each credit application. Sources include observations from site visit, experts in this field and the public (commuters /residents) being directly affected due to the project in these areas.
3. For the purpose of identifying sustainability indicators and verifying their weightage, a proforma with the required indicators enlisted were presented to the people (after taking their consent towards giving a fair viewpoint regarding those indicators).
4. **These indicators were prepared by soliciting expert opinion and taking into account the complaints from the local people, the workers involved and the nearby residents.**
5. The duly filled questionnaire was to be sent back to the address mentioned within 20 days. The distribution of proforma started on 5th April 2015 and all the questionnaires were received latest by 30th April 2015.
6. For evaluation of the project, in the areas under scrutiny, the data was collected by conducting a survey in public (commuters/ residents) availing facilities in those sites. The proforma which included indicators and a column for the quantitative ratings for each site was distributed in the neighbouring colonies and the shops near the construction sites.
7. The results obtained from the proforma were created into a tabular form and the reults were collated by calculating the average according to the following criteria –
    a. Point 1 to point 5 => 27 % (5.4% * 5) importance.
    b. Point 6 to Point 9 => 23 % (5.75% * 4) importance.
    c. Point 10 to Point 13 => 29 % (7.25% * 4) importance.
    d. Point 14 to point 16 => 21 % (7% * 3) importance.
8. The conclusions were drawn and recommendations were given.
9. The proforma is as follows –

SUBJECT: SURVEY TO ASSESS THE SUSTAINABILITY OF ODISHA INTEGRATED SANITATION IMPROVEMENT PROJECT IN DISTRICT-VI, BHUBANESWAR

A survey of the Residents residing/using the stretches near the construction site of the Odisha Integrated Sanitation Improvement Project has been undertaken by a team comprising of research students of Delhi Technological University, Delhi & College of Engineering and Technology, Bhubaneswar to assess the sustainability impacts during the construction of the project – Sewerage project in District – VI of Bhubaneswar, Odisha.

The indicators identified have been listed on left hand side. Construction agency is expected to make suitable arrangements so that there is least impact or in-convenience to the public residing nearly or passing through the corridor. The rating from 0 to 10 can be given depending upon the inconvenience caused to the public. Better arrangements of any conditions listed should be assigned with a high mark as against the comparatively poor -conditions with a corresponding poor rating.

The study has been undertaken with the express aim of ascertaining the public opinion regarding the viability, ease of project construction and its benefits to the people.

A common Proforma with various sustainability indicators is enclosed herewith and it is requested that the respondent rate the indicators in a free and fair manner depending on the knowledge of the sites under consideration. The areas have been chosen according to the high population density and the existing conditions in those areas.

The areas under consideration are :

1. Chandrasekharpur OSHB Area & VSS Nagar
2. Kanan Vihar Phase – II & Maitri Vihar
3. Sainik School & Utkal University Area

The opinions expressed by the residents shall be strictly confidential and would only be used for research purposes. We respect confidentiality.

NOTE: It is requested to rate only those indicators which a resident/commuter is aware of. Else, the space may be left blank.

Please furnish your fair comments/ opinion in so that indicators identified may be used for grading a project from sustainability point of view and we can make more sustainable projects in future.

Opinions can be furnished to **Sankalp Swastik Sahoo,** Plot – 887/4, Millennium Colony, NK Marg, Baramunda, Bhubaneswar (E-mail : sankalpswastik@gmail.com / Mob - +91 – 8800305330 (*You can also send the photo of the filled in form to the above Email ID or to the above mobile number*) **or,** to **Er. Binod Kumar Sahu, O/o the Project Engineer, Project management Unit (PMU), OISIP, JICA – OWSSB, 2nd Floor, Public Health (PH) Circle Building, Unit – V, Bhubaneswar – 01.**

PROFORMA

Name :…………………………………………………………………………… Address (optional) ………………………………………………………………………………………			Mobile No.(optional) Email ID (optional)
Area	CSPur OSHB & VSS Nagar	Maitri Vihar & Kanan Vihar Phase-2	Sainik School & Utkal University
	☐	☐	☐

Sl. No.	SUSTAINABILITY INDICATORS	Qualitative Rating (0-10 scale) 0 = Worst, 10 = Best		
		Before project	**After project**	**Remarks / Suggestions**
1	Acceptability of the project			
2	Problems to commuters with reference to handling of traffic activites in the area			
3	Other factors like lighting, presence of supervisors etc.			
4	Visibility and sight distance to moving traffic			
5	Increase in Travel time and cost			
6	Public conveniences in project area like proper parking spaces.			
7	Use of proper signage to alert commuters about construction activities			
8	Perceived changes in water logging during Monsoon/rains, as against absence of project			
9	Maintenance of and changes in existing drainage conditions.			
10	Filling up of earthwork after completion of construction in the section.			
11	Regarding pollution on-site.			
12	Handling of C & D Waste			
13	Removal of trees/ depletion of Green Belt.			
14	Impact on Health and safety of residents			
15	Disturbance to the business/Employment of nearby residents			
16	Safety measures for workers and availability of First Aid kit.			

Chapter 7 : Waste Water Testing

7.1 Wastewater Characteristics and Per Capita Flows

This Chapter evaluates the results of a field sampling program in the sewer systems in Bhubaneswar District – VI for the purpose of collecting samples for laboratory analysis of wastewater characteristics and measuring wastewater flows. The results are included for both cities to give the most comprehensive view of available data. This Chapter also includes an evaluation of available water records to gain insight into resulting per capita wastewater flows.

The objective is to determine design values for the influent wastewater to the treatment plants for BOD5 and Total Suspended Solids (TSS) and per capita flow contributions.

7.2 Flow Measurement Program

To test the reliability and basis of the above data, the Flow measurements were taken between 10.03.2015 and 20.03.2015 at 4 locations in Bhubaneswar as below;

Table 7.1: Flow Measurement Points

City	Flow Measurement Points	Duration
Bhubaneswar	1. Chandrasekharpur, BDA Colony Phase-I, at Nilamadhav Basti. 2. Sailashree Chowk, Near Sailahsree Vihar Area 3. Kanan Vihar Phase-I, Near Nandan Kanan Road 4. VSS Nagar	10.03.2015 To 20.03.2015

The data were taken for a continuous period of 48 hours, with the help of the contractor involved. The results are summarized in Table 7.2.

Table 7.2: Flow Measurement Results

Location		Flow in MLD		
		Average	Maximum	Minimum
Bhubaneswar District VI				
BSA 1	Chandrasekharpur, BDA Colony Phase-I, at Nilamadhav Basti.	0.07	0.22	0
BSA 2	Sailashree Chowk, Near Sailahsree Vihar Area	0.36	1.17	0.01
BSA 3	Kanan Vihar Phase-I, Near Nandan Kanan Road	0.15	0.52	0.02
BSA 4	VSS Nagar	0.12	0.26	0.01

7.3 Per Capita Flow Estimates

Based on the flow measurement results and the population data (from the available data with the Bhubaneswar Municipal Corporation), the per capita wastewater generation (LPCD) was calculated by using following formula;

Per capita Waste Water generation (litres per capita per day) = (Average Flow (MLD)/Total Population) X 10,00,000

The results are summarized in Table 7.3 as below;

Table 7.3: Per Capita Flow Estimates

Per Capita Flow Estimates				
Location	**Tributary Area**	**Average Flow, MLD**	**Tributary Population**	**Per Capita Flow, Liters per capita per day**
Bhubaneswar				
BSA 1	Chandrasekharpur, BDA Colony Phase-I, at Nilamadhav Basti.	0.07	7160	10
BSA 2	Sailashree Chowk, Near Sailahsree Vihar Area	0.36	7662	47
BSA 3	Kanan Vihar Phase-I, Near Nandan Kanan Road	0.15	735	210
BSA 4	VSS Nagar	0.12	3814	32
		Total	19371	36
Recommended Per Capita Flow Estimate, CPHEEO				120

The data in Table 7.3 indicates that the per capita flow estimates measured in Bhubaneswar District VI are below the value recommended in the CPHEEO Manual of 120 litres per capita per day in three areas and above in one area.

Like the wastewater concentrations these values are representative of existing conditions, but are not values to be used for the design of new sewers, pumping stations or treatment plants. The lower values in Bhubaneswar suggest that there are problems in the collection systems related to operational and/or structural conditions in the sewers or household connections. It also doesn't account for changing water use practices that are likely to occur over the life of the system as properly functioning water and sewer systems are more fully used.

For these reasons the CPHEEO design value of 120 lpcd will be used for design of the sewers, pumping stations and treatment plants.

7.4 Water Use – Data Analysis

In addition to direct measurements of wastewater flows a review and analysis of the water use data was conducted for Bhubaneswar. The purpose of the analysis is to determine if the data are representative of actual water consumption and to use the data as a guide in selecting per capita wastewater generation rates.

The Bhubaneswar data were obtained from the Office of the Assistant Engineer P.H. Sub-Division of Chandrasekharpur. The data include the present and future demand of water from Hill Top Reservoir at Niladrivihar (obtained from official sources)

7.5 Peaking Factor.

In addition to average flows, it is important to understand the relationship between average and peak conditions. The ratio of average to instantaneous peak flows range from 2.1 to 4 for the 9 locations where flow measurements were taken. The average peaking factor is 2.9 for both Bhubaneswar and Cuttack. This is typical, although on the lower side, for small tributary areas and the diurnal timing of the peak flows in the morning and evenings is consistent with typical domestic wastewater patterns. Therefore the peaking factors that are in the CPHEEO manual will be used.

Chapter 8 : STP Process Selection Analysis

8.1 Background

This chapter includes an evaluation of treatment processes and recommends the process to be used in Sewer District VI, Bhubaneswar.

Prior to the initiation of the SAPROF report the OWSSB had prepared a Detailed Project Report (DPR, June 2007) concerning this work and, among other items, analyzed several sewage treatment processes for plants that ranged from 10 MLD to 70 MLD. The DPR had proposed sequential batch reactor process for plants greater than 10 MLD and extended aeration for smaller plants below 10 MLD. Their recommendation was based on capital cost - low operation and maintenance cost and good track records of these processes. But, with recent tested research in this field, it has also been possible to use some of these processes with an additional benefit of power generation – low cost.

8.2 Sewage Treatment Practices In India

The population of India is likely to reach 1.7 billion people by 2050. Based on this projected population the wastewater generation shall be approximately 132,000 MLD. As minimum dry weather flows in rivers decrease due to additional water demand for various purposes, the wastewater generation in urban centres shall further adversely affect downstream water quality. Considering this growth scenario, there is a need to attain a high level of sewage treatment in each city.

The Central Pollution Control Board (CPCB) has carried out a series of studies on performance of Sewage Treatment Plants (STPs) in different parts of the country to evaluate their performance. The findings reveal that the majority of the treatment plants serving medium-sized cities are based on:

- Primary Settling followed by Activated Sludge Process (PS+ASP) technology (with anaerobic digesters for sludge treatment)
- Oxidation Pond or Waste Stabilization Pond(OP or WSP) technology; and

- UASB followed by Final Polishing Unit (UASB+FPU) technology.

Table 8.1 shows some of the recent plants constructed in Delhi based on ASP technology.

Table 8.1: Examples of Existing STPs Constructed/under construction in Delhi

Item	**Units**	**Okhla STP**	**Rithala STP**	**Nilothi STP**
Process		**ASP (including Nitrification & Denitrification) with Power Generation & Disinfection.**	**High Load ASP with Power Generation**	**ASP with Power Generation**
Plant Capacity	MLD	136.4	180	180
Land Area Required	Acre	40	39	52.5
Unit Land Area Requirement	Acre/MLD	0.29	0.22	0.29
Year of Award of Work		2008	1996	1995
Total Power Requirement	KWH/d	42,000	32,000	33,600
Unit Power Requirement	KWH/d/MLD	308	178	187
Power Generation	KWH/d	25,000	27,000	(See note b)

Notes:

- Rithala STP. The high load process prevents incidental nitrification in summers thus consistently meeting BOD/TSS guarantees. Power generation at 27,000 KWH/d was guaranteed (by contract).
- Nilothi STP. The plant shall produce energy from anaerobic digestion.

8.3 Project Requirements

The project requirements for the selection of the treatment process include:

- Compliance with discharge standards
- Operational reliability
- Proven track record
- Best life-cycle cost
- Ability to supplement the plant energy demand

8.4 Compliance With Discharge Standards

Sewage treatment plants must produce an effluent that protects the environment and meets regulatory requirements. The effluent in this project shall be discharged to drainage canals or nallahs ultimately to rivers, or use for agricultural irrigation.

The standard established for Odisha is Class C, which is for drinking water source with conventional treatment. The numerical standards for discharge to Class C waters are as follows:

- 5 day BOD = 30 mg/l
- Total suspended solids = 50 mg/l
- Total coli-form = 5000 counts /100 ml
- Dissolved solids = 1500 mg/l
- Chloride = 400 mg/l
- Dissolved oxygen = 4 mg/l
- pH = 6.5 – 8.5

8.5 Operational Reliability

With a Design-Build-Operate mode of operation, the contractor has a multi-year contract for plant operation. The contractor shall be required to provide a performance and cost guarantee for the operations period, but eventually the plant operation shall be turned over to the Bhubaneswar Municipal Corporation. For this reason it is important that the technology selected be easy to operate and troubleshoot, and provide reliability under a wide range of operational conditions.

8.6 Proven Track Record

All treatment options have operational risks. Tried and tested processes enjoy the advantage of world-wide knowledge and experience, with much training and information available to operators.

Innovative processes improve efficiencies or widen the range of applications but they may also introduce operational uncertainties. Since this would be a project of large magnitude, therefore the opportunity cost of taking risks should be minimal and hence the process selected should have enjoyed a fair degree of success. Untested processes, are more suitable for communities where technical expertise and resources are readily available and have only been in operation for a limited period of time.

Given the expected capabilities of the local labour force, the Odisha project requires that proven technology be used in the plant design. And therefore analysis has been done regarding those processes which have had a fair amount of successes in their operation in India given the changes in climate and other associated conditions.

8.7 Best Life-Cycle Cost

Life-cycle costs shall also be used as an indicator of best value for the process. The analysis requires that capital and operational costs are considered. The analysis, therefore, requires knowledge of availability of land and cost, construction cost, and operational inputs, such as manpower, energy, chemicals, and repair costs, which were obtained from the relevant authorities during the duration of the project.

8.8 Resource Recovery

The State Govt. is interested in minimizing the electricity requirements inorder to bring down operational costs and ensure the project is less burdening on the public. The project shall be designed to reduce capital, land and operational cost. Utilizing effluent and stabilized sludge as resource recovery may also be considered during the analysis.

8.9 Selection Criteria

One of the most challenging aspects of a wastewater treatment system design is the analysis and selection of the treatment process and technologies capable of meeting the project requirements.

The process shall be selected based on compliance with discharge standards as stated above. While costs are important, other factors shall also be given due consideration. For instance, effluent quality, process complexity, process reliability, environmental issues and land requirements should be evaluated and weighted along with cost considerations as summarized in Table 8.2.

Table 8.2: Sewage Treatment Process Selection Considerations

Consideration	Goal
Power requirement	Minimizing power requirements
Land required	Minimize land requirement
Capital Cost of Plant	Optimum utilization of capital
Operation & Maintenance costs	Attaining lower running cost
Maintenance requirement	Simplicity and reliability
Operator attention	Easy in understand procedures
Reliability	Deliver the desired quality on a consistent basis
Resource Recovery	Ability to abate operational costs.

8.10 Resource Recovery

Methane generated in anaerobic digestion can be used to supplement the energy requirement of the plant. Typically the gas is used for providing heat for maintaining the digester temperature in the mesophilic range of 35 degrees Celsius and to run blowers for the aeration oxygen requirements. Some plants in India have reported energy recovery in the range of above 80% of the total plant requirement (Rithala STP) (Tokyo Engineering Consultants 2004). Recent experience with the Jaipur STP and Rithala STP seem to suggest that the expected amount of energy generated by the anaerobic digesters is in the order of 60 to 85 percent of the plant needs.

Temperature in Odisha is very favourable for anaerobic digestion. The ambient temperature, ranges from 20°C in the winter to 45°C in the summer and thus minimizes heat loss from the digesters, compared to locations in the colder climate. So a small fraction of biogas would be used for maintaining the digester temperature in the mesophilic range of 35 degrees Celsius. The majority of biogas can be used to generate electricity.

Once pre-treated, the biogas is supplied to a gas engine where it is converted to mechanical or electrical energy.

A ***side benefit*** of producing energy is that the Government of India shall be able to sell carbon credits in the world market. Carbon credits are pollution equivalencies that some industrialized countries buy to offset their own emissions. Carbon credit is generated by converting the methane produced in the plant to carbon dioxide, via power generation. It may be noted with interest that Governments of Tamil Nadu and Uttar Pradesh have carbon credit units of 4,44,000 and 16,20,000 units respectively till 2012 from methane gas.

8.11 Process Descriptions

The following are descriptions of processes under evaluation.

a. Activated Sludge Process

Activated Sludge Process is a suspended growth aerobic process, similar to extended aeration. It includes a primary clarifier to reduce the organic load to the biological reactor. Apart from the normal processes followed till clarification, the following unit operations are also involved in this process.

- Sludge Thickening
- Anaerobic Sludge Digestion
- Sludge Dewatering
- Gas Holder
- Gas Engine for Power Generation

About 35% of the organic load is intercepted in the primary clarifier in the form of sludge, decreasing the loading in the aeration tank. (Jahan et al. 2011). Detention period in the aeration tank is maintained between 4-6 hours at a sufficient temperature. Then the mixed liquor is sent to the secondary clarification where sludge and liquid are separated. A major portion of the sludge is re-circulated and excess sludge is wasted to a digester. Significant improvement in effluent quality can be obtained by applying the variable solid retention time (5–7 days) dependent on temperature variation (Shahzad et al. 2015).

Membrane fouling is responsible for decreasing treated water production and simultaneously increasing maintenance as well as operation costs. Even though economically unsustainable, addition of powdered activated carbon could reduce membrane fouling.(Torretta et al. 2013)

Sludge generated in the primary clarifier and excess sludge from the activated sludge requires digestion for multiple reasons; pathogen reduction, volume reduction and biogas generation. The digestion also improves de-waterability of the sludge.

Primary sludge contains high volatile solids and secondary sludge contains a lesser amount. The biogas, thus generated can be used for power generation by gas engines. Generated power can be used for operation of the plant. It may meet 60 - 80% of the power required for running the entire sewage treatment plant under favourable climatic condition for anaerobic digestion.

b. <u>Aerated Lagoon</u>

Aerated lagoons are completely mixed aerobic biological reactor without recycling. Lagoons are normally earthen basin where air is supplied for biological activity. Overflow of aerated lagoon is either sent to a sedimentation basin or clarifier. Mean cell residence time is maintained at 3 to 6 days. Depth of aerated lagoon is generally maintained 3 to 3.5 Meter.

Some researchers have also argued against the huge spending of economic resources towards other systems. Because BOD5 – the main indicator assumed to be a test of waste water strength is highly over-reported. (Rich 2010) It has been reported that as many as 60 percent of the BOD5 violations nationally may have been caused by nitrification in the BOD5 test rather than by improper design or operation.

Since lagoons are quite big with hydraulic detention time is 3 to 4 days, they require a very large area. Operation of the plant is simple but power consumption is high to maintain the Mixed Liquor Suspended Solids (MLSS) in suspended solids.

c. **Extended Aeration**

Extended aeration is a modified version of the activated sludge process. It is a suspended growth aerobic biological process. In this system sewage, after screening and degritting, is fed to an aeration tank. No primary clarification is done before feeding to the aerobic process. The food to microorganism ratio or F/M ratio is kept low usually below 0.05 mg BOD/mg MLSS and detention period is maintained between 12 to 14 hours.

Due to high detention period and low F/M ratio, endogenous respiration of biological mass takes place. Sludge generation is comparatively low but, up to certain extent, it is matured. In most applications the sludge generated from this process is directly disposed to drying beds. Alternatively, after thickening the sludge is dewatered mechanically.

The extended aeration process comprises of following units:

- Screening
- Degritting
- Aeration Tank
- Clarifier
- Sludge Recirculation System
- Sludge Drying Bed / Sludge Dewatering System

Extended aeration process is simple to operate. It is a proven process to produce treated effluent with BOD and TSS less than 30 mg/l, and often below 20 mg/l.

Since there is no primary clarifier, the entire BOD load goes to the aeration tank. Oxygen / air requirement is higher than with primary clarifiers.

Because extended aeration is a proven process and simple in operation, it is favoured in small facilities. This process, however, is not advantageous for large plants because it requires more space and its operating cost is high due to power consumption.

d. <u>Moving Bed Bio Reactor (MBBR)</u>

The Moving Bed Bio Reactor is an aerobic attached biological growth process. It does not require a primary clarifier. The raw sewage, after screening and degritting, is fed to the biological reactor. It comprises of the following unit operations:

- Screening
- Degritting
- Moving Bed Reactor
- Clarifier
- Sludge Dewatering

Since it is an attached growth process, sludge recirculation to the reactor is not required.

In the reactor, floating plastic media is provided which remains in suspension. Biological mass is generated on the surface of the media. Attached biological mass consume organic matter for their metabolism. Excess biological mass leaves the surface of the media and is settled in the clarifier.

Moving Bed Reactor needs less space since there is no primary clarifier and detention periods are generally 4-5 hours. Approximately 2 man hours per week were needed for operation of a plant originally designed with the MBBR process. (RUSTEN et al. 1997)

Moving Bed Reactors were initially used for small sewage and effluent treatment plants in the range of 1 to 5 MLD because of less space requirement. This process was not successful at higher capacities. In large plant, media quantity is high and requires long shut down period for the plant. Moreover the plastic media is patented and not available in the open market, leading to single supplier conditions which limits price competition.

Also, the membrane fouling behavior was more severe in the MBMBR than in the CMBR due to a thick and dense cake layer formed on the membrane surface, which was speculated to be caused by the filamentous bacteria in the MBMBR (Yang et al. 2009).

e. <u>**Sequential Batch Reactor, or SBR**</u>

The Sequential Batch Reactor is an aerobic process where raw sewage is treated in batches. After screening and de-gritting, sewage is fed to the batch reactor. Reactor operations take place in sequence. In one cycle biological processes and sedimentation takes place in the following steps.

- Filling tank
- Aeration
- Settling
- Decantation
- Sludge withdrawal

For continuous treatment of sewage a number of reactors are installed and synchronized so that different activities take place in different reactors so that sewage can be treated continuously. In this process some nitrification may takes place, where excess oxygen is available.

Since all unit operations take place in one tank without separate clarifiers, a smaller foot print is required.

According to (Zhang et al. 2006), COD removal averaged at 94.9 and 97.7%, respectively, for SBMBR and CMBR during their 8 months experimental period. So, efficiency-wise, the SBR can be said to be highly effective.

Power requirements are high, since the process includes larger electrical equipment; blower, pumps and chemical feeders. Moreover, according to (Ahmed et al. 2007), membrane fouling was also observed due to the cluster growth of microbes - *Proteobacteria*.

Nevertheless, a number of large scale plants exist around the world with several years of continuous operation. In India there are large plants operating efficiently for more than a year. This technology was started in smaller plants with controlled and skilled operation and maintenance.

f. UASB

UASB process is an Up-flow Anaerobic Blanket Process wherein the organic matter is digested, absorbed, adsorbed and metabolized into bacteria cell mass and bio-gas.

The UASB process is a combination of physical and biological processes. Main feature of the physical process is separation of solids and gases from the liquid and of the biological process is degradation of decomposable organic matter under anaerobic conditions. The bio-gas generated can be utilized for generation of electricity. Sludge cakes after dewatering and drying on sludge drying beds are suitable to be used on field as manure. The UASB system also does not require any other external energy and require very less mechanical equipment.

There have been novel ways towards resolving problems associated with UASB system (Chowdhury & Mehrotra 2004). But these have not been found to be sustainable in the long run.

However adequate post treatment is always required to polish the UASB effluent to meet standards. UASB reactor can bring down the BOD and TSS of the domestic wastewater up to 65-75% and 70-85% respectively.

Therefore post treatment in form of final polishing unit is always required. Even after the post treatment with final polishing unit (FPU), it is difficult to achieve the desired effluent standards. Faecal coli forms removal varies from 1-2 log units.

g. Waste Stabilization Pond (Combination of Anaerobic and Aerobic Pond)

In waste stabilization ponds sewage is treated in a series of earthen ponds. Initially after screening and degritting it is fed to an anaerobic pond for pre-treatment. Depths of anaerobic ponds are usually 3 to 3.5 m and as a result the lower sections of the ponds do not get oxygen and an anaerobic condition is developed. BOD reduction takes place by anaerobic metabolism and gases like phenols and methane is produced creating odour problems. After reduction of BOD by 40% it enters the aerobic pond, which is normally 1.0 m to 1.5 m in depth. Lesser depth allows continuous oxygen diffusion from atmosphere. In addition, algae in the pond also produce oxygen.

Although BOD at the outlet remains below 30 mg/l, the effluent can have a green colour due to presence of algae. The algae growth can contribute to the deterioration of effluent quality (higher total suspended solids).

The operating cost of a waste stabilization pond is low, mostly related to the cost of cleaning the pond once in two to three years.

Waste stabilization ponds require large land areas and they are normally used for small capacity plant, especially where open land is available.

h. **Wetland Construction**

Wetlands are natural processes similar to stabilization ponds. After degritting, sewage is fed to the wetland. Wetlands are shallow ponds comprising submerged plants and floating islands of marshy species.

Chapter 9 : Sustainability Analysis

The United Nations (Brundtland 1987) defines sustainability as the ability of this generation to meet the needs of their present without compromising on the ability of future generations to meet theirs.

Sustainability, whether weak or strong (in environmental economics) holds human and natural capital equally responsible for ensuring continuity of every form of life. Working out a fine balance between the two forms is more acceptable than

Appropriate selection of effective indicators is a fundamental key to the success of an index or a rating system. A common procedure must be followed while establishing appropriate indicators. (Bossel 1999) developed four key steps for going from a whole system to individual indicators and later implementing them into the participating processes.

The four main steps are as follow (Bossel 1999):

1. Basic understanding of the entire system

2. Identification of representative indicators

3. Conduct a participative process of ascertaining sustainability.

The first step, understanding the working of the system – how the system has developed, how it works are key to the viability of the orienteers and the indicators. The next step is identifying the representative indicators, which is further comprised of sub-steps, which are discussed as below. In these sub-steps, representative indicators are chosen from the immense number of potential candidate (Bossel 1999).

The third step requires the prioritization of the indicators in order to convert indicator information into orienteer satisfaction. The final step involves input through external opinions in order to compensate the decisions made by the person who has established the indicators. By having appropriate external reviewers, a broad spectrum of knowledge, mental models, experience, and social/environmental concerns can be highlighted (Bossel 1999).

Mitchell (1996) has developed a practice, specific to the sustainable development, for identifying appropriate indicators for the entire system. The broad parameters of the method are:

1. System objectives definition with clear definition and purpose of the objectives.
2. Finding out which data is available from trusted sources and verifying the authenticity of them with respect to clear definitions.
3. Defining locally and globally important issues. Perception of such issues may vary from person to person and hence taking the help of experts and other technical persons is critical towards finding out the local relevance of globally relevant data and vice-versa.
4. Developing a rating system based on the levels of information available and then ensuring that the rating system is based on scientifically established facts.
5. Selection of the sample population is another crucial factor in improving the efficiency of data collection, analysis and generation of scientifically valuable results. More so, in a developing country like India where levels of education are not so well balanced.

Chapter 10 : Results and Conclusion

10.1 Waste Water testing results

The results of the tests done are mentioned below.

1. Wastewater Characteristics

The field sampling program was conducted between 10.01.2015 and 18.01.2015 (Phase – 1) and between 10.03.2015 and 20.03.2015, at 5 locations in Bhubaneswar as below;

Table 10.1: Wastewater Sampling and Flow Measurement Program at Bhubaneswar & Cuttack

City	Wastewater Sampling Points	Duration	
		Phase-I	Phase-II
Bhubaneswar	1. Chandrasekharpur, BDA Colony Phase-I. 2. Sailashree Chowk, Near Sailahsree Vihar Area 3. Kanan Vihar Phase-I, Near Nandan Kanan Road 4. Salia Sahi (at Pumping Station) 5. VSS Nagar (Near Market)	9:00 A:M, 10.01.2015 To 9:00 A:M, 18.01.2015	10.03.2015 To 20.03.2015

Table 10.2: Sampling Results: Bhubaneswar (as per OWSSB data in 2007)

Chemical Analysis of Water Collected From Different Area												
SL No	Parameter	Bhubaneswar										
		Phase I					Phase 2					
		C.S Pur, BDA Ph-I	Sailshree Vihar	Kannan Vihar	Salia Sahi Station	Average	BDA Ph-1, Nilmadhav basti	Sailshree Vihar	Kannan Vihar	Salia Sahi Station	VSS Nagar, near market area	Average
1	PH at 25°c	6.9	6.7	6.9	6.8	6.80	7.4	7.1	7.2	7.2	7.3	7.2
2	Dissolved Oxygen, mg/l	Nil	Nil	2.6	Nil	0.65	Nil	Nil	Nil	Nil	Nil	-
3	Total suspended Solid, mg/l	154	138	128	102	130.5	162	172	16	86	120	129
4	Volatile Suspended Solid mg/l	82	86	48	64	70	76	80	64	46	78	69
5	Biochemical Oxygen Demand 5 days at 20°c	70	95	18	75	64.5	78	72	62	92	122	85
6	Chemical Oxygen demand mg/l	176	168	77	154	133	195	184	152	224	296	210
7	Total Nitrogen(as N), mg/l	18	25	6	16	16	16.5	14.2	12.8	16.1	28.9	17.7
8	Iron (as Fe), mg/l	5 56	1.68	451	1.18	-	2.2	2.7	1.4	1.57	2.1	-
9	Fecal Coliform/100ml	$1.6*10^3$ Organism	$9.01*10^4$ Organism	$1.6*10^3$ Organism	$9.0*10^5$ Organism	-	$3.5*10^6$ Organisms	$5*10^5$ Organisms	$5.4*10^5$ Organisms	$1.1*10^5$ Organisms	3.5*104 Organisms	-

Source : OSPCB (2007) and OWSSB collaborative study.

Table 10.3: Sampling Results: Bhubaneswar (as per experiments conducted during the above given period - 2015)

SL No	Parameter	Chemical Analysis of Water Collected From Different Area										
		Bhubaneswar										
		Phase I					Phase 2					
		C.S Pur, BDA Ph-I	**Sailshree Vihar**	**Kannan Vihar**	**Salia Sahi Station**	**Averag e**	**BDA Ph-1, Nilmadhav basti**	**Sailshree Vihar**	**Kannan Vihar**	**Salia Sahi Station**	**VSS Nagar, near market area**	**Average**
1	PH at 25°c	6.6	6.7	6.6	6.4	6.575	7.4	7.1	7.2	7.2	7.3	7.2
2	Dissolved Oxygen, mg/l	1.1	0.5	1.3	0.9	0.95	0.8	0.7	1.2	0.7	1.4	0.96
3	Total suspended Solid, mg/l	278	231	120	255	246.0	273	255	131	199	225	214.5
4	Volatile Suspended Solid mg/l	82	86	48	64	70	76	80	64	46	78	69
5	Biochemical Oxygen Demand 5 days at 20°c	146	132	120	104	125.5	122	128	136	98	154	127.6
6	Chemical Oxygen demand mg/l	201.5	186	184	120	172.875	121	151	110	138	203	144.6
7	Nitrogen(as N), mg/l	25	32	18	12	21.75	21.5	20	17.9	21.5	41.2	24.42
8	Iron (as Fe), mg/l	5.40	2.19	4.75	6.03	4.6	5.1	2.8	4.2	5.6	5.1	4.56
9	Fecal Coliform/100ml	$1.82*10^3$ Organism	$7.65*10^4$ Organism	$2.14*10^3$ Organism	$10.25*10^5$ Organism	-	$3.74*10^3$ Organisms	$8.6* 10^4$ Organisms	$4.2 *10^5$ Organisms	$9.12 * 10^5$ Organisms	$5.29*10^4$ Organisms	-

Table 10.4: Key Sampling Parameters: Ranges and Averages

Parameters	Bhubaneswar		
	High	**Low**	**Average**
Total suspended Solid, mg/l	278	120	230.25
Biochemical Oxygen Demand 5 days at 20°c	130	55	126.2
Chemical Oxygen demand mg/l	203	110	153.74

The water data in Bhubaneswar provided an average per capita use of 168 LPCD. According to the CPHEEO Manual on Sewerage and Sewage Treatment, Second Edition, and in accordance with standard engineering practice 80% of the water demand should be used to estimate wastewater flows. Using 80% of the average water use value results in wastewater flows of 134 LPCD for Bhubaneswar.

There are a number of variables that can influence and add a level of uncertainty into an evaluation of water records. They include:

- Lack of actual metered water usage
- Variations in the number of persons per household
- Estimates of unaccounted for water

The key influent parameters for the design of the wastewater treatment plants are BOD5 and Total Suspended Solids (TSS). In order to better understand what values to use for these key parameters it is useful to compare them with the recommended design values and to data in other parts of India. These comparison data are shown in Table 10.5.

Table 10.5: Wastewater Characteristics: Comparison Data

Wastewater Characteristics, Comparison Data					
Location	**Design Flow**	**BOD, mg/l**		**TSS, mg/l**	
	MLD	Actual	Design	Actual	Design
Amritsar	95	192	210	185	340
Mumbai (Mundhwa)	45	202	250	334	350
Bagalore	-	-	350	-	450
Arioli	80	134	210	186	156
Vashi	100	142	194	236	311
Khagar	25	115	175	132	200
Nerul	100	199	175	170	200

PCMC	30	90	-	142	-
GOA	125	140	-	195	-
Okhla	136	-	250	-	400
	Average	152	254(1)	198	322(1)
Odisha (Bhubaneswar/New findings)	<60	74 / 127.6	275	246	300
Design (CPHEEO)	-	-	375	-	750

1. Excludes values less than 200 mg/l which are judged below acceptable design limits.

The concentrations measured in the field program are representative of existing conditions but are not representative of those found in a new properly functioning sewerage system where infiltration will be better controlled and connection of house sewers will be high.

For these reasons the field data should not be used as a guide to setting influent design concentrations for BOD and TSS. These concentrations are too low for design purposes because it is critical that the influent design concentrations not be underestimated or the treatment plants will not have the built-in capacity to reliably treat more typical wastewater concentrations as well as the higher concentrations that would be expected to occur during a 30-day maximum month period.

On the other hand designing the treatment plants to meet Government design guidelines of BOD5 375 mg/l and TSS 750 mg/l (Manual on Sewerage and Sewage Treatment, Central Public Health and Environmental Engineering Organization (CPHEEO)) would likely over design the systems, in part because it does not account for infiltration and would not be cost effective.

Based on the available data as presented in Table 10.4, the influent design concentrations of BOD5 275 mg/l and TSS 300 mg/l should be used, which are the same as the original Bhubaneswar DPR recommendation (that provided in 2007) and are similar with other treatment plants in India. As such such system shall control infiltration and deliver sewage to the treatments plants at the strengths noted above.

The remainders of the sampling data are consistent with the dilute domestic wastewater. The nitrogen concentrations and bacteria counts are low and in line with dilute wastewater as noted above. The metal (Fe) concentrations are also low and do not suggest industrial discharges that may adversely impact a biological treatment process.

2. Conclusions

Several conclusions can be derived from the above data :

1. Technical conclusions :
    a. DO levels in most of the sample areas are quite low. This may be due to the presence of high organic content in the waste water.
    b. The amount of Total Suspended solids is within the limits (as per CPCB guidelines).
    c. BOD5 levels are within limits. Yet, the results are alarming considering the steep rise with respect to the historical data.
    d. The rise in faecal coliform numbers is a cause of concern.

3. Recommendations

On the basis of the explanations above, the following recommendations are being made.

Technical recommendations:

1) The design value of wastewater generation at the rate of **120 LPCD** should be taken as a base-line for designing of the sewers, pumping stations and treatment plants, similar to the one recommended in the CPHEEO manual.
2) The peaking factors that are in the sewer design criteria and recommended in CPHEEO Manual shall be used as earlier.
3) Usage of decentralised waste water treatment methods must be made mandatory for new buildings, building societies and apartments and penalties should be levied by successful legislations and its enforcements.
4) The design of an efficient sewerage collection system should be done on a priority basis and any changes/modification to the already designed criteria should be made now (as the project is already in the half-way stage) so as to prevent unnecessary problems in the future.
5) Heavily populated areas like Salia Sahi area (in District-VI, Bhubaneswar) (the difference in COD and BOD levels is not that significant, thus indicating high organic content in the wastes of this area. Thus it can be inference that the) must be given

priority for the setting up of public sanitary toilets and latrines under various Govt. schemes. Individual toilets must be emphasised and financial considerations should be made for people unable to do so.

6) Industrial areas like VSS nagar (which hosts a cluster of Small and Medium Scale industries dealing with several metal industries) should be instructed to make small scale industrial treatment plants and all possible help should be provided to them to do so.

7) The future use scenario suggest a rapid rise in the population of these areas. So, it may happen that the steep change in the above statistics may further rise steeply unless steps are taken on an urgent basis.

2. Other recommendations :

1) Housing Board colonies like those in Chandrashekharpur and Kanan Vihar should be sensitised about the importance of an elaborate sewerage system and best use practises should be developed for them.
2) Use of Rain water harvesting should be promoted.
3) Situated in a tropical area, Bhubaneswar enjoys heavy rainfall in late summer months (July, August and early September), thereby leading to overflowing of sewerage tanks in many areas. This can be attributed to non-provision of separate drains for storm-water and sewerage channel. Separation of storm water drainage and sewerage should be included in the blueprints of the sewerage design system.
4) Apart from the above recommendations, public information sharing and public awareness must be done. They must be sensitized about the legislation regarding such systems and the benefits associated with it.

10.2 Process Selection Results

1. Initial Process Screening

The different processes are subjected to a qualitative analysis as a first step to find those that shall meet the project requirements. Table 10.3 shows advantages and disadvantages of the technologies under consideration.

Table 10.6: Sewage Treatment Process Merits and Demerits

Process	Advantages	Disadvantages
Activated Sludge (Plug Flow Mode)	• Process flexibility • Reliable operation • Proven track record in all plant sizes • Ability to absorb shock loads • Very low odor emission • Energy production	• Higher energy costs (offset by some gas production) • Skilled operator level
Aerated Lagoons	• Simple to operate	• High energy costs • High area requirements • No energy production
Extended Aeration	• Simple and flexible operation • Easy to operate	• High operating cost • No energy production
Moving Bed Bio Reactor	• Low area requirement • Sludge recirculation not needed • small area around 1/10th of conventional system is required • Higher degree of treatment	• Plastic media must be cleaned periodically, with some breakage • Suitable for small applications • Skilled operators needed • Installation cost is high • This is a new technology and is yet to be proven for bigger plants. • Polymer addition for sludge settlement • No energy production
Sequential Batch Reactor	• Good effluent quality • Smaller footprint because of absence of primary clarifiers and digester	• High energy consumption • Recent track record in large applications in India • High automation • No energy production • High skilled operators needed
Up flow Anaerobic Sludge Blanket + FPU	• Low operating cost • Simple operation • Energy production	Has not performed as expected in India
Waste Stabilization Pond	• Low operating cost	• Requires extremely large areas • Massive dredging when cleaning required • If liner is breached, groundwater is impacted • Poor Effluent quality • No energy production
Wetlands	• Low energy requirements	• High construction cost • Effluent quality varies seasonally • Not easy to recover from massive upset • No energy production

The processes were subject to various factors reflecting the project requirements. Table 10.6 shows the project requirements and assigns a simple "Yes" or "No" to compliance. The "No" findings have been shaded for ease of identification.

Acceptable Effluent Quality considers the ability of the process to consistently achieve the required discharge quality. Natural processes like waste stabilization lagoons and wetlands have an important seasonal variability in the effluent quality due to natural processes. As a result they re-stabilize slowly after an operational upset.

Operational Reliability considers the ease with which the operator can affect changes in the plant and get predictable results. It also addresses the ability of the process to work as designed on a consistent basis, when properly operated.

Proven Record is a variable that captures the differences in the real world between design and performance. All processes work on a theoretical basis but when faced with implementation factors some prove less adequate than others in delivering the expected performance. This category is important because it compiles the industry experience under a multitude of conditions and applications.

Table 10.7 : Compliance with Project Requirements

Process	Acceptable Effluent Quality	Operational Reliability	Proven Record	Power Generation
Activated Sludge Process	Yes	Yes	Yes	Yes
Aerated Lagoon	Yes	Yes	Yes	No
Extended Aeration	Yes	Yes	Yes	No
Moving Bed Bio Reactor	Yes	No	No	No
Sequential Batch Reactor	Yes	Yes	Yes	No
UASB + FPU	No	Yes	No	Yes
Waste Stabilization Pond	No	Yes	Yes	No
Wetlands	No	Yes	Yes	No

2. Decision Matrix For Pre-Screening Technologies

Key parameters were evaluated and weighed as shown in the Table 11.5 to reach a final recommendation on the preferred treatment process.

The matrix attributes were ranked as Very Good, Good, Average, or poor recognizing that differences between processes are relative, and often, the result of commonly accepted observations by industry experts.

The column entitled "Typical Capacity Range" is added to illustrate the range in which the processes are usually found and it should not be construed as showing technological limitations, nor to affirm that plants outside that range do not exist. The ranges simply indicate most frequently found sizes.

Based on evaluation of the decision matrix and discussions provided, it is concluded that the original technologies like activated sludge over 10 MLD and extended aeration for plants up to 10 MLD should be selected. The main attributes are costs, proven track records, ease of operation and maintenance, power consideration and land requirements.

Table 10.8: Decision Matrix for Comparing Secondary Processes

Decision Matrix for Secondary Treatment Processes

Process	Effluent Quality	Process Reliability	Land Use	Ease of Operation	Ease of Maintenance	Energy Recovery	Electrical Demand	Capital Cost	Track Record	Typical Capacity Range, MLD
Activated Sludge Process	Very Good	Very Good	small	Very Good	Good	Very Good	Avg	Avg	Very Good	All flows
Aerated Lagoon	Good	Avg	Large	Avg	Easy	None	Low	High	Poor	Smaller
Extended Aeration	Very Good	Very Good	Ave.	Very Good	Very Good	Poor	High	High	Good	Small plants
Moving Bed Bio Reactor	Very Good	Good	small	Poor	Avg	Poor	Avg	Good	Poor	Smaller
Sequential Batch Reactor	Very Good	Good	Very Good	Avg.	Good	Poor	High	Avg	Good	Small to Large
UASB + FPU	Poor	Avg	Good	Avg	Very Good	Very Good	Very Good	Very Good	Poor	Small to medium
Waste Stabilization Pond	Avg	Poor	Large	Avg	Very Good	None	Lowest	Good	Avg	Small to medium
Wetlands	Poor	Poor	Poor	Avg	Poor	None	Very Low	Good	Poor	Small to medium

3. Recommendations

On the basis of the preceding evaluation, the PMC recommends the activated sludge process be used for Odisha treatment plants above 10 MLD. For smaller facilities, extended aeration is recommended.

The following processes were screened out from further considerations.

- Aerated Lagoon is not an attractive process because it requires a large area and has high operating expenses related to maintaining the required mixing in the lagoons.
- Moving Bed Bioreactor is a process that has not been proven in large scale and much is unknown about future operational cost.
- UASB plus FPU is a technology which has not been functioning properly in India, despite its popularity.
- Waste Stabilization Lagoons and Wetlands are rejected because they require large areas and are not controllable processes with reliable effluent quality.
- Sequencial Batrch Reactors are rejected because of high energy consumption, limited energy production capability and need for skilled operators.

10.3 Sustainability Analysis Results

Sustainability anaysis, as has been shown earlier, is generally found necessary in each and every infrastructure project today inorder to ascertain the environmental load, human impact and economic cost accrual during the proceeding of the project.

The aim of the analysis done here is to know whether the project, which has been going on since 2007 and has not yet neared the halfway mark, is finding its acceptance among the general public or not. It would also be able to highlight the concerns of the people regarding the project and provide the department concerned with a framework regarding mitigating these errors and avoiding such future ones.

People at random were chosen in the mentioned areas and they were asked to fill up a proforma regarding various features that were carefully chosen after discussion with officials and experts.

Individual ratings thus generated were analysed. They were tabulated and only the average of all the values provided in each category were indicated. A uniform colour coding, with an equal interval of 4 rating points was adopted and the subsequent result was obtained.

The following results were obtained for the sustainability analysis tests done.

CRITERIA	FOR PROJECT SITE 1 : CSPUR OSHB & VSS NAGAR											
	Before the project						After the project					
	P1	P2	P3	P4	P5	Avg	P1	P2	P3	P4	P5	Avg
C1	6	10	8	13	16	10.6	10	13	12	15	5	11
C2	NA	NA	NA	NA	NA	NA	16	9	8	9	14	11.2
C3	NA	NA	NA	NA	NA	NA	8	9	13	13	15	11.6
C4	8	8	10	8	9	8.6	9	13	9	15	11	11.4
C5	8	15	18	9	8	11.6	8	12	14	14	14	12.4
C6	17	15	10	16	9	13.4	5	6	4	8	3	5.2
C7	NA	NA	NA	NA	NA	NA	11	16	18	14	10	13.8
C8	15	17	17	9	18	15.2	14	14	18	16	8	14
C9	NA	NA	NA	NA	NA	NA	12	14	15	10	10	12.2
C10	NA	NA	NA	NA	NA	NA	12	11	11	11	11	11.2
C11	17	17	17	11	11	14.6	16	11	17	16	12	14.4
C12	18	11	9	12	10	12	16	10	18	12	12	13.6
C13	13	17	15	18	16	15.8	13	14	17	18	18	16
C14	10	13	15	9	16	12.6	9	9	9	11	12	10
C15	8	13	8	10	15	10.8	10	13	11	9	10	10.6
C16	14	13	14	9	13	12.6	14	9	8	12	8	10.2

It is important to note that –

1. The area consisted of mostly middle-income group families, low-income group families and slum areas. Their acceptance of the matters prescribed above refers to the most prevalent trend in decision making and can thus be inferred to be the general conception among the public.

0 – 4	Deep Red
4 – 8	Red
8 – 12	Yellow
12 – 16	Light Green
16 – 20	Deep Green

CRITERIA	FOR PROJECT SITE 2 : MAITRI VIHAR & KANAN VIHAR PH- 2											
	Before the project						After the project					
	P1	P2	P3	P4	P5	Avg	P1	P2	P3	P4	P5	Avg
C1	11	6	11	12	7	9.4	8	4	5	16	17	10
C2	NA	NA	NA	NA	NA	NA	8	10	16	18	18	14
C3	NA	NA	NA	NA	NA	NA	12	15	14	16	14	14.2
C4	12	13	10	10	7	10.4	16	10	15	9	11	12.2
C5	10	8	9	9	10	9.2	9	13	15	13	8	11.6
C6	15	13	16	13	13	14	7	7	8	9	8	7.8
C7	NA	NA	NA	NA	NA	NA	17	13	8	11	8	11.4
C8	11	9	12	13	8	10.6	8	8	17	13	17	12.6
C9	NA	NA	NA	NA	NA	NA	18	18	18	10	11	15
C10	NA	NA	NA	NA	NA	NA	10	8	8	9	9	8.8
C11	17	10	9	17	8	12.2	14	18	12	12	13	13.8
C12	18	14	13	15	17	15.4	18	10	16	13	14	14.2
C13	17	18	10	10	13	13.6	18	14	14	15	17	15.6
C14	13	15	12	10	16	13.2	9	9	10	8	14	10
C15	16	16	16	13	10	14.2	8	14	11	11	13	11.4
C16	14	16	15	16	16	15.4	14	13	8	8	8	10.2

It is important to note that –

1. This area consists of the upper middle income groups and the higher income groups of the society. The pattern referred to above is a generalised classification of the population and should not be treated as strictly.
2. Furthermore, the questionnaires were distributed keeping in mind the above generalisation.

0 – 4	Deep Red
4 – 8	Red
8 – 12	Yellow
12 – 16	Light Green
16 – 20	Deep Green

CRITERIA	FOR PROJECT SITE 3 : SAINIK SCHOOL & UTKAL UNIVERSITY											
	Before the project						After the project					
	P1	P2	P3	P4	P5	Avg	P1	P2	P3	P4	P5	Avg
C1	12	14	8	4	15	10.6	7	13	10	12	13	11
C2	NA	NA	NA	NA	NA	NA	15	18	14	11	8	13.2
C3	NA	NA	NA	NA	NA	NA	8	18	13	17	13	13.8
C4	12	9	10	13	8	10.4	11	18	10	8	13	12
C5	12	13	12	16	18	14.2	17	8	11	18	11	13
C6	8	11	11	13	13	11.2	8	8	7	7	7	7.4
C7	NA	NA	NA	NA	NA	NA	14	9	10	9	8	10
C8	8	16	8	13	8	10.6	13	8	11	12	15	11.8
C9	NA	NA	NA	NA	NA	NA	10	11	9	11	18	11.8
C10	NA	NA	NA	NA	NA	NA	10	9	8	10	10	9.4
C11	12	11	18	15	8	12.8	10	14	13	12	16	13
C12	16	13	15	15	10	13.8	13	15	16	11	11	13.2
C13	12	16	11	16	10	13	12	16	11	12	11	12.4
C14	10	9	9	15	9	10.4	8	13	8	9	12	10
C15	9	12	16	11	16	12.8	9	14	9	12	12	11.2
C16	14	16	9	16	14	13.8	10	14	11	9	14	11.6

It is important to note that –

1. The constituents of this survey area belong to the educational institutions in the project area and they offer a balanced approach keeping in view the existing conditions, problems faced on the field and reasonable expectation levels.

0 – 4	Deep Red
4 – 8	Red
8 – 12	Yellow
12 – 16	Light Green
16 – 20	Deep Green

So analysing these results, we get that,

RESULTS	RECOMMENDATIONS
1. C1, i.e. problems to commuters are in the below acceptable range.	R1. Analysing and solving the problems
2. C2 and C3 i.e. Lighting and traffic control – these are found to be acceptable in most of the areas.	R2. Smoothening the traffic flow without hampering progress of work should be given due care by the department.
3. C4 and C5 i.e.travel related problems = Is okay in the areas surveyed.	R3. No recommendations.
4. C6, i.e. public conveniences in project areas has been rated poorly.	R4. Conveyance facilities like parking spaces in market residential areas should be adequately earmarked and provided for.
5. C7, C8 and C9 i.e. Signage and drainage problems were found inadequate in many areas.	R5. Proper care should be taken towards this.
6. C10, C11, C12 and C13 - Post – construction activities and its environmental impact – were found well within limits and acceptable.	R6. Even though they were found acceptable by the majority of the people surveyed, still there was a lot of things to be done.
7. C14, C15, C16 – Impact on humans and establishments nearby. The impact of the construction activites had a huge impact on these entities. Frequent disturbances and night-time construction activities caused a lot of disturbance.	R7. Night time construction activites to be completely stopped. Drilling activities should be done with as less disturbance as possible.

However, on personal review of the areas surveyed (on 3 different occasions), it was found that –

1. Adequate safety and precautions needed for the commuters, residents and workers were not taken by the authorities concerned. Non erection of proper signboards and markers especially during the night time was very much inconveniencing for the people and had the potential to cause damage to life and property.
2. Drainage works were not adequate and quality control of the material used needed attention.

3. Perceived water logging problems were very much on the horizon. The perception was not visible in the summer months but the pace of works suggested that unless the speed of the work was not enhanced, there were sustained chances of waterlogging.

1. Recommendations

The recommendations are tabulated as follows :

Parameter	Problems (as raised by people after survey)	Proposed mitigation measures
Construction Stage		
Air	Dust from construction sites due to stockpiles, construction vehicles travelling on unpaved haul roads.	- Pave frequently used haul roads - Water unpaved areas and haul roads - Control vehicle speeds on construction sites - Cover stockpiles and trucks carrying dusty materials - Minimize on-site storage time of construction and demolition wastes - Restore disturbed land timely.
Noise	Noise from powered mechanical equipment	- Maintain construction machinery regularly - Stop work from 2200 hr to 0600 hr when near residential areas
Water	Wastewater from the work force and uncontrolled muddy water runoff from construction site	- Provide portable toilets on-site - Install interim holding tanks and pipelines to convey sewage to nearby sewers if sewers are nearby - Use sediment control by installing sedimentation tanks to treat runoff water with high concentrations of SS - Maintain and monitor efficient sanitation
Solid Wastes	Refuse from the work force and construction and demolition wastes	- Provide closed containers for storing on-site refuse - Transport refuse for proper off-site disposal regularly - Clean up and remove construction and demolition wastes regularly to prevent build-up on-site - Explore opportunities to reuse excavated soil for backfilling
Traffic	Construction traffic may cause traffic congestion on nearby roads	- Design temporary traffic management schemes and carry out these schemes during construction - Schedule construction traffic to avoid morning and afternoon peak traffic hours - Select alternative transport routes to reduce disturbance to regular traffic

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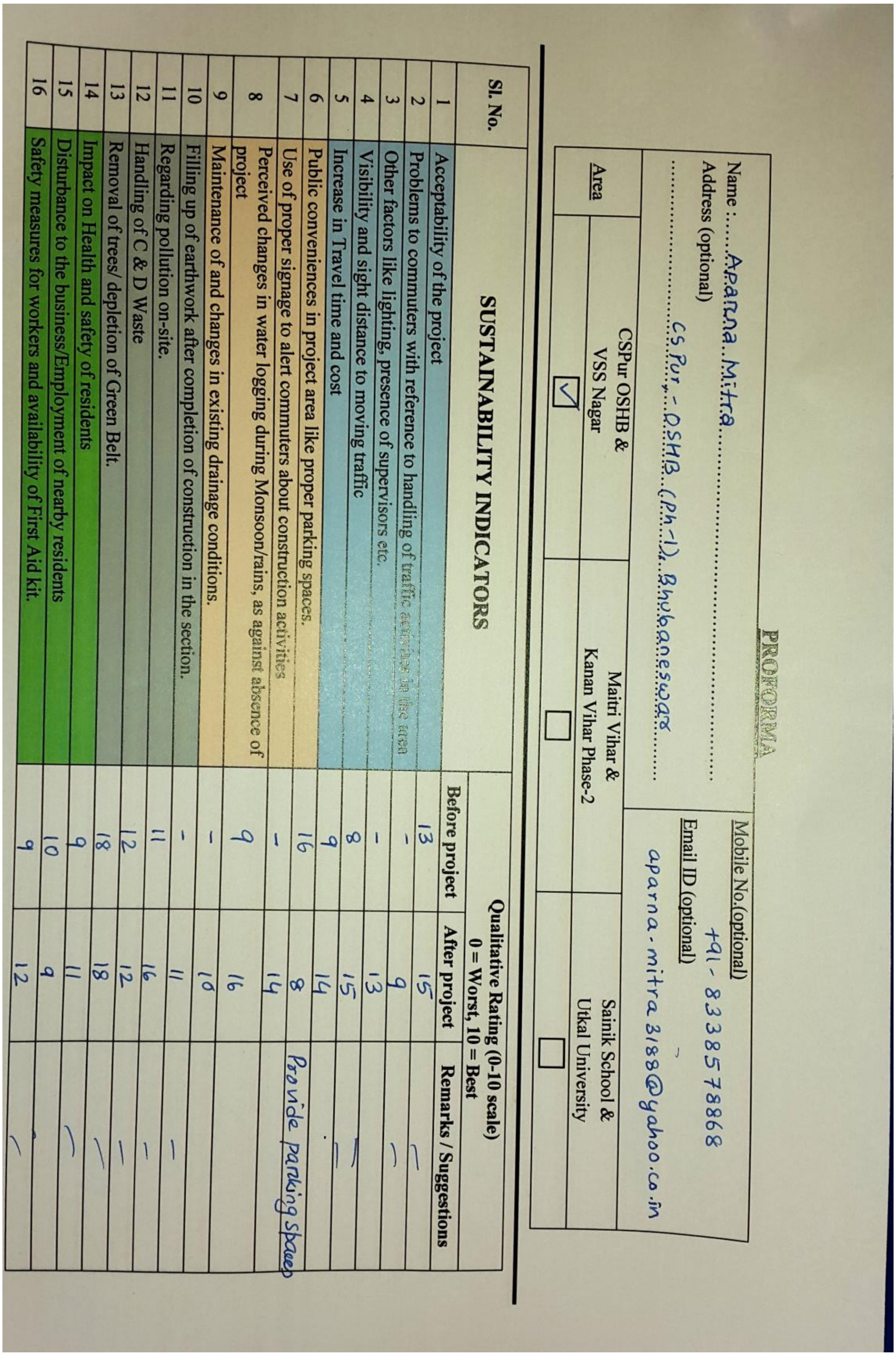
APPENDIX

A. List of the people who had participated in the survey

Sl No.	Name of person	Address
1	Anant Sharan Parida (M, 62) (#ZQZ1054139)	Chandrasekharpur OSHB
2	Ambarish Samantaray (M, 23) (#YLP0568717)	Sainik School
3	Ranjita Samal (F, 32) (#J0355648)	Utkal University
4	Asima Mohapatra (F, 31) (#OR/09/050/382695)	Maitri Vihar (Ph-2)
5	Bibhu Meher (M, 41) (#OR/10/067/875309)	Kanan Vihar
6	Trivubhan Sahoo (M, 65) (#J0548975)	Gajapati Nagar
7	Sabyasachi Panda (M, 35) (#AIUPS4563S)	VSS Nagar
8	Loknath Mohanty (F, 55) (#OR-02112354678798)	Maitri Vihar
9	Ramesh Tripathy (M, 45) (#897525644879)	Sainik School
10	Pradip Nayak (M, 33) (#OR/07/089/867432)	CSPur OSHB
11	Aparna Mitra (F, 31) (#K5624935)	CSPur OSHB
12	Ramakanta Swain (M, 42) (#BGLFD5479R)	Kanan Vihar
13	Sharad Kumar Kar (M, 45) (#OR-07569128456387)	Kanan Vihar
14	Shanti Sharma (F, 46) (-NA-)	VSS Nagar
15	Harjot Singh (M, 28) (#987536584975)	Utkal University

B. Sample of the filled proforma :



PROFORMA

Name :......Aparna Mitra..................... Address (optional) ....CS Pur, - OSHB (Ph-1), Bhubaneswar..........	Mobile No.(optional) +91- 8338578868 Email ID (optional) aparna.mitra3188@yahoo.co.in

Area	CSPur OSHB & VSS Nagar	Maitri Vihar & Kanan Vihar Phase-2	Sainik School & Utkal University
	☑	☐	☐

Sl. No.	SUSTAINABILITY INDICATORS	Qualitative Rating (0-10 scale) 0 = Worst, 10 = Best		
		Before project	After project	Remarks / Suggestions
1	Acceptability of the project	13	15	
2	Problems to commuters with reference to handling of traffic activities in the area	–	9	–
3	Other factors like lighting, presence of supervisors etc.	–	13	–
4	Visibility and sight distance to moving traffic	8	15	–
5	Increase in Travel time and cost	9	14	–
6	Public conveniences in project area like proper parking spaces.	16	8	Provide parking spaces
7	Use of proper signage to alert commuters about construction activities	–	14	
8	Perceived changes in water logging during Monsoon/rains, as against absence of project	9	16	
9	Maintenance of and changes in existing drainage conditions.	–	10	
10	Filling up of earthwork after completion of construction in the section.	–	11	
11	Regarding pollution on-site.	11	16	–
12	Handling of C & D Waste	12	12	–
13	Removal of trees/ depletion of Green Belt.	18	18	–
14	Impact on Health and safety of residents	9	11	–
15	Disturbance to the business/Employment of nearby residents	10	9	–
16	Safety measures for workers and availability of First Aid kit.	9	12	–

PROFORMA

Name : Trivubhan Saho		Mobile No.(optional) 9437524396	
Address (optional) Gajapati Nagar, BBSR		Email ID (optional) trivubhan.sahoo7672@gmail.com	
Area	CSPur OSHB & VSS Nagar ☐	Maitri Vihar & Kanan Vihar Phase-2 ☐	Sainik School & Utkal University ☑

Sl. No.	SUSTAINABILITY INDICATORS	Qualitative Rating (0-10 scale) 0 = Worst, 10 = Best		
		Before project	After project	Remarks / Suggestions
1	Acceptability of the project	8	10	
2	Problems to commuters with reference to handling of traffic activities in the area	–	14	
3	Other factors like lighting, presence of supervisors etc.	–	13	Provide proper lighting.
4	Visibility and sight distance to moving traffic	10	10	
5	Increase in Travel time and cost	12	11	
6	Public conveniences in project area like proper parking spaces.	11	7	
7	Use of proper signage to alert commuters about construction activities	–	10	
8	Perceived changes in water logging during Monsoon/rains, as against absence of project	8	11	
9	Maintenance of and changes in existing drainage conditions.	–	9	
10	Filling up of earthwork after completion of construction in the section.	–	8	
11	Regarding pollution on-site.	18	13	
12	Handling of C & D Waste	15	16	Use properly
13	Removal of trees/ depletion of Green Belt.	11	11	Check this
14	Impact on Health and safety of residents	9	8	
15	Disturbance to the business/Employment of nearby residents	16	9	
16	Safety measures for workers and availability of First Aid kit.	9	11	