SOLID WASTE MANAGEMENT FOR ABATEMENT OF POLLUTION OF RIVER AT PUDUKKOTTAI TOWN

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF TECHNOLOGY

in

CONSERVATION OF RIVERS AND LAKES

By

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CANDIDATE'S DECLARATION

I hereby declare that the work which has been presented in the dissertation entitled **"SOLID WASTE MANAGEMENT FOR ABATEMENT OF POLLUTION OF RIVER AT PUDUKKOTTAI TOWN"** in partial fulfillment of the requirements for the award of the degree of **Master of Technology in Conservation of Rivers and Lakes**, submitted in Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee, is an authentic record of my own work carried out during the period from July 2006 to June 2007 under the supervision of Dr. Renu Bhargava, Professor, Department of Civil Engineering and Dr. Vikas Pruthi, Assistant Professor, Department of Biotechnology, Indian Institute of Technology Roorkee.

The matter embodied in the dissertation has not been submitted by me for the award of any other degree or diploma.

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CERTIFICATE

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ABSTRACT

The problem of Municipal Solid Waste Management (MSWM) has acquired alarming dimensions in India especially during last decade. The present system of Solid Waste Management (SWM) in India is fraught with many inadequacies. Numerous impacts of waste disposal that have been identified are: pollution of surface and ground water, creation of malodorous environments facilitating insect/mosquito breeding. Illegal dumping is a major problem that raises significant concerns with regard to safety, property values, and quality of life in communities. In addition, it is a major economic burden on local body, which is typically responsible for cleaning up these open dumps sites. The federal body Ministry of Environment and Forests (MoEF) along with the apex body Central Pollution Control Board (CPCB) has issued guidelines for municipal solid waste management and handling namely Municipal Solid Waste (management and handling) Rules, Amendment, 2000. The 74th Constitutional Amendment by MoEF is a very important milestone in introducing the decentralized local urban governance in India.

In Pudukkottai town, inadequate facilities are available for the collection and segregation of solid waste as well as transportation. The leachate generated from the dumping ground is not collected and leachate directly finding its way into storm water drain and road. There is an urgent need to select appropriate treatment and disposal facility for Pudukkottai town. To carry out the study, the present SWM practice in the town has been analysed. The samples were collected and percentages of physical compositions have been studied. About 32 tons of solid wastes are generated everyday in the town. The waste generation was found to be 300 gm per capita per day. Obvious gaps have been identified between the present management practice and the MSWM Rules. To fill up the gap, a management plan is proposed which covers all aspects of segregation at the point of generation, collection and transportation, treatment and disposal at the common facility. As a part of the plan, the capacity of detachable containers, handcarts, storage bins, transport vehicles, transport routes, and the treatment & disposal have been designed. The initial investment for the treatment plant, its O&M cost, Benefit Cost ratio, Internal Rate of Return and the cess have been calculated.

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ABBREVIATIONS AND NOTATIONS

ABBREVIATIONS / NOTATIONS	DESCRIPTION
A.M.	Ante Meridiem
BC	Before Christ
BD	Bio Degradable
BOD	Biochemical Oxygen Demand
BMW	Biomedical Waste
BOO	Built Own and Operate
BOOT	Built Own Operate and Transfer
cm	centimetre
CBO	Community Based Organization
$CaCO_3$	Calcium Carbonate
CMDA	Chennai Metropolitan Development Authority
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health and Environmental Engineering Organization
cu.m	cubic metre
DBOT	Design Built Operate and Transfer
DBOLT	Design Built Operate Lease and Transfer
EPA	Environmental Protection Agency
Fig.	Figure
ft	feet
gm	gram
GIS	Geographic Information System
HDPE	High Density Polyethylene
ha	hectare
hr	hour

IEC	Information Education and Communication
IITR	Indian Institute of Technology Roorkee
i.e.	that is
kg	kilogram
kcal	kilocalorie
km	kilometer
kW	kilowatt
kWh	kilowatt per hour
LA	Local Authority
L.S	Lump Sum
Ltd.	Limited
MSW	Municipal Solid Waste
min	minute
mm	millimetre
m	metre
m.s.l.	mean sea level
m^3	metre cube
mg	milligram
MES	Medicare Enviro Systems
MoEF	Ministry of Environment and Forest
MRF	Materials Recovery Facility
NBD	Non Bio Degradable
NEPA	National Environmental Policy Act
NGO	Non Government Organization
NSIC	National Small Industries Corporation
No.	Number
nos.	numbers
O&M	Operation and Maintenance
PCB	Pollution Control Board
P.M.	Post Meridiem
PMC	Pudukkottai Municipal Council

ppm	parts per million
Pvt.	Private
PWD	Public Works Department
RM	Running Metre
RCRA	Resource Conservation and Recovery Act
Rs.	Rupees
sec	seconds
SHG	Self Help Group
Sl.	Serial
Sq.m	Square metre
Sq.km	Square kilometre
SWM	Solid Waste Management
TDS	Total Dissolved Solids
TNTC	Too Numerous To Count
TUFIDCO	Tamilnadu Urban Finance and Infrastructure Development Corporation Ltd
TWAD	Tamilnadu Water supply And Drainage
UIDSSMT	Urban Infrastructure Development Scheme for Small and Medium Towns
US	United States
USA	United States of America
VS	Volatile Solids
W.R.O	Water Resource Organization
^0C	degree centigrade
%	percentage
@	at the rate of
$	Dollar

CHAPTER 1

INTRODUCTION

1.1 GENERAL

The percentage of India's population living in cities and urban areas doubled to 28.8% by 2001 from 14% at the time of Independence, showing the rapid pace of urbanization. This will accelerate even further, and by 2021 over 41% of Indians are expected to reside in the urban area. This has been fueled by rapid growth in industrialization, commercialization, development of secondary and tertiary sectors of economy, and mass migration (Gupta, 2003). Human activities create waste, and it is the way these wastes are handled, stored, collected and disposed of, which can pose risks to the environment and to public health. Where intense human activities concentrate, such as in urban centre, appropriate and safe Solid Waste Management (SWM) are of utmost importance to allow healthy living conditions for the population (Zurbrugg, 2003). The present system of solid waste management in India is fraught with many inadequacies. Illegal dumping is a major problem that raises significant concerns with regard to safety, property values, and quality of life in communities. In addition, it is a major economic burden on local government, which is typically responsible for cleaning up these open dumps sites. The report of High Power Committee on Urban Solid Waste Management in India stated that Urban Solid Waste Management continues to remain one of the most neglected areas of urban development in India. The report informs that there is no system of segregation of organic, inorganic, and recyclable wastes at the household level (Gupta, 2003) sites.

The federal body Ministry of Environment and Forests (MoEF) along with the apex body Central Pollution Control Board (CPCB) has issued guidelines for municipal solid waste management and handling namely Municipal Solid Waste (management and handling) Rules, Amendment, 2000. The 74th Constitutional Amendment by MoEF is a very important milestone in introducing the decentralized local urban governance in India. It provides good opportunity and ways for efficient working of the municipal bodies.

1.2 DESCRIPTION OF THE AREA UNDER STUDY

1.2.1 General

Pudukkottai town has a population of over 109217 as per 2001 census, covers an area of 12.95 Sq.Km and the literacy rate is 78% (Source: Statistical Hand Book of Pudukkottai, 2005-2006). The city is experiencing rapid urbanization as indicated by the population increase (as depicted in the Fig 1.1).

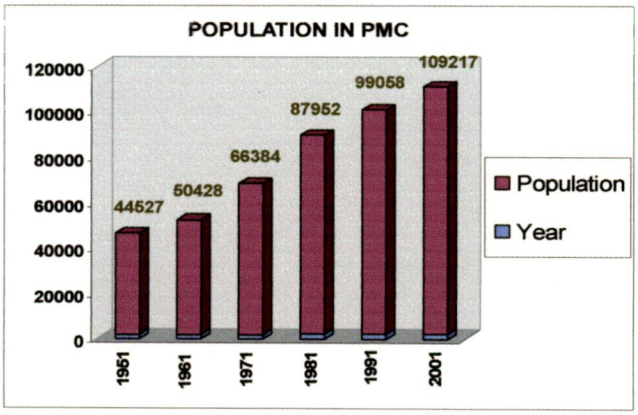


Fig 1.1:- Population Growth of Pudukkottai

1.2.2 Location

Pudukkottai, the headquarters of Pudukkottai District and selection grade municipality, is situated in the valley of Vellar 6.4 km north of the river and 3.2 km north of the Kundar. The Pudukkottai district lies between 78°25' and 79°15' of the Eastern Longitude and between 9°50' and 10°40' of the Northern Latitude. The location of Pudukkottai is shown in Fig. 1.2.

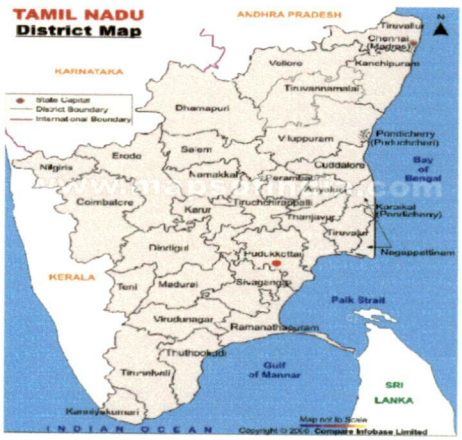


Fig 1.2:- Location of Pudukkottai

1.2.3 Climate

The climate in general is dry and hot. The maximum and minimum temperatures for Pudukkottai are 38.7° C and 19.6° C respectively. The Pudukkottai rainfall details are shown in Fig 1.3.

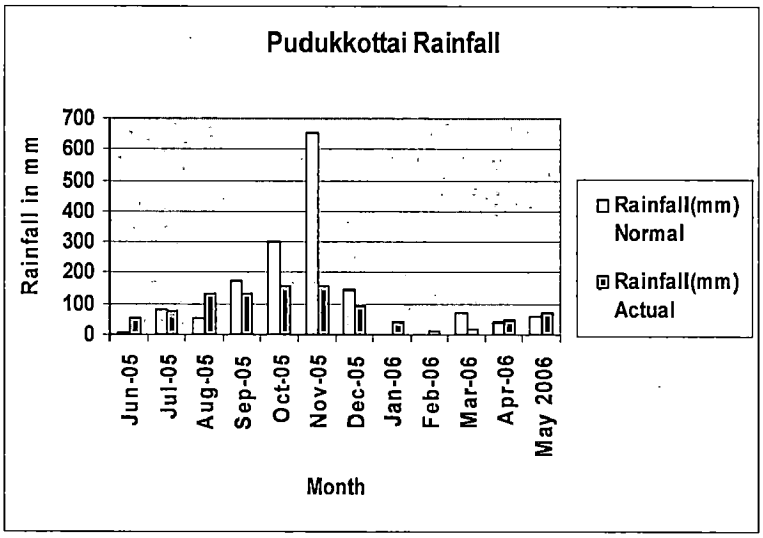


Fig 1.3:- Rainfall details

1.2.4 Topography

The topography of Pudukkottai town is generally flat with a falling gentle slope towards southeast. The altitude of the town is 87.78m above m.s.l.

1.3 NEED OF THE STUDY

There is an inadequacy of the collection and segregation of solid waste as well as transportation facility. At present no community bins/masonry bins available for storing the solid waste. The municipal solid waste generated from the town is disposed improperly along the road sides, storm water drains and water bodies, which results in additions of leachates/ runoffs. The leachates generated from the dumping ground are not collected properly and untreated leachates directly finding its way into the road sides and drains. Numerous impacts of waste disposal that have been identified are: pollution of surface and ground water, creation of malodorous environments facilitating insect/mosquito breeding. The present scenario necessitates the need to study and adopt scientific method for treatment and disposal of municipal solid waste in the town.

1.4 OBJECTIVES OF THE STUDY

- Study of the management of municipal solid waste in Pudukkottai town.
- To find out the shortcomings and gaps in the system.
- To chalk out an optimal transportation route for solid waste collection.
- To design a common facility for treatment and disposal of municipal solid waste.

1.5 MSW MANAGEMENT PRACTICE

In this study, the MSW management practice in the different wards and places have been studied and analyzed to identify shortfalls in the system. Primary data collected from sample in order to compute the waste generation per day and to calculate the percentages of composition of waste. To deal with the MSW problem, a management plan is proposed. The proposed management plan covers all aspects i.e. segregation, collection and transportation, treatment and disposal at a common facility. The cost estimate of the system is also calculated.

1.6 ORGANIZATION OF THE DISSERTATION

The dissertation has been organized as follows:

- Chapter 1 gives the introduction to the subject matter. This chapter describes the area under study and focuses the need and objective of the study.
- Chapter 2 reviews the available literature related to the subject matter.
- Chapter 3 describes the methodology used in the study.
- Chapter 4 presents the observations and discusses the results with the aid of tables, figures, drawings, flowcharts and map. It also covers the cost estimation and cess calculation.
- Chapter 5 gives the conclusions, limitations and further scope of the work.

CHAPTER 2

LITERATURE REVIEW

2.1 SOLID WASTE MANAGEMENT HISTORICAL

Solid wastes comprise all the wastes arising from human and animal activities that are normally solid and that are discarded as useless or unwanted. When humans abandoned nomadic life at around 10,000BC, they began to live in communities, resulting in the production of solid waste (Aarne Vesilind et al, 2004). In the Indus valley the city of MahenjoDaro had houses with rubbish chutes and probably had waste collection systems. The sanitary laws written by Mosses in 1600 BC still survive in part. The Great Sanitary Awakening in the1840's was spearheaded by a lawyer, Edwin Chadwick (1800-1890), who argued that there was a connection between disease and filth. In the United States the conditions in many of the cities were appalling. Waste was disposed of by the judicious method of throwing it into streets where rag pickers would try to salvage what had secondary value. The first organized municipal recycling program was attempted in 1874 in Baltimore, but it did not succeeded. The first incinerator in the New World was built in 1887 on Governor's Island in New York. In 1895 the garbage problem finally became a factor in politics, and great effort was made politically to clean up the cities. Municipal collection systems were created, the most famous and best organized one being in New York City by Col. George Waring. The fouling of beaches forced the passage of federal legislation in 1934 making the dumping of municipal refuse into the sea illegal. The first hole - in – the –ground that was periodically covered with dirt, a precursor of today's landfill, was started in 1935 in California. The American Society of Civil Engineers in 1959 published the first engineering guide to sanitary landfilling. Still, in 1965, SWM practices in the United States, Congress concluded that inefficient and improper methods of disposal of solid waste create serious hazards to public health, pollution of air and water resources, accident hazards, and public nuisances. The failure or inability to salvage and reuse such materials economically results in the unnecessary waste and depletion of natural sources (Tchobanoglous et al, 1993).

2.2 LEGISLATION AND REGULATIONS

Prior to the 1960s the only federal legislation that addressed solid waste was the 1899 Rivers and Harbors Act, which prohibited the dumping of large objects into navigable waterways. The first federal legislation intended to assist in the management of solid waste was the 1965 Solid Waste Disposal Act, which provided technical assistance to the states through the U.S. Public Health service. The emphasis in this legislation was the development of more efficient methods of disposal, and not the protection of human health. On 1 January, 1970, President Nixon signed the National Environmental Policy Act (NEPA), which led to the creation of the Environmental Protection Agency (EPA). In 1976 the Congress of the United States passed the Resource Conservation and Recovery Act (RCRA). With its 1984 amendments RCRA is a strong piece of legislation that mainly addresses the problem with hazardous waste, but also specifies guidelines for nonhazardous solid waste disposal. Subtitle D, in this Act is the municipal solid waste section, and landfills. In 1991 under Subpart D, the EPA adopted regulations to establish minimum national landfill criteria for solid waste landfills. Most states have passed strong legislation encouraging and promoting recycling. In the 1990s over 40 states established recycling goals. For example, California mandated that 25 percent of the waste be diverted from landfills by 1995 and that 50 percent be diverted by 2000 (Aarne Vesilind et al, 2004).

2.3 FUNCTIONAL ELEMENTS OF MSWM

The activities associated with the management of municipal solid waste from the point of generation to final disposal can be grouped into the six functional elements:

i) waste generation; ii) waste handling and separation, storage, and processing at the source; iii) collection; iv) separation and processing and transformation of solid wastes; v) transfer and transport; and vi) disposal (Tchobanoglous et al, 1993). Interrelationships between the functional elements in a solid waste management system are shown in Fig 2.1.

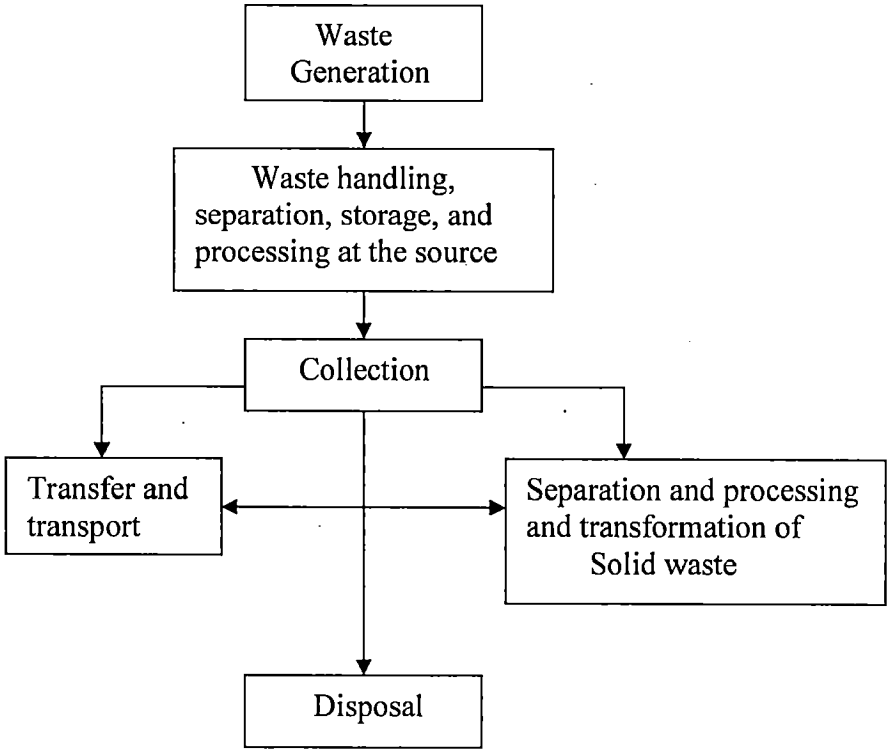


Fig 2.1:-Interrelationships between the functional elements source: Tchobanoglous et al, 1993

2.3.1 Waste generation

Waste generation rates in India vary in relation to the cities sizes. The average rates of 0.21kg/capita/day for cities between 100000-500000 population and 0.5 kg per capita per day for cities larger than 5000000 populations. The Indian average waste characteristics are shown in Fig 2.2 (Zurbrugg, 2003).

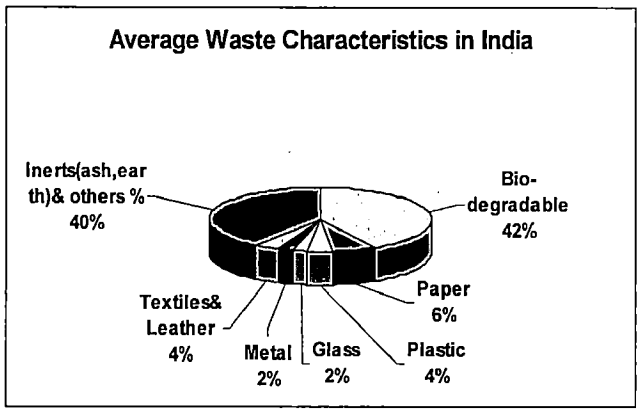


Fig 2.2:- Waste characteristics in India Source: Zurbrugg, 2003

2.3.2 Waste Handling, Sorting, Storage and Processing at the Source

Waste handling and sorting involves the activities associated with management of wastes until they are placed in storage containers for collection. Handling also encompasses the movement of loaded containers to the point of collection. Sorting of waste components is an important step in the handling and storage of solid waste at the source. The cost of providing storage for solid wastes at the source is normally borne by the household in the case of individuals, or by the management of commercial and industrial properties. Processing at the source involves activities such as backyard waste composting.

2.3.3 Collection

The waste collection and storage lies at the very hub of municipal waste management and hence these elements must be designed in such a way to ensure efficient storage and collection of waste from each community, establishments and even each part of the city. The storage and collection system both are interrelated hence the design of collection system must be well suited with the storage system provided for storage of the waste generated (Gupta, 2003).

2.3.4 Sorting, Processing and Transformation of Solid waste

The first hand- sorting facility in the U.S was built by Colonel Waring for New York City in 1898. The refuse from 116,000 people was sorted, and over 2 ½ years of operation about 375 of the refuse was recovered, a major part of which was rags. The recovered material yielded an income of about $ 1 per ton (Aarne Vesilind et al, 2004). Waste processing is undertaken to recover conversion products and energy. The organic fraction of MSW can be transformed by a variety of biological and thermal process. The most commonly used biological transformation process is aerobic composting. The most commonly used thermal transformation process is incineration. Waste transformation is undertaken to reduce the volume, weight, size or toxicity of waste without resource recovery. Transformation may be done by a variety of mechanical (e.g, shredding), thermal (e.g, incineration without energy recovery) or chemical (e.g, encapsulation) techniques (Municipal Solid Waste Management Manual, 2000).

2.3.5 Transfer and Transport

The functional element of transfer and transport involves two steps: i) the transfer of wastes from the smaller collection vehicle to the larger transport equipment and ii) the subsequent transport of the wastes, usually over long distances, to a processing or disposal site. The transfer usually takes place at a transfer station.

2.3.6 Disposal

Today the disposal of wastes by landfilling or uncontrolled dumping is the ultimate fate of all solid wastes, whether they are residential wastes collected and transported directly to a landfill site, residual materials from Materials Recovery Facilities (MRFs), residue from the combustion of solid waste, rejects of composting, or other substances from various solid waste- processing facilities.

2.4 WASTE HIERARCHY

There are a number of concepts about waste management, which vary in their usage between countries or regions. The waste hierarchy classifies waste management strategies according to their desirability. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste. The waste hierarchy arrangements are shown in Fig 2.3.

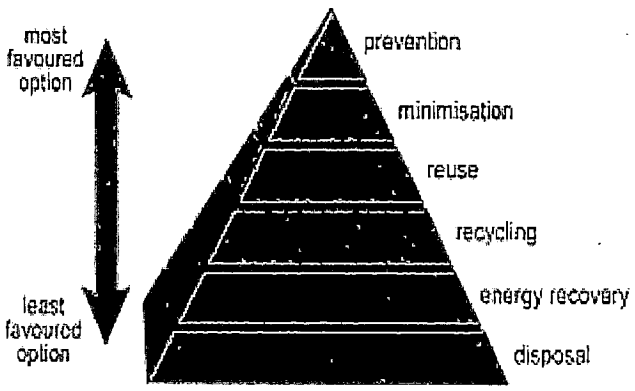


Fig 2.3:-The waste hierarchy source: Waste_management_concepts, 2007

2.4.1 Reduction

Reduction of the amount of municipal solid waste being produced include refusing bags at stores, using laundry detergent refills instead of purchasing new containers, bringing one's own bags to grocery stores, and stopping junk mail deliveries. The level of participation in source reduction is low compared to recycling activities. Public information programs can significantly help in reducing the amount of waste generated. A study of 250 homes in Greensboro, North Carolina, found that a 10% waste reduction can be achieved following a public information program (Aarne Vesilind et al, 2004).

2.4.2 Reuse

Many of our products are reused without much thought given to ethical considerations. These products simply have utility and value for more than one purpose. The classic examples of conventional reuse is the doorstep delivery of milk in reusable bottles, paper bags obtained in the supermarket are often used to pack refuse for transport from the house to the trash can or to haul recyclables to the curb for pickup. Newspapers are rolled up to make fireplace logs, and coffee cans are used to hold bolts and screws. Reusing products, when possible, is even better than recycling because the item does not need to be reprocessed before it can be used again (epa.gov/msw/reduce, 2006).

2.4.3 Recycling

Recycling is one of the best environmental success stories of the late 20th century. Recycling, including composting, diverted 79 million tons of material away from landfills and incinerators in 2005, up from 34 million tons in 1990. By 2002, almost 9,000 curbside collection programs served roughly half of the American population. Curbside programs, along with drop-off and buy-back centers, resulted in a diversion of about 32 percent of the nation's solid waste in 2005. Benefits of Recycling: Conserves resources for our children's future, Prevents emissions of many greenhouse gases and water pollutants, Supplies valuable raw materials to industry, Stimulates the development of greener technologies, and reduces the need for new landfills and incinerators (epa.gov/msw/recycle, 2006).

The surveys revealed that an estimated 14,800 rag pickers are involved in the recycling activities in the city of Bhopal, and collect an estimated average of nearly 13.86 kilograms of recycled waste per rag picker per day. The waste trade is carried out through a hierarchy of small, medium, and large sized waste dealers. This chain involves dealings in progressively increasing waste specificities and growing profits at each level for each item sold. At every stage of the transaction, the waste was sorted more specifically and dealt in bulk, and finally sold out to the Recycling units for processing (Mukul Kulshrestha, 2007).

2.4.4 Recovery

Recovery is defined as the process in which the refuse is collected without prior separation, and the desired materials are separated at a central facility. Currently, no such technology exists. In fact, most recovery operations employ pickers, human beings who identify the most readily separable materials – such as corrugated cardboard and HDPE (High density Polyethylene) milk bottles – before the refuse is mechanically processed. Mechanical processing is difficult sometimes for example; "tin can" contains steel in its body, Zinc on the seam, a paper wrapper on the outside, and perhaps an aluminum top. Other common items in refuse provide equally challenging problems in separation.

2.4.5 Disposal of solid waste in landfills

Our present practices amount to nothing more than hiding waste on a long- term basis are in the oceans (or other large bodies of water) and on land. The placement of solid waste on land is called a dump in the USA and a trip in Great Britain (as in tipping). Rodents, odor, air pollution, and insects at the dump, however, can result in serious public health and aesthetic problems. Open dumps- unfortunately still mostly observed in developing countries- where the waste is dumped in an uncontrolled manner, can be detrimental to the environment. The basic principle of a landfill operation is to prepare a site with liners to deter pollution of groundwater, deposit the refuse in the pit, compact it with specially built heavy machinery with huge steel wheels, and cover the material with earth at the conclusion of each day's operation. Siting and develop proper landfill require planning and engineering design skills.

Engineers designing the landfills first estimate the total volume available to them and then estimate the density of the refuse as it is deposited and compacted in the landfill. The as generated bulk density of Municipal Solid Waste (MSW) is perhaps 100 to 300 lb/yd^3 (60 to 180 kg/m^3), while the compacted waste in a landfill exceeds 1200 lb/yd^3 (700 kg/m^3) (Aarne Vesilind et al, 2004). When solid waste management systems based on user fees are in place, often the fees only barely cover costs of collection and transport leaving practically no financial resources for the safe disposal of waste. Financing this part of the solid waste management cycle is made even more difficult as most people are willing to pay for the removal of the refuse from their immediate environment but then "out of sight- out of mind" is generally not concerned with its ultimate disposal (zurbrugg, 2003).

2.4.6 Energy conversion

The conversion of municipal solid waste (MSW) to energy can conserve more valuable fuels and improve the environment by lessening the amount of waste that must be landfilled and by conserving energy and natural resources. The importance of utilizing MSW was recognized in the 1991 U.S. National Energy Strategy, which sought to "support the conversion of municipal solid waste to energy." Of the 217 million tons of waste generated annually in the United States, over 80% is combustible, yielding a heat value equivalent to about 1 million barrels of oil per day. This figure is equivalent to about 4.6% of all the fuel consumed by all utilities, 10% of all the coal consumed by all utilities, and about 20% of the electrical energy demand of the private sector of a municipality (Aarne Vesilind et al, 2004). Recent studies for Indian scenario clearly show that while net power generation for thermo-chemical conversion processes is around 14.4 times the quantity of waste input (in kW), the same for bio-chemical conversion process is 11.5 times the waste inputs (provided 50% of waste inputs are volatile solids). However, in terms of environmental impact, the later is far safer option than the previous (Infrastructure Professionals Enterprises, 2004).

2.5 WASTE DISPOSAL

Local Authorities (LAs) are responsible for collection and disposal of waste, inadequate resource availability has hindered their work. Numerous impacts of waste disposal that have been identified are: reduction in flood retention areas; pollution of wetland habitats, pollution of surface and ground water, creation of malodorous environments facilitating insect/mosquito breeding and other impacts on health. Uncollected waste may accumulate on the streets and clog drains when it rains, which may cause flooding. Wastes can also be carried away by runoff water to rivers, lakes and seas, affecting those ecosystems. Open dumping of solid wastes generates various environmental and health hazards. The decomposition of organic materials produces methane, which can cause fire and explosions, and contributes to global warming. The biological and chemical processes that occur in open dumps produce strong leachates, which pollute surface and groundwater (Medina, 2000).

2.6 WASTE TREATMENT TECHNOLOGIES

The hierarchy of waste management and the concept of sustainable waste management have led to the development of alternative waste treatment and disposal options rather than the traditional reliance on the option of landfill.

2.6.1 Incineration

To reduce waste volume, local governments or private operators can implement a controlled burning process called combustion or incineration. MSW can generate energy while reducing the amount of waste by up to 90 percent in volume and 75 percent in weight. EPA's Office of Air and Radiation is primarily responsible for regulating combustors and incinerators because air emissions from combustion pose the greatest environmental concern (Gupta, 2003). It is also usually a cost effective method of disposal (Infrastructure Professionals Enterprises, 2004). However, in Indian conditions, it is not always very successful due to the low calorific value of Indian wastes (low combustible material).

2.6.2 Composting

Composting is nature's way of recycling organic wastes. In India, aerobic composting plants have been used to process up to 500 tons per day of waste (Municipal Solid Waste Management Rules, 2000). Compost is also used for land restoration and landscaping, where it is used as mulch (Williams, 2005). There are various methods and equipment available for the composting process.

(i) *Windrows*

Windrows are a traditional form of composting in which the material is placed into long piles or rows (windrows), usually between 2-3m high and 3-4m wide. Aeration of the windrow is achieved by turning the material. To turn the piles, tractors with front end loaders or different kinds of machinery are used.

(ii) *Enclosed vessels (in vessels)*

In vessel systems usually use forced aeration. Differently silo-type systems which are rely on gravity to move material through the vessel. Because there is a lack of internal mixing, it limits the silos to homogeneous materials like sludge. Agitated bed is another enclosed vessel systems. It includes internal mixing that physically moves materials through the vessel, combining the advantage of the windrow method. In general composting process in this method can be very rapid (Maarten Dubois et al, 2004).

(iii) *Vermi composting*

In India the species, like Eudrilus euginae, Parionyx excavatus and Eisenia fetida are being used for vermicomposting (Kaviraj et.al, 2003). Worms @ 350 worms per m3 of bed space should be adequate to build up the required population in about two to three cycles. The compost pits are of the size of 9 x 4 x 3 ft and it takes an average of 60 days for a compost to be ready, which is then sieved to retrieve the finer compost, while the coarser compost is put back into the pits with fresh garbage. As compared to above, this is a much more precision-based option and requires overseeing of work by an expert. It is also a more expensive option (especially O&M costs are high). It is a completely preferred solution in residential areas (Infrastructure Professionals Enterprises, 2004).

2.6.3 *Anaerobic digestion*

The biodegradable fraction of the waste requires separation from the other components of the waste. Source separation using kerbside or bring systems to civic amenity sites, or mechanical separation may be used. Fig 2.4 shows the main steps in the anaerobic digestion of biodegradable waste. In Chennai, Chennai Metropolitan Development Authority (CMDA) handling 30 tones per day of market wastes and producing about 104 kW power and 5 tones of wet compost cakes.

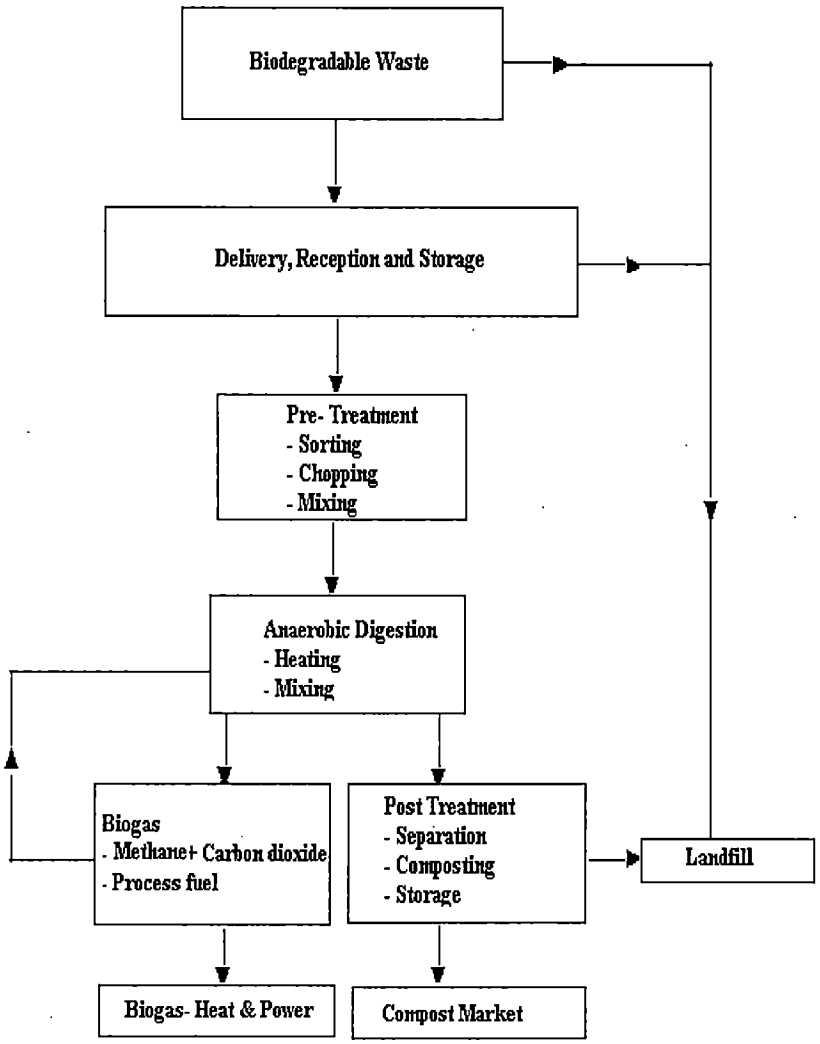


Fig 2.4:- Anaerobic Digestion Process Source: Williams, 2005

The advantages and disadvantages of waste disposal systems in Indian scenario are given in Table 2.1(Infrastructure Professionals Enterprises, 2004).

Table 2.1:- Advantages and Disadvantages of Waste Disposal Systems (in Indian Scenario)

S.No	Item	Aerobic Composting	Anaerobic Composting	Vermicomposting
1.	Foul odour in process	Yes	Yes	No
2.	Quality of End Product	Moderate	Moderate to Good	Good to Excellent
3.	Time for Composting	2-3 weeks	6-8 months (minimum)	6 months (minimum)
4.	Use for production of gas (CH_4)	No	Yes (in controlled environment)	No
5.	Attracts rodents, pests, dogs, etc.	Yes	No	No
6.	Need for Constant Monitoring	Low	High	Very High
7.	Storage capacity of end product	Low	Low	High
8.	Market demand	Moderate	Moderate	High (for agriculture)
9.	Power requirements	Yes (if mechanised)	No	Yes
10.	Intensity of skilled labour requirement	Low	Moderate	High
11.	Land requirement	Low	Moderate	High
12.	Quality of waste segregation	Moderate	High	Very high
13.	Leachate pollution	High	High	Low
14.	Contamination of aquifers (large scale)	High	Moderate to high	Low
15.	Capital Investment	Moderate	Moderate	High
16.	O&M Costs	Moderate	Moderate	High

CHAPTER 3

METHODOLOGY

3.1 GENERAL

This chapter gives the description of the methodology followed in the present dissertation. Primary data were collected during the study while Secondary data were obtained from the various agencies.

3.2 SECONDARY DATA COLLECTION

The following agencies were contacted for the secondary data collection;

i) Municipal Office, Pudukkottai

ii) Statistical department, Pudukkottai

iii) Pollution Control Board (PCB), Pudukkottai

iv) Public Works Department (W.R.O), Pudukkottai

v) Medicare Enviro Systems (MES), Thanjavur District

vi) National Small Industries Corporation (NSIC), Cochin

Secondary data collected from the above agencies were solid waste generation, Map of the entire study area, City Location, Climate, Population, Slums, Heritage water bodies, Commercial areas, Institutional areas, Industries, Hospitals, Hotels & restaurant, Infrastructure such as Roads, storm water drainage, reports of PMC relating to Waste handling & Management covering sweeping of streets, collection of waste, storage of waste, transportation, treatment of biomedical waste, disposal of waste, manpower deployed, allocation of resources and constraints faced.

3.3 PRIMARY DATA COLLECTION

The various methods used for primary data collection were

(i) Field Visit

A field survey was conducted to find out the number of wards their boundary and sanitary divisions in the town. Questionnaire was prepared for public to know their views/opinions and awareness regarding solid waste is at Annexure – I.

Households (100) were selected by random sampling method belonging to three economic groups, such as high, middle, and low. Out of 39 wards, ward nos 17, 33, 38 for high income, 22, 27, 28 for middle income and 9,14,29,31 for low-income houses were selected for this study.

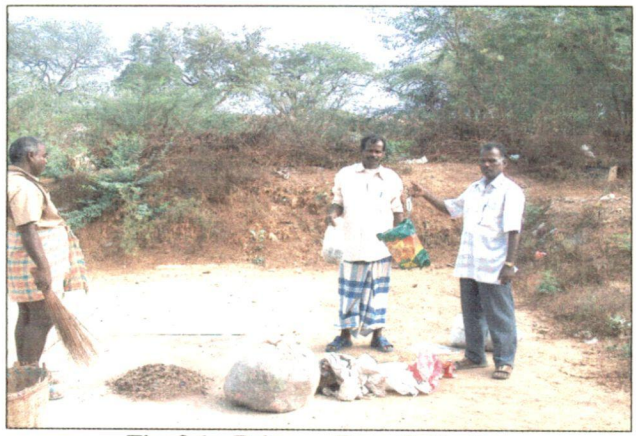


Fig. 3.1:- Primary Data Collection

(ii) Sampling Methods

(a) Solid waste

Primary data was generated for Physical characteristics, Density, Moisture content, chemical composition for solid waste. Twenty kg of waste was collected from lorries contains solid waste from different sanitary zones. The wastes with bags were weighed by a cylindrical weighing scale to determine the weights of the different waste categories.

One kg of solid waste taken for laboratory analysis and the test results were obtained from Tamilnadu Agricultural University (TNAU), Coimbatore.

(b) Water sampling

Water samples were collected from Kundar River, ponds, and dumping yard. The Physical, Chemical and Bacteriological tests for quality of water were carried out by Tamilnadu Water supply And Drainage Board, Pudukkottai.

(iii) Interview

The information was collected personnel engaged in policy- making, law enforcing, Solid waste management and handling and general public regarding waste handling & management and abatement of pollution through interview.

3.4 DATA ANALYSIS

The tabulated data were analysed to find out the percentage of biodegradable waste and non- biodegradable waste. An effort has also been made to design waste treatment facility and to chalk out an optimal route and shortest routes for transportation of waste.

CHAPTER 4

OBSERVATIONS, RESULTS AND DISCUSSION

4.1 GENERAL

Increase in population, commercial and industrial development results in increase in waste generation in this town. Solid waste disposal is one of the major problems faced by Pudukkottai Municipal Council (PMC). Inadequate facilities are available for the collection and segregation of solid waste as well as transportation. The leachate generated from the dumping ground is not collected and leachate directly finding its way into storm water drain and road. There is an urgent need to select appropriate treatment and disposal facility for municipal solid waste. Pudukkottai municipality is divided in 9 sanitary divisions for managing the solid waste. Table 4.1 & Fig 4.1 shows the number of sanitary divisions and wards covered in this division.

Table 4.1:- Sanitary divisions and wards covered in PMC

DIVISION NO	WARDS COVERED
1	10,11,12,13,14,15,27(part)
2	7(part), 8,9,16,17(part)
3	6,7(part), 17(part), 18
4	3,4,5,19,23(part)
5	25,26,28,29,30
6	31,32,33,36,37,39(part)
7	23,24,34,35
8	1,2,20,21,22(part)
9	22(part), 35(part), 38,39

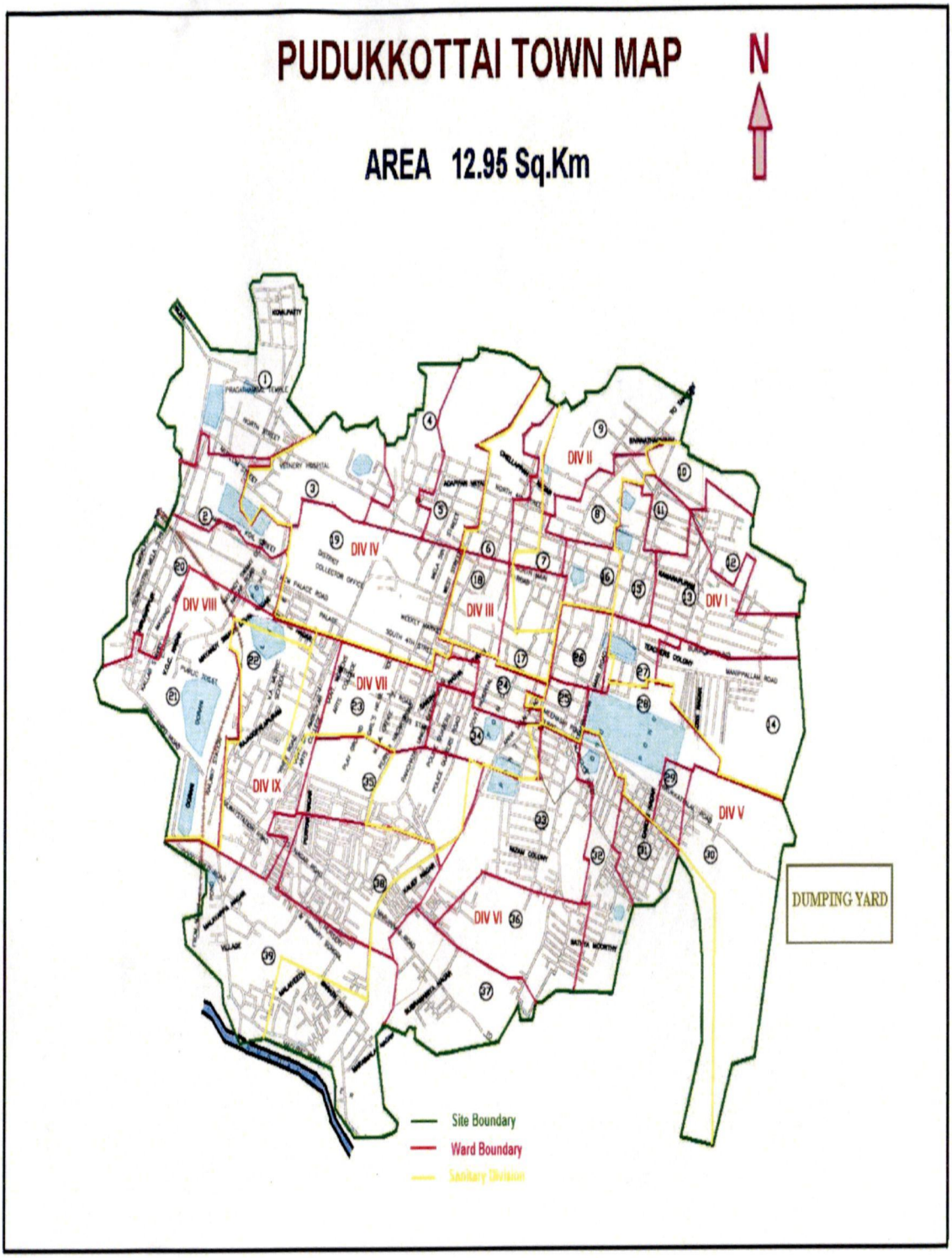


Fig 4.1:- Sanitary Divisions & Wards in Pudukkottai Town

Totally 39 wards covered in this town. Ward wise population & Household particulars are given in Table 4.2.

Table 4.2:- Ward wise population & household particulars as per Census2001

WARD.NO	MALE	FEMALE	TOTAL	HOUSEHOLD
1	1961	1933	3894	823
2	1499	1465	2964	684
3	1659	1834	3493	728
4	1539	1598	3137	692
5	1236	1225	2461	544
6	1047	989	2036	419
7	910	873	1783	401
8	1275	1243	2518	571
9	1709	1721	3430	763
10	1650	1578	3228	727
11	1180	1157	2337	526
12	2043	2022	4065	923
13	2165	2080	4245	936
14	1925	1841	3766	843
15	885	977	1862	397
16	744	752	1496	366
17	831	757	1588	308
18	1120	1134	2254	484
19	1835	1863	3698	817
20	1791	1767	3558	816
21	1523	1583	3106	650
22	2040	2078	4118	933
23	985	1017	2002	348
24	666	722	1388	285
25	650	638	1288	260
26	788	779	1567	338
27	1016	1062	2078	448
28	1327	1396	2723	606
29	872	889	1761	335
30	1470	1500	2970	568
31	1135	1120	2255	480
32	935	971	1906	429
33	1822	1629	3451	708
34	802	816	1618	361
35	1426	1515	2941	651
36	1183	1006	2189	435
37	1815	1750	3565	692
38	3038	3168	6206	1400
39	2117	2155	4272	959
TOTAL	54614	54603	109217	23654

4.2 EXISTING STATUS OF SWM PRACTICES IN PUDUKKOTTAI TOWN

Disposal of solid waste poses the serious problem in PMC. The Municipal Solid Waste (Management and handling) Rules 2000 (vide Ministry of Environment and Forest, Government of India notification S.O. 908(E) dt. 25th September 2000) (MoEF, 2000) makes it mandatory for the Local bodies to setup effective collection, treatment and disposal infrastructure for managing the solid waste.

4.2.1 Generation pattern of Solid Waste

The solid waste is generated in this town from various commercial, domestic and industrial activities. Some of the normal sources of the solid waste in the town are:

- Household garbage
- Vegetable waste from the markets.
- Building and construction debris.
- Solid waste generated from Commercial activities.

The solid waste generation is increasing with population growth of the town. 32 tons of solid waste is generated per day in Pudukkottai town. The ward wise waste generation is given as per PMC in Table 4.3. Data were collected from the wards and generation was found to be 300gm/capita/day.

Table 4.3:- Ward wise waste generation in Pudukkottai town

WARD NO	WASTE IN Kgs	WARD NO	WASTE IN Kgs
1	974	21	776
2	739	22	1079
3	872	23	540
4	784	24	550
5	615	25	1325
6	509	26	391
7	892	27	519
8	629	28	680
9	856	29	440
10	809	30	742
11	590	31	519
12	1016	32	681
13	1059	33	445
14	942	34	1245
15	465	35	519
16	794	36	329
17	1828	37	1013
18	1480	38	405
19	1924	39	1235
20	890	**TOTAL**	**32100**

4.2.2 Characteristics of the Waste

Composition of solid waste generated from this town is depicted in Fig 4.2.

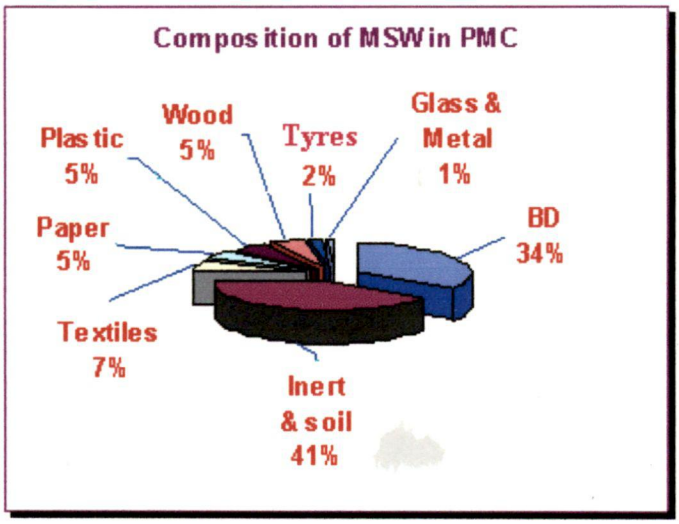


Fig 4.2:- Composition of MSW

The physico- chemical characteristic of the solid waste generated in the town is given in Table 4.4.

Table 4.4:- Characteristics of the solid waste

Parameters	Concentration
Moisture	24 %
Bulk density	0.9 g/cm^3
pH	7.92
Organic carbon	11.88 %
Nitrogen	1.28 %
Phosphorus	0.78 %
Potassium	0.85 %
C/N ratio	9.28

4.2.3 Storage of Solid Waste

Solid waste from the household is transferred to the pushcart by the residents shown in Fig 4.3. PMC has provided 144 nos of pushcart of 0.40cum capacity each for the town. After door- to- door collection of solid waste storing at near by temporary storage places within the wards. Totally 46 places are identified as open storage points.

Fig 4.3:- Solid waste collection from the houses

There is no provision for proper community bins, masonry bins for storing the waste. The temporary storage places are shown in Fig 4.4.

Fig 4.4:- Solid waste temporary storage places

4.2.4 Street Sweeping

Length of streets about 168 km. Total Length of storm water drains about 113.50 km as per PMC. Streets and drains are cleaned daily and wastes are stored in temporary storage places, which is further transferred to disposal sites. Sanitary division wise existing pushcart and workers availability are given in Table 4.5. In this town the generation of waste from sweeping is 14 Tons of Biodegradable and 2.5 Tons of Non Biodegradable.

Table 4.5:- Division wise Push cart & Workers availability

Division No	Wards covered	Push cart in Nos	Female in Nos	Male in Nos
1	10,11,12,13,14,15, 27(part)	24	24	11
2	7(p), 8,9,16,17(part)	16	16	12
3	6,7(part), 17(part), 18	13	13	11
4	3,4,5,19,23(part)	13	13	11
5	25,26,28,29,30	17	15	9
6	31,32,33,36,37,39(part)	16	16	12
7	23,24,34,35	15	26	14
8	1,2,20,21,22(part)	15	10	14
9	22(part), 35(part), 38,39	15	8	7
	Total	144	141	101

4.2.5 Marriage Halls

There are 39 Marriage Halls in Pudukkottai town. During a year, on an average, 60-80 days the Marriage Halls remain occupied. They cater, on an average from 300 to 1500 guests. During the peak period, the Marriage Hall generates 1 Tons of Biodegradable and 0.25 Tons of Non Biodegradable waste per day. However, this is a seasonal affair. It was observed that most of the food waste collected by the sweepers as a food for pigs.

4.2.6 Vegetable Market

There are six vegetable markets in this town. The average waste generation is 7 Tons of Biodegradable and 1 Ton of Non Biodegradable waste per day. Market wastes are stored in open places only.

4.2.7 Fish & Slaughter House

The waste generations from Fish & Slaughter House are 0.5 Ton of Biodegradable and 0.25 Ton of Non Biodegradable waste per day. Especially in Wednesday and Sunday, the waste generation rate is higher than the other days in a week.

4.2.8 Slum

There are 11 approved and 9 unapproved slums in this town. Total number of households in the slums is 9037 and population is around 45482. The survey was conducted with the help of Self Help Groups (SHGs). At present community bins are not available to store the solid waste in slums. The ward wise slum population and households are given in Table 4.6.

4.2.9 Hotel, Restaurants & Food stall

There are 40 numbers of Hotels, Restaurants & 68 numbers of Food stall approximately in Pudukkottai town. Waste generations from these are not stored in separate places. It is observed that most of the food waste collected by the sweepers as a food for pigs. The remaining wastes are collected by PMC workers without any cost.

4.2.10 Construction and Demolition Waste

Construction and Demolition Waste was observed in all the wards – more in growing wards. In such wards, the waste was observed to be lying by the roadside and drains. It was observed that the traffic was congested particularly in main bus routes. In rainy season, it was found that most of the places the rainwater stagnated without free flow.

Table 4.6:- Slum population & households

Approved Slum						
Sl.no	Slum Area	Ward No	Female	Male	Total	No of Houses
1	Kovilpatti	1	1740	2017	3757	614
2	Adappanvayal	4	1502	1533	3035	903
3	Matchuvadi	9	397	405	802	182
4	Sivanandapuarm	9	497	537	1034	213
5	Kamarajapuram	10 to 13	6692	6766	13458	2688
6	Bosenagar	14	2046	2070	4116	660
7	Thiruvapoor V.O.C	21	107	99	206	42
8	Gandhi nagar	29,30	2724	2698	5422	1086
9	Usilangulam	31	1208	1183	2391	421
10	Thiruvalluvar nagar	36	1279	1349	2628	525
11	Malaiyeedu	37	178	182	360	60
Un Approved Slum						
1	Ponnappan urani	21	258	286	544	105
2	Rajagopalapuram	22	1329	1307	2636	407
3	Pitchathanpatti	39	76	82	158	35
4	Malaiyappan nagar	39	114	128	242	78
5	Maharajapuram	20	257	232	489	139
6	M.U.Chinnappa theru	3	144	156	300	61
7	Samathiveethi	4	89	101	190	51
8	Thondaiman nagar	19	531	545	1076	206
9	Ayyanarpuram	28	1236	1402	2638	561
	Total		22404	23078	45482	9037

4.2.11 Bio Medical Waste (BMW)

Bio-medical waste generated in the hospitals and dispensaries are stored in separate bins and further transferred to centralized Bio-medical treatment unit set up at by Medicare Enviro Systems (MES). Bio-medical waste disposal facility is situated in Sengipatti village that is 40km away from Pudukkottai town. Out of 34 hospitals 28 hospitals made agreement with Medicare Enviro Systems (MES) as per Pollution Control Board (PCB) records & visits conducted. The list of hospitals signed with Medicare Enviro Systems (MES) in Pudukkottai town is given in Table 4.7.

Table 4.7:- List of hospitals signed with Medicare Enviro Systems

Sl.No	Hospital Name	No of Beds
1	Senthil Nursing Home	22
2	SRV Hospital	12
3	Life care clinic	2
4	Sugam Nursing Home	11
5	Sivakamu clinic	15
6	Heart Line Hospital	4
7	Thangam clinic	6
8	Padma clinic	12
9	Kannan Hospital	10
10	Susheela Nursing Home	10
11	Rasi Nursing Home	18
12	JJ clinic	2
13	Sri Meenakshi Poly clinic	20
14	Sri Ramana clinic	15
15	Duraisamy Nursing Home	12
16	Srinivasan Hospital	6
17	Krishna Eye Hospital	5
18	Manimegalai clinic	5
19	Bhuvana Nursing Home	20
20	Suresh Hospital	3
21	Jayaraja Hospital	3
22	M.J Hospital	5
23	Vaitheswara clinic	2
24	Lalitha clinic	10
25	Mamalar Hospitals	12
26	Praveen Hospitals	10
27	Team Hospital	15
28	Ayyan Hospital	2

Wastes collected from door – to –door and street sweeping etc, are gathered together at open and unpaved dumping sites, which is further transferred to disposal sites.

4.3 TRANSFER TRANSPORT, PROCESSING AND DISPOSAL

4.3.1 Collection System

Collection and transportation of waste is one of the important and critical activities. Any slip in these activities can result a lot of nuisance and public health hazard. In the other hand this activity has a maximum share in cost.

Quantity of waste collected in the year 2003-2007 is shown in Fig 4.5. The daily waste collections from 03/12/2006 to 09/12/2006 are given in Table 4.8 to give the idea of daily variation

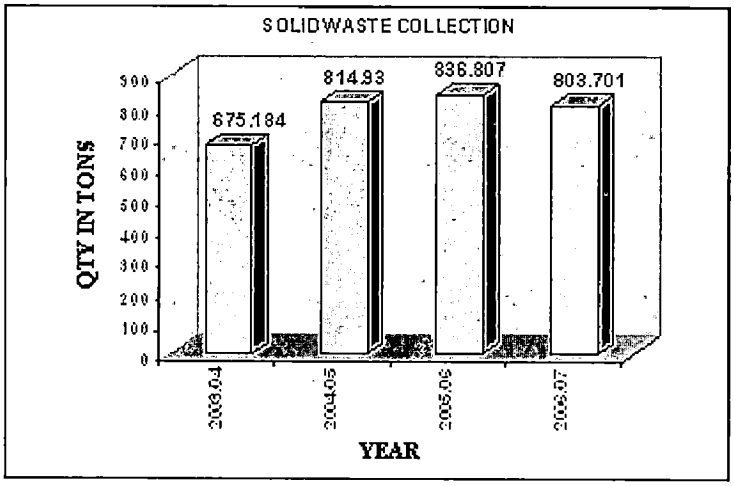


Fig 4.5:- Year wise waste Collection

Table 4.8:- Daily collection details of solid wastes

SL.NO	DATE	Bio Degradable (Kg)	Non Bio Degradable (Kg)
1	3/12/2006	500	3600
2	4/12/2006	3700	29600
3	5/12/2006	2900	30000
4	6/12/2006	5100	29100
5	7/12/2006	8100	27800
6	8/12/2006	3900	36300
7	9/12/2006	3500	17500
	TOTAL	27700	173900

The year wise waste collections from 2003-2007 are given in Table 4.9, 4.10, 4.11 & 4.12 respectively.

Table 4.9:- Year wise solid waste collection 01/06/03 TO 31/03/2004

SL.NO	MONTH	BD in Kg	NBD in Kg	TOTAL in Kg
1	JUNE	62810	527390	590200
2	JULY	62740	576950	639690
3	AUG	51310	583480	634790
4	SEP	51500	566180	617680
5	OCT	63150	632590	695740
6	NOV	53580	694350	747930
7	DEC	57960	698650	756610
8	JAN	51450	629800	681250
9	FEB	51780	589570	641350
10	MAR	49960	696640	746600
	TOTAL	556240	6195600	6751840

Table 4.10:- Year wise solid waste collection 01/04/04 TO 31/03/2005

SL.NO	MONTH	BD in Kg	NBD in Kg	TOTAL in Kg
1	APRIL	48430	627500	675930
2	MAY	46290	626140	672430
3	JUN	47430	659140	706570
4	JULY	49090	702080	751170
5	AUG	48070	642140	690210
6	SEP	48400	685510	733910
7	OCT	46510	602990	649500
8	NOV	35980	585980	621960
9	DEC	47630	575110	622740
10	JAN	59740	535820	595560
11	FEB	59410	626420	685830
12	MAR	61440	682050	743490
	TOATL	598420	7550880	8149300

Table 4.11:- Year wise solid waste collection 01/04/05 TO 31/03/2006

SL.NO	MONTH	BD in Kg	NBD in Kg	TOTAL in Kg
1	APRIL	50940	701400	752340
2	MAY	58570	662870	721440
3	JUN	66880	631950	698830
4	JULY	52910	565250	618160
5	AUG	48460	605810	654270
6	SEP	57860	650510	708370
7	OCT	52320	623890	676210
8	NOV	27190	625030	652220
9	DEC	46510	717220	763730
10	JAN	32700	684930	717630
11	FEB	25850	646160	672010
12	MAR	30800	702060	732860
	TOATL	550990	7817080	8368070

Table 4.12:- Year wise solid waste collection 01/04/06TO 31/01/2007

SL.NO	MONTH	BD in Kg	NBD in Kg	TOTAL in Kg
1	APRIL	27500	604520	632020
2	MAY	56360	661910	718270
3	JUN	141505	612605	754110
4	JULY	113860	671935	785795
5	AUG	94100	665100	759200
6	SEP	85500	784000	869500
7	OCT	63700	814100	877800
8	NOV	84800	825900	910700
9	DEC	113730	736585	850315
10	JAN	99700	779600	879300
	TOTAL	880755	7156255	8037010

4.3.2 Transportation of waste

Different types of vehicles, shown in Fig 4.6 such as, Lorry of 6 Tons capacity, mini lorry of 4 Tons capacity, Tipper of 6.5 Tons capacity and Tractors with trailers of 3 Tons capacities have been pressed into service for transportation of wastes from different wards to the designated dumping site. The dumping site is situated 4 km away from the town. At present, PMC has deployed 3 Lorries, 3 mini Lorries, 2 tractors with trailers and 1 tipper. Each vehicle makes 1-2 trips per day between the assigned wards and dumping site. During survey it was observed that in the first trip the transport vehicles were collecting biodegradable market waste. The details of vehicles used for transporting the solid waste from temporary storage places given in Table 4.13. The existing temporary storage places and transport routes shown in town map in Annexure II.

Table 4.13:- vehicles used for transporting the solid waste

SL.NO	TYPE OF VECHICLE	YEAR OF PURCHASE	VECHILE CAPACITY IN cum
1	LORRY	1988	7.5
2	LORRY	1985	7.5
3	LORRY	1993	7.5
4	MINI LORRY	1992	5.8
5	MINI LORRY	1999	5.8
6	MINI LORRY	1992	5.8
7	TRACTOR WITH TRAILER	1997	5.0
8	TRACTOR WITH TRAILER	1997	5.0
9	TIPPER	1996	7.13

Fig 4.6:- Vehicles used for collection of solid waste from temporary storage places

4.3.3 Processing, Treatment and Disposal of Waste

Presently, there is no proper facility for processing and treatment of MSW. Waste can be minimized by recycling and reuse. Recyclable wastes with commercial value generated by households, commercial establishments, institutions, hotels & restaurants are generally stored at sources. 15 percent to 20 percent of waste is segregated through rag pickers from temporary storage places. It was observed that waste collectors are not ready to segregate the waste in dumping yard due to non-availability of safety arrangements. Fig 4.7 is showing the waste segregation by rag picker in temporary storage place. Some of the material is recycled through PMC workers at the source from the door-to-door collection. Plastic wastes collected from PMC workers are stored in dumping yard and the same is sold to the private vendors. Revenue earned by selling of plastic waste to private parties is shown in Fig 4.8 and Table 4.14.

Fig 4.7:- waste segregation by rag picker

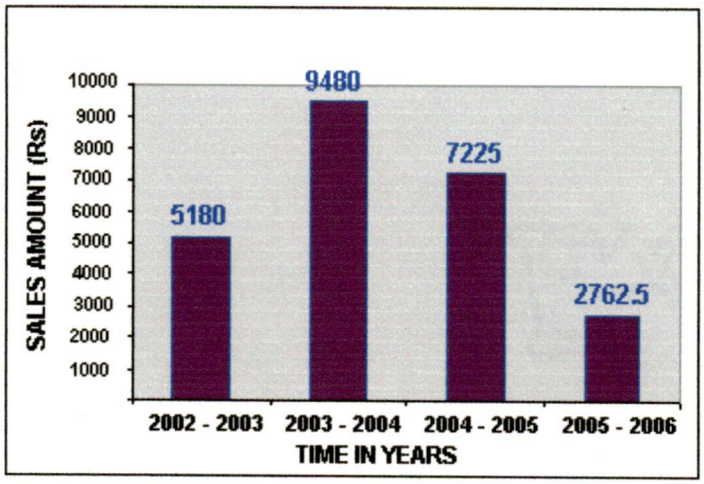


Fig 4.8:- Plastic waste sales details

Table 4.14:- Plastic waste sales details

Year	Sales in tons	Amount / ton	Total Amount
2002-2003	14	370	5180
2003-2004	24	395	9480
2004-2005	17	425	7225
2005-2006	6.5	425	2762.5

The composting is also done in dumping yard process are doing by PMC, but no proper composting process followed. 10m x 4.20 x 1.20m size pits are excavated and the waste is dumped in these pits up to the height of 1.80m above the ground level shown in Fig 4.9. After 3 months the compost manure is directly sold to the farmers at the rate of Rs. 100 per ton. Earning from compost manure is shown in Fig 4.10 and Table 4.15. During interview, it was found that most of the farmers are not interested to buy the compost manure due to sharps and unwanted scraps present in compost manure.

Fig 4.9:- Natural degradation of waste to Compost in dumping yard

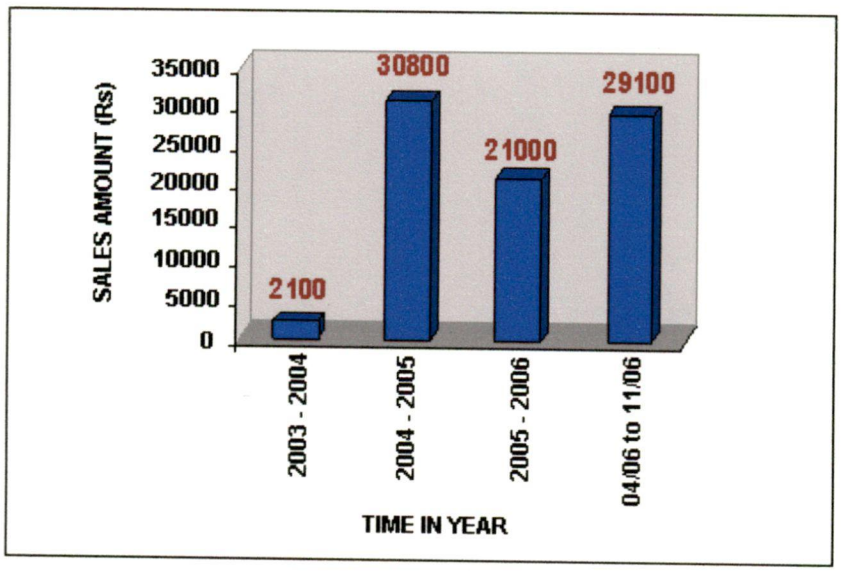


Fig 4.10:- Compost manure sales details

Table 4.15:- Compost manure sales details

Year	Production in tons	Sales in ton	Amount / ton	Total Amount
2003-2004	370	21	100	2100
2004-2005	398	308	100	30800
2005-2006	368	210	100	21000
04/06 to 11/06	446	291	100	29100

The Municipal Solid Waste Rules issued by the Central Pollution Control Board make safe and proper handling and disposal mandatory. The analysis of the responses to the questionnaire suggests that sanitary inspectors, and sanitary workers have problem pertaining to shortage of vehicles, disposal of collected waste with inadequate road facility in dumping yard, non availability and/or maintenance of tools and equipments. The available land area of dumping site is 13.13 acres. It was observed that there is no entrance gate, proper approach roads, street light arrangement, and drinking water facility in the dumping yard. It was found that 4 watchmen, 1 supervisor (incharge), 1 Sanitary Inspector (incharge) were working in dumping yard. Fire fighting arrangements and First aid box were not available in the yard. Till now total sanitary treatment and disposal is not achieved and looks still a dream. Even today, open dumping areas have significant quantities of solid wastes dumped. Most of the solid waste is dumped randomly and secured landfill practices are not being followed as shown in Fig 4.11& 4.12. This presents a grave concern to the population of the town. Uncontrolled, illegal dumping of solid waste, especially plastic wastes continue to overburden the PMC as shown in Fig 4.13.

Illegal dumping of solid waste in and around the dumping area and leachate has created severe nuisance and also affected the ground water. In rainy season, the leachate from the dumping yard flowing in and around the yard and near by roads is shown in Fig 4.14. The water samples collected from the dumping yard and near by area are tested in Tamilnadu Water supply And Drainage board (TWAD) lab in Pudukkottai town and test results are given in Table 4.16. Inspite of administration making lot of efforts and expenditure in improving solid waste management system, the satisfactory results are not achieved.

Public awareness programmes and training programmes for sanitary workers were conducted by PMC jointly with PCB, SHGs, and NGO's in the year 2002-2004 are shown in Fig 4.15, 4.16, 4.17 & 4.18. It is observed that all the sanitary workers are expected to conduct such kind of programmes frequently to improve public awareness about the waste segregation at source itself. The sanitary inspectors and sanitary workers feel the need of training programs to increase their work productivity and effectiveness. In addition to this the sanitary workers feel that there are no litter bins in commercial streets like Sathyamoorthy road, East main street, South main street, West main street and North main street. The survey revealed that the staffs of the commercial establishments / shops and offices in charge of waste handling are not aware of segregation practice and the categories of wastes that are to the segregated. The respondents from households, commercial establishments & shops and institutions are not aware of hazardous wastes. Hence, these wastes are also let into the general waste stream or sold to the vendors. Use of plastic carry bags is common to both consumers and shopkeepers. The Owner of the shops and buyers are throwing the wastes in roads and drains, which is creating nuisance to others. Majority of the respondents are interested to know about how to manage different kinds of waste. The collected data suggests that citizens are ready to pay for effective solid waste management services. The system can be made effective by a positive participation by the public awareness, effective community participation, transparent and clean administration, introduction of citizen charters and accountability at all levels.

Fig 4.11:- Dumping yard

Fig 4.12:- Solid waste dumped in yard

Fig 4.13:- Plastic waste in dumping yard

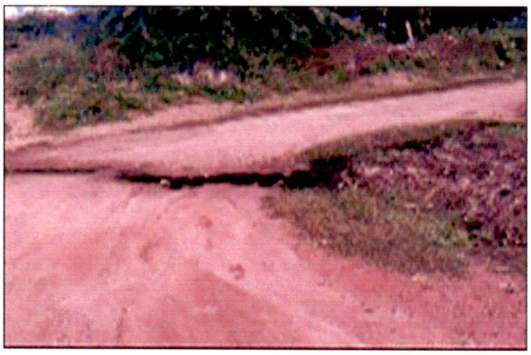


Fig 4.14:- Leachate from dumping yard

Fig 4.15:- Training Programmes conducted by PMC

Fig 4.16:- Training for sanitary workers

Fig 4.17: - Public Awareness programme

Fig 4.18: - Public Awareness programme

Table 4.16:- Water quality results as on 18/12/06

Parameters			Compost yard Hand Pump	Compost yard Borewell	Compost yard Opp Open Well
Physical Examination	Acceptable limit	Permissible limit			
Appearance			Turbid	Slightly yellowish	Slightly Greenish
Odour	Unobjectionable		None	None	Objectionable
Turbidity NTU	2.5	10	71	240	10
TDS	500	2000	3699	1449	405
Conductivity MicS/cm			5285	2142	579
Chemical Composition					
pH	6.5	9.2	6.64	7.14	6.5
Alkalinity pH as $CaCO_3$			0	0	0
Alkalinity Total as $CaCO_3$	..	600	567	339	86
Total Hardness as $CaCO_3$	200	600	1814	577	132
Calcium as Ca	75	200	627	104	33
Magnesium as Mg	30	150	71	78	12
Iron Total as Fe	0.1	1	4.55	5.64	0.55
Manganese as Mn	0.05	0.5	0	0.292	0
Free ammonia as NH_3	..	..	0	0	0.25
Nitrite as NO_2	..	..	0.17	0.09	0
Nitrate as NO_3	45	100	1	6	0
Chloride as Cl	200	1000	1366	440	123
Flouride as F	1	1.5	0.1	0.6	0.1
Sulphate as SO_4	200	400	274	39	17
Phosphate as PO_4	..	..	0	0.05	0.05
Tidy's test 4 hrs as O	..	..	3.41	1.08	4.92

Note: Result of Chemical Examination is expressed in mg/Litre.

4.3.4 Institutional Arrangement and Budgetary provision for SWM

Solid Waste Management in the PMC is the responsibility of the solid waste department. The organization of the solid waste department is shown in Fig 4.19.

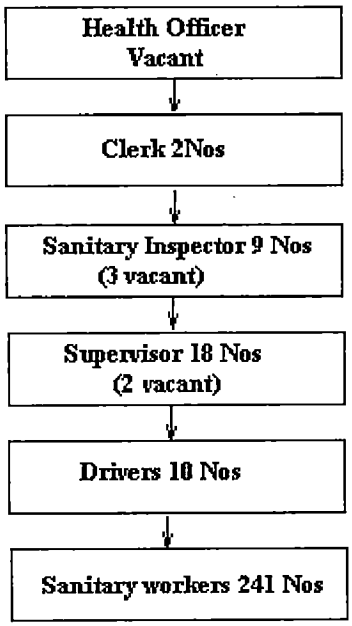


Fig: - 4.19:- Number of employees catering to solid waste management in PMC

Study of year wise Statement of Expenditures of PMC shows that the expenditure on Solid Waste Management was 48.28%, 37.04%, 28.68%, 38.22%, 25.41% and 25.08% pertaining to the financial years 2001-02, 2002-03, 2003-04, 2004-05, 2005-06 & estimated expenditure for 2006-07 is shown in Fig 4.20.

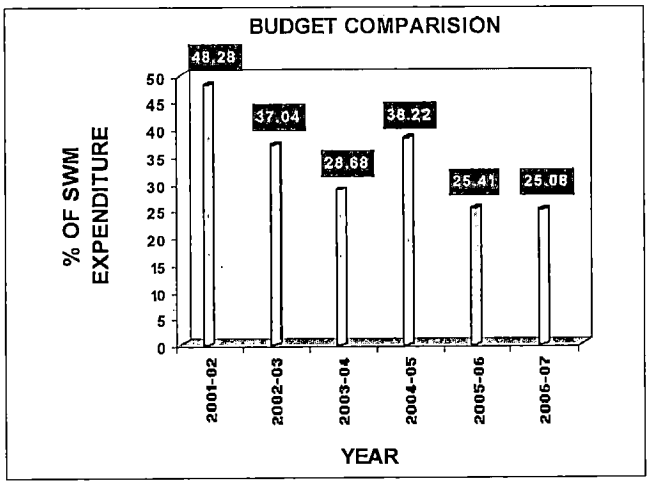


Fig 4.20:- Budget comparison

4.3.5 Citizens Perception about the Present Solid Waste Management Practices

During interview and site visits the contact was made with the peoples & found that the citizens perceive that the main Solid Waste Management related problems are; infrequent collection, location of temporary storage places and foul odor. Households 100 were selected by random sampling method belonging to three economic groups, such as high, middle, and low. Out of 39 Wards, Ward nos 17, 33, 38 for high income, 22, 27, 28 for middle income and 9,14,29,31 for low-income houses were selected for this study. A total of 100 households were interviewed out of which non-slum respondents are 60 and slum dwellers are 40. The analysis of the data suggests that people give second priority to solid waste management related problems after sanitation. Peoples are facing main problem due to mosquito breeding in drains. During interview 75% of the respondents repeated the same and pointed out about the drains choked with solid wastes especially plastics and construction wastes. The wastes in drains are shown in Fig 4.21 & 4.22 respectively. More than 60% of peoples are expecting to remove debris from drains daily and the same to be disposed of within 2 to 3 days. In Alangulam and Bus stand near Housing unit residents are insisting to put community bins at the area, so that they can store the wastes in bins. It was found that first floor & second floor residents are throwing the solid wastes from balcony to rear side. The sanitary workers are facing much more problem to collect the wastes, at the same time labour & time also consuming doubly. 20% of the respondents are expecting to collect the wastes daily, especially in slum peoples. Majority of households preferred door-to-door waste collection method. All the 100 respondents are aware that the 'garbage' should go out of premises otherwise, that will create environment for diseases. On the whole, the behaviour and attitude of the sample households revealed that everyone wants to take out their wastes from their premises. Most of the peoples reported that the wastes are accumulated in water bodies like ponds/tanks and Kundar River is shown in Fig 4.23 & 4.24. Especially slum & residing near to river, peoples are taking bath and washing cloths in ponds, river and pollute these sources. Due to aesthetic and odour problem they are hesitating to take bath and washing cloths. All the ponds in the town are interconnected through drains.

In rainy season, the excess water from ponds and drains carrying the wastes entire town and entering to the river kundar. It was observed that the wastes flowing in the river & water hyacinths growth are in abundance as shown in Fig 4.25 & 4.26.

Fig 4.21:- Plastic wastes in drain

Fig 4.22:- Construction debris in drain

Fig 4.23:- Santhanathapuram pond

Fig 4.24:- Keela nainari pond

Fig 4.25:- Wastes flowing in Kundar River

Fig 4.26:- Water hyacinth in Kundar River

4.3.6 Impact of Solid Waste on Water bodies

Water samples were collected from river kundar and tested in TWAD Lab in Pudukkottai town given in Table 4.17. The lists of ponds in the town as per PMC are given in Table 4.18. For ponds the testing was carried out by PMC and the results are given in Table 4.19, 4.20, 4.21 & 4.22.

Water samples were collected from ponds such as Westnainarikulam, Rajakulam & Pallavankulam and tested in TWAD Lab in Pudukkottai town given in Table 4.23.

Table 4.17:- Kundar river water quality results as on 18/12/2006

Parameters			Malaiyeedu	Maraimalai nagar	Near Kundar Bridge
Physical Examination	Acceptable limit	Permissible limit			
Appearance			C&C	Slightly yellowish	Slightly Greenish
Odour	Unobjectionable		None	None	Objectionable
Turbidity NTU	2.5	10	10	240	10
TDS	500	2000	733	1449	405
Conductivity MicS/cm			1047	2142	579
Chemical Composition					
pH	6.5	9.2	7.36	7.14	6.5
Alkalinity pH as $CaCO_3$			0	0	0
Alkalinity Total as $CaCO_3$	..	600	310	339	86
Total Hardness as $CaCO_3$	200	600	227	577	132
Calcium as Ca	75	200	68	104	33
Magnesium as Mg	30	150	15	78	12
Iron Total as Fe	0.1	1	0.18	5.64	0.55
Manganese as Mn	0.05	0.5	0	0.292	0
Free ammonia as NH_3	..	..	0.16	0	0.25
Nitrite as NO_2	..	..	0	0.09	0
Nitrate as NO_3	45	100	0	6	0
Chloride as Cl	200	1000	170	440	123
Flouride as F	1	1.5	0.2	0.6	0.1
Sulphate as SO_4	200	400	19	39	17
Phosphate as PO_4	..	..	0.1	0.05	0.05
Tidy's test 4 hrs as O			2.31	1.08	4.92
BOD			3	12	9
COD			12	32	24
Fecal Coliform	..	..	84	850	384

Note: Result of Chemical Examination is expressed in mg/Litre

Table 4.18:- Pudukkottai Municipality Ponds/Tanks details

SL. NO	NAME OF TANK / WATER BODIES	TOWN SURVEY NO	OWNED BY	EXTENT IN HEC
1	Periyakulam	6793	HR & E	1.56
2	Brahadambal kovil tank	6802	HR & E	0.37
3	Pallavankulam	2655/1	HR & E	1.6
4	Adappankulam	7784	Municipal	9.01
5	Mangulam	6110	Municipal	0.8
6	Servarayankulam	8859	Municipal	1.75
7	Mappillaiyar kulam	1142	Municipal	1.22
8	Ayyarkulam	481	Municipal	1.53
9	Nattampallam	245	Municipal	1.75
10	Sengalpallam	194/2	Municipal	0.63
11	Akkachiyakulam	2023	Municipal	3.5
12	Palaniyandi kulam	1333	Municipal	0.71
13	Ponnappan urani	7329	Municipal	2.92
14	kakachi urani	5332	Municipal	1.29
15	Mattukulam	3594/1	Municipal	7.91
16	west nainarikulam	3543	Municipal	1.68
17	Vathampallam	272	Municipal	2.3
18	Rajakulam	4595	Municipal	2.19
19	East nainarikulam	4712/2	Municipal	1.39
20	kallapallm	8201/1	Municipal	4.45
21	Perankulam	6370	Municipal	0.89
22	Malaiyeedukulam	8592	Municipal	0.72
23	Edachikualm	9918	Municipal	0.45
24	Alangulam	6089	Municipal	0.51
25	Devarkulam	8649	Municipal	3.36
26	Thenkulam	4869	Municipal	0.5
27	Mariyankulam	8201/1	Municipal	4.45
28	Sangligundu urani	251	Municipal	0.45
29	Vengappa Iyer oothu	1922	Municipal	0.83
30	Pudukkulam	4709	Municipal	13.6

Table 4.19:- Water quality results for Ponds / water Bodies as on 20/07/05

Parameters			Akachiya kulam	Palaniyandi kulam	Ponnappan urani	Kakachi urani
Physical Examination	Accep table limit	Permi ssible limit				
Appearance			Slightly Greenish	Greenish	Greenish	C&C
Odour	Un objectionable		Un objectionable	Un objectionable	Un objectionable	None
Turbidity NTU	2.5	10	20	28	42	10
TDS	500	2000	1388	1367	1381	1995
Conductivity MicS/cm			1984	1953	1973	2850
Chemical Composition						
pH	6.5	9.2	8.81	8.75	8.43	8.48
Alkalinity pH as $CaCO_3$			64	28	28	36
Alkalinity Total as $CaCO_3$	..	600	256	160	224	224
Total Hardness as $CaCO_3$	200	600	236	328	236	284
Calcium as Ca	75	200	61	82	45	45
Magnesium as Mg	30	150	20	30	30	41
Iron Total as Fe	0.1	1	0.11	1.12	0.33	0
Manganese as Mn	0.05	0.5	0	0	0	0
Free ammonia as NH_3	..	..	1.64	2.13	1.88	0.65
Nitrite as NO_2	..	..	0	0	0	0.02
Nitrate as NO_3	45	100	0	0	0	0
Chloride as Cl	200	1000	520	568	444	844
Flouride as F	1	1.5	0.4	0.6	0.4	0.4
Sulphate as SO_4	200	400	85	58	109	95
Phosphate as PO_4	..	..	0.46	1.82	0.57	0.2
Tidy's test 4 hrs as O	..	..	9.33	13.73	14.62	6.82
BOD			24	33	36	15
COD			56	84	88	36
Bacteriological Examination						
Fecal coliform	0/100ml		1500	0	TNTC	TNTC

Note: Result of Chemical Examination is expressed in mg/Litre

TNTC- Too Numerous To Count

Table 4.20:- Water quality results for Ponds / water Bodies as on 20/07/05

Parameters			Maatu kulam	Westnainar kulam	Vatham pallam	Raja kulam
Physical Examination	Acceptable limit	Permissible limit				
Appearance			Slightly Blackish	Greenish	Slightly Yellowish	Greenish
Odour	Un objectionable		objectionable	objectionable	objectionable	objectionable
Turbidity NTU	2.5	10	36	71	82	26
TDS	500	2000	8820	888	1799	1361
Conductivity MicS/cm			12600	1269	2570	1945
Chemical Composition						
pH	6.5	9.2	7.72	8.58	7.81	8.56
Alkalinity pH as $CaCO_3$			0	48	0	40
Alkalinity Total as $CaCO_3$	..	600	672	180	76	244
Total Hardness as $CaCO_3$	200	600	750	260	544	364
Calcium as Ca	75	200	188	46	122	61
Magnesium as Mg	30	150	67	34	58	51
Iron Total as Fe	0.1	1	0.33	0.56	1.12	0.45
Manganese as Mn	0.05	0.5	0	0	0	0
Free ammonia as NH_3	..	..	21.32	2.21	2.05	6.56
Nitrite as NO_2	..	..	0.15	0.11	0	1
Nitrate as NO_3	45	100	1	0	0	1
Chloride as Cl	200	1000	4140	352	860	532
Flouride as F	1	1.5	0.6	0.4	0.4	0.6
Sulphate as SO_4	200	400	220	16	56	70
Phosphate as PO_4	..	..	5.2	0.93	0.4	3.53
Tidy's test 4 hrs as O	..	..	25.57	8.84	5.21	12.84
BOD			60	21	12	30
COD			132	52	32	72
Bacteriological Examination						
Fecal coliform	0/100ml		450	TNTC	100	TNTC

Note: Result of Chemical Examination is expressed in mg/Litre

TNTC- Too Numerous To Count

Table 4.21:- Water quality results for Ponds / water Bodies as on 20/07/05 & 14/07/05

Parameters			Eastnainari kulam	Kallapallam	Servarayan kulam	Mangulam
Physical Examination	Desirable limit	Permissible limit				
Appearance			Slightly Yellowish	Slightly Yellowish	Slightly Greenish	Greenish
Odour	Unobjectionable		objectionable	objectionable	objectionable	objectionable
Turbidity NTU	2.5	10	32	55	62	28
TDS	500	2000	779	809	1004	1988
Conductivity MicS/cm			1114	1156	1435	2840
Chemical Composition						
pH	6.5	9.2	8.28	7.94	8.9	9.32
Alkalinity pH as $CaCO_3$			16	0	28	112
Alkalinity Total as $CaCO_3$	..	600	116	132	320	340
Total Hardness as $CaCO_3$	200	600	208	192	216	232
Calcium as Ca	75	200	50	46	42	29
Magnesium as Mg	30	150	20	18	27	38
Iron Total as Fe	0.1	1	0.22	1.35	1.01	0.67
Manganese as Mn	0.05	0.5	0	0	0	0
Free ammonia as NH_3	..	..	0.98	1.72	1.48	3.6
Nitrite as NO_2	..	..	0	0.08	0	0.02
Nitrate as NO_3	45	100	0	1	1	1
Chloride as Cl	200	1000	292	288	268	712
Flouride as F	1	1.5	0.4	0.4	0.6	0.6
Sulphate as SO_4	200	400	75	82	78	146
Phosphate as PO_4	..	..	0.52	0.46	0.31	1.5
Tidy's test 4 hrs as O	..	..	6.34	5.25	7.11	16.63
BOD			15	12	15	39
COD			36	32	32	80
Bacteriological Examination						
Fecal coliform	0/100ml		250	TNTC	620	480

Note: Result of Chemical Examination is expressed in mg/Litre

TNTC- Too Numerous To Count

Table 4.22:- Water quality results for Ponds / water Bodies as on 14/07/05

Parameters			Pallavan kulam	Periya kulam	Prahadambal tank	Adappan kulam
Physical Examination	Acceptable limit	Permissible limit				
Appearance			Slightly Greenish	Slightly yellowish	C&C	C&C
Odour	Unobjectionable		objectionable	objectionable	None	None
Turbidity NTU	2.5	10	15	22	0	32
TDS	500	2000	819	1449	367	238
Conductivity MicS/cm			1170	2070	525	340
Chemical Composition						
pH	6.5	9.2	8.55	8.49	9.04	7.44
Alkalinity pH Ph as $CaCO_3$			28	32	20	0
Alkalinity Total as $CaCO_3$	..	600	112	204	84	100
Total Hardness as $CaCO_3$	200	600	198	452	90	100
Calcium as Ca	75	200	55	77	24	33
Magnesium as Mg	30	150	14	62	7	4
Iron Total as Fe	0.1	1	0.22	0.11	0	0.34
Manganese as Mn	0.05	0.5	0	0	0	0
Free ammonia as NH_3	..	..	0.49	1.39	0.33	0.33
Nitrite as NO_2	..	..	0	0	0.01	0.01
Nitrate as NO_3	45	100	0	1	0	1
Chloride as Cl	200	1000	294	592	112	46
Flouride as F	1	1.5	0.4	0.4	0.4	0.4
Sulphate as SO_4	200	400	46	48	21	15
Phosphate as PO_4	..	..	0.36	0.52	0.31	0.31
Tidy's test 4 hrs as O	..	..	5	8.21	3.32	2.82
BOD			12	18	6	6
COD			24	40	16	12
Bacteriological Examination						
Fecal coliform	0/100ml		810	TNTC	380	410

Note: Result of Chemical Examination is expressed in mg/Litre

TNTC- Too Numerous To Count

Table 4.23:- Water quality results for Ponds as on 10/05/07

Parameters			Westnainarikulam	Rajakulam	Pallavankulam
Physical Examination	Acceptable limit	Permissible limit			
Appearance			Greenish	Sl Greenish	Sl yellowish
Odour	Unobjectionable		Some Odour	Some odour	Some Odour
Turbidity NTU	2.5	10	284	68	24
TDS	500	2000	1647	1214	1092
Conductivity MicS/cm			2353	1734	1560
Chemical Composition					
pH	6.5	9.2	8.37	9.14	7.98
Alkalinity pH as $CaCO_3$			4	24	0
Alkalinity Total as $CaCO_3$	..	600	180	94	143
Total Hardness as $CaCO_3$	200	600	265	224	249
Calcium as Ca	75	200	31	45	48
Magnesium as Mg	30	150	45	27	31
Iron Total as Fe	0.1	1	0.56	0	0.11
Manganese as Mn	0.05	0.5	0	0	0
Free ammonia as NH_3	..	..	1.15	0.74	0.49
Nitrite as NO_2	..	..	0	0.07	0
Nitrate as NO_3	45	100	5	5	2
Chloride as Cl	200	1000	630	483	376
Flouride as F	1	1.5	0.3	0.2	0.2
Sulphate as SO_4	200	400	73	1	61
Phosphate as PO_4	..	..	0.31	0.21	0.1
Tidy's test 4 hrs as O			18.16	8.16	5.87
BOD			45	21	15
COD			96	40	32
Fecal Coliform	..	..	TNTC	350	TNTC

Note: Result of Chemical Examination is expressed in mg/Litre

TNTC- Too Numerous To Count

4.4 PROPOSED SOLID WASTE MANAGEMENT SYSTEM

The improvement of SWM services in Pudukkottai town requires significant improvement as an integral part of the conservation of water bodies like ponds/tanks and Kundar river. Therefore, it is urgent requirement to improve the present SWM system. The action taken by PMC should be coupled with continuous awareness generation programme. Emphasis could be on development of landfill site in addition to making operations more efficient, following proper routes and scheduling of waste collection and transportation. For the collection and storage of waste various types of namely in-situ constructed ready-made bins and containers made up of plastic and steel have to be considered. Initiative towards delivery of better service and establishing the institutional, operational and financial foundations for further improvement is needed.

4.4.1 Projected Waste Generation

Projected population is calculated by the exponential growth model as recommended by the Central Planning Commission (Source: Statistical Department hand book 2005-06). The population projection is shown in Fig 4.27. Wardwise projected population is given in Table 4.24. The exponential model was used as given below

$$Pt = Po \times e^{rt}$$

Where P_t = Population in the t^{th} year

Po = Population in the (o) year

r = Annual growth rate

t = Time in Number of years

$$r = \frac{\log_{10} Pt - \log_{10} Po}{t \times \log_{10} e}$$

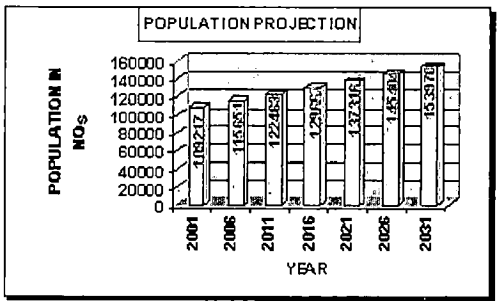


Fig: - 4.27:- Population Projection

Table 4.24:- Wardwise Population Projection

WARD.NO	2001	2006	2011	2016	2021	2026	2031
1	3894	4123	4366	4623	4896	5184	5490
2	2964	3139	3323	3519	3727	3946	4179
3	3493	3699	3917	4147	4392	4650	4924
4	3137	3322	3517	3725	3944	4176	4422
5	2461	2606	2759	2922	3094	3276	3469
6	2036	2156	2283	2417	2560	2711	2870
7	1783	1888	1999	2117	2242	2374	2514
8	2518	2666	2823	2990	3166	3352	3550
9	3430	3632	3846	4073	4312	4566	4835
10	3228	3418	3619	3833	4058	4298	4551
11	2337	2475	2620	2775	2938	3111	3295
12	4065	4304	4558	4827	5111	5412	5731
13	4245	4495	4760	5040	5337	5652	5984
14	3766	3988	4223	4471	4735	5014	5309
15	1862	1972	2088	2211	2341	2479	2625
16	1496	1584	1677	1776	1881	1992	2109
17	1588	1682	1781	1885	1997	2114	2239
18	2254	2387	2527	2676	2834	3001	3178
19	3698	3916	4147	4391	4649	4923	5213
20	3558	3768	3990	4225	4473	4737	5016
21	3106	3289	3483	3688	3905	4135	4379
22	4118	4361	4617	4889	5177	5482	5805
23	2002	2120	2245	2377	2517	2665	2822
24	1388	1470	1556	1648	1745	1848	1957
25	1288	1364	1444	1529	1619	1715	1816
26	1567	1659	1757	1861	1970	2086	2209
27	2078	2200	2330	2467	2613	2767	2929
28	2723	2883	3053	3233	3424	3625	3839
29	1761	1865	1975	2091	2214	2344	2483
30	2970	3145	3330	3526	3734	3954	4187
31	2255	2388	2528	2677	2835	3002	3179
32	1906	2018	2137	2263	2396	2538	2687
33	3451	3654	3870	4097	4339	4594	4865
34	1618	1713	1814	1921	2034	2154	2281
35	2941	3114	3298	3492	3698	3915	4146
36	2189	2318	2454	2599	2752	2914	3086
37	3565	3775	3997	4233	4482	4746	5026
38	6206	6572	6959	7369	7803	8262	8749
39	4272	4524	4790	5072	5371	5687	6022
TOTAL	**109217**	**115651**	**122463**	**129677**	**137316**	**145404**	**153970**

Projected waste generation is calculated for various years for different category of waste based on the population and waste characteristics. Yearwise per day total waste generation is depicted in Figure 4.28. Wardwise waste generation details with physical composition are given in Table 4.25, 4.26 & 4.27 and in Fig 4.29, 4.30 & 4.31.

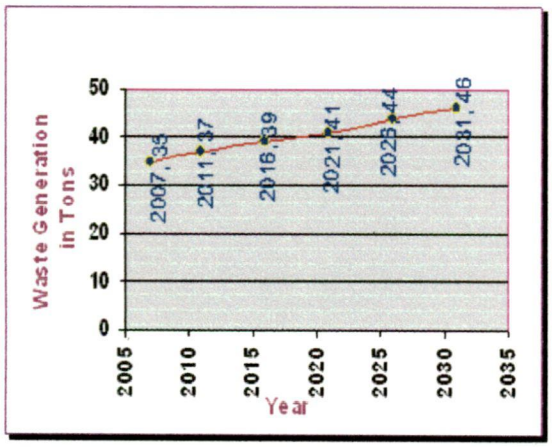


Fig: - 4.28:- Estimated daily waste Generation

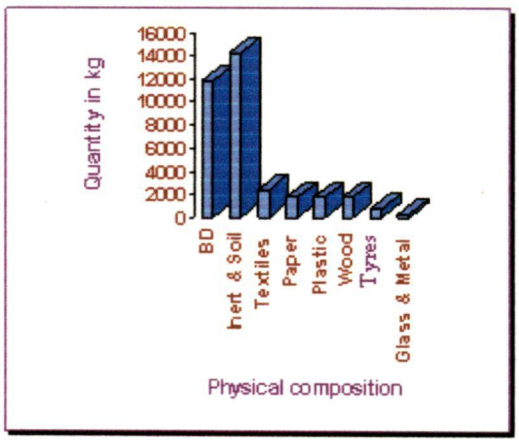


Fig: - 4.29:- Waste Generation in 2007

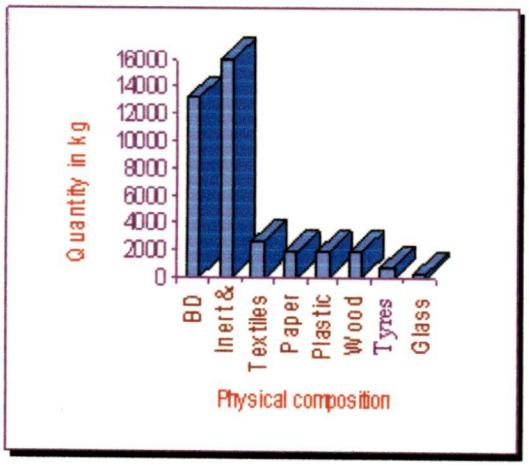


Fig: - 4.30:- Estimated Waste Generation in 2016

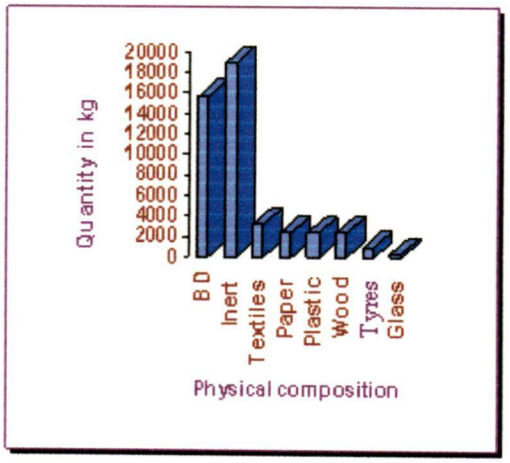


Fig: - 4.31:- Estimated Waste Generation in 2031

Table 4.25:- Waste generation in year 2007 & its Physical composition

Sl.no	BD (kg)	Inert & Soil (kg)	Textiles (kg)	Paper (kg)	Plastic (kg)	Wood (kg)	Tyres (kg)	Glass & Metal (kg)	Total (kg)
1	425	513	88	63	63	63	25	13	1253
2	324	390	67	48	48	48	19	10	954
3	382	460	79	56	56	56	22	11	1122
4	343	413	71	50	50	50	20	10	1007
5	269	324	55	40	40	40	16	8	792
6	222	268	46	33	33	33	13	7	655
7	195	235	40	29	29	29	11	6	574
8	275	332	57	40	40	40	16	8	808
9	375	452	77	55	55	55	22	11	1102
10	353	425	73	52	52	52	21	10	1038
11	255	308	53	38	38	38	15	8	753
12	444	536	91	65	65	65	26	13	1305
13	464	559	95	68	68	68	27	14	1363
14	411	496	85	61	61	61	24	12	1211
15	203	245	42	30	30	30	12	6	598
16	163	197	34	24	24	24	10	5	481
17	173	209	36	26	26	26	10	5	511
18	246	297	51	36	36	36	14	7	723
19	404	487	83	59	59	59	24	12	1187
20	389	469	80	57	57	57	23	11	1143
21	339	409	70	50	50	50	20	10	998
22	450	543	93	66	66	66	26	13	1323
23	219	264	45	32	32	32	13	6	643
24	152	183	31	22	22	22	9	4	445
25	141	170	29	21	21	21	8	4	415
26	171	206	35	25	25	25	10	5	502
27	227	274	47	33	33	33	13	7	667
28	297	359	61	44	44	44	17	9	875
29	192	232	40	28	28	28	11	6	565
30	324	391	67	48	48	48	19	10	955
31	246	297	51	36	36	36	14	7	723
32	208	251	43	31	31	31	12	6	613
33	377	455	78	55	55	55	22	11	1108
34	177	213	36	26	26	26	10	5	519
35	321	387	66	47	47	47	19	9	943
36	239	288	49	35	35	35	14	7	702
37	389	470	80	57	57	57	23	11	1144
38	678	818	140	100	100	100	40	20	1996
39	467	563	96	69	69	69	27	14	1374
TOTAL	**11932**	**14389**	**2457**	**1755**	**1755**	**1755**	**702**	**351**	**35096**

Table 4.26:- Estimated waste generation in year 2016 & its Physical composition

Ward. No	BD (kg)	Inert & Soil (kg)	Textiles (kg)	Paper (kg)	Plastic (kg)	Wood (kg)	Tires (kg)	Glass & Metal (kg)	Total (kg)
1	472	569	97	69	69	69	28	14	1387
2	359	433	74	53	53	53	21	11	1057
3	423	510	87	62	62	62	25	12	1243
4	380	458	78	56	56	56	22	11	1117
5	298	359	61	44	44	44	18	9	877
6	247	297	51	36	36	36	15	7	725
7	216	260	44	32	32	32	13	6	635
8	305	368	63	45	45	45	18	9	898
9	415	501	86	61	61	61	24	12	1221
10	391	471	80	57	57	57	23	11	1147
11	283	341	58	42	42	42	17	8	833
12	492	594	101	72	72	72	29	14	1446
13	514	620	106	76	76	76	30	15	1513
14	456	550	94	67	67	67	27	13	1341
15	226	272	46	33	33	33	13	7	663
16	181	218	37	27	27	27	11	5	533
17	192	232	40	28	28	28	11	6	565
18	273	329	56	40	40	40	16	8	802
19	448	540	92	66	66	66	26	13	1317
20	431	520	89	63	63	63	25	13	1267
21	376	454	77	55	55	55	22	11	1105
22	499	601	103	73	73	73	29	15	1466
23	242	292	50	36	36	36	14	7	713
24	168	203	35	25	25	25	10	5	496
25	156	188	32	23	23	23	9	5	459
26	190	229	39	28	28	28	11	6	559
27	252	303	52	37	37	37	15	7	740
28	330	398	68	48	48	48	19	10	969
29	213	257	44	31	31	31	13	6	626
30	360	434	74	53	53	53	21	11	1059
31	273	329	56	40	40	40	16	8	802
32	231	278	48	34	34	34	14	7	680
33	418	504	86	61	61	61	25	12	1228
34	196	236	40	29	29	29	12	6	577
35	356	430	73	52	52	52	21	10	1046
36	265	320	55	39	39	39	16	8	781
37	432	521	89	63	63	63	25	13	1269
38	752	906	155	111	111	111	44	22	2212
39	517	624	107	76	76	76	30	15	1521
TOTAL	13227	15950	2723	1945	1945	1945	778	389	38902

Table 4.27:- Estimated waste generation in year 2031 & its Physical composition

Ward. No	BD (kg)	Inert & Soil (kg)	Textiles (kg)	Paper (kg)	Plastic (kg)	Wood (kg)	Tires (kg)	Glass & Metal (kg)	Total (kg)
1	560	675	115	82	82	82	33	16	1645
2	426	514	88	63	63	63	25	13	1255
3	502	606	103	74	74	74	30	15	1478
4	451	544	93	66	66	66	27	13	1326
5	354	427	73	52	52	52	21	10	1041
6	293	353	60	43	43	43	17	9	861
7	256	309	53	38	38	38	15	8	755
8	362	437	75	53	53	53	21	11	1065
9	493	595	102	73	73	73	29	15	1453
10	464	560	96	68	68	68	27	14	1365
11	336	405	69	49	49	49	20	10	987
12	585	705	120	86	86	86	34	17	1719
13	610	736	126	90	90	90	36	18	1796
14	542	653	111	80	80	80	32	16	1594
15	268	323	55	39	39	39	16	8	787
16	215	259	44	32	32	32	13	6	633
17	228	275	47	34	34	34	13	7	672
18	324	391	67	48	48	48	19	10	955
19	532	641	109	78	78	78	31	16	1563
20	512	617	105	75	75	75	30	15	1504
21	447	539	92	66	66	66	26	13	1315
22	592	714	122	87	87	87	35	17	1741
23	288	347	59	42	42	42	17	8	845
24	200	241	41	29	29	29	12	6	587
25	185	223	38	27	27	27	11	5	543
26	225	272	46	33	33	33	13	7	662
27	299	360	62	44	44	44	18	9	880
28	392	472	81	58	58	58	23	12	1154
29	253	305	52	37	37	37	15	7	743
30	427	515	88	63	63	63	25	13	1257
31	324	391	67	48	48	48	19	10	955
32	274	331	56	40	40	40	16	8	805
33	496	598	102	73	73	73	29	15	1459
34	233	281	48	34	34	34	14	7	685
35	423	510	87	62	62	62	25	12	1243
36	315	380	65	46	46	46	19	9	926
37	513	618	106	75	75	75	30	15	1507
38	892	1076	184	131	131	131	52	26	2623
39	614	741	126	90	90	90	36	18	1805
TOTAL	15705	18938	3233	2310	2310	2310	924	462	46192

4.4.2 Storage of Waste

(i) ***For domestic wastes***

Use of a non-corrosive container with lid is proposed for the storage of food/biodegradable/wet waste. A container of 15 litre (0.015 cu.m) capacity for a family of five members would ordinarily be adequate. The wastes shall be stored in two bins one for Bio Degradable & other for Non Bio Degradable.

(ii) ***Slums***

In slums, community bins of suitable sizes ranging from 40 to 100 litres (0.04 to 0.1 cu.m.) capacity will be placed at suitable locations to facilitate the storage of waste generated by them.

(iii) ***Hotels and Restaurants***

They shall store their waste on-site in sturdy containers of not more than 100 Litre (0.1 cu.m) capacity. The container should have appropriate handle or handles on the top or side and rim at the bottom for ease of emptying and unloading.

(iv) ***Marriage Halls***

Suitable containers of 2.5 cu.m capacity shall be provided by these establishments at their cost and the sites of their placement should be finalized in consultation with local body to facilitate easy collection of waste.

(v) ***Vegetable/Fruit Markets***

Local body itself will provide large size containers of 2.5 cu.m capacity with lid for storage of market waste at suitable locations within the markets on full cost/partial cost recovery.

(vi) ***Fish/Meat Markets***

They shall keep their waste within their premises in sturdy containers (of size not exceeding 100 litres i.e. 0.1 cu.m) having lid, handle on the top or on the sides and rim at the bottom of the container with adequate spare capacity to handle expected loads.

(vii) *Hospitals/Nursing Homes*

They shall keep their waste in colour-coded bins or bags as per the directions of the Govt. of India, Ministry of Environment Bio-medical Waste (Management & Handling) Rules 1998, and follow the directions of Central Pollution Control Boards and State Pollution Control Boards from time to time for the storage of biomedical waste and the hospitals which are not sending their waste through recognized body shall be asked to send their waste to proper place.

(viii) *Construction and Demolition Wastes*

No person shall dispose of construction waste or debris on the streets, public spaces, footpaths or pavements. The owner of the establishments should be provided the adequate facility for storing of such wastes at their own costs in the site premises. PMC shall collect the waste separately.

(ix) *Recyclable wastes*

It is essential to save the recyclable waste material going to the waste processing and disposal sites and using landfill space. Profitable use of such material could be made by salvaging it at source for recycling. This will save national resources and also save the cost and efforts to dispose of such wastes. This can be done by forming a habit of keeping recyclable waste material separate from food wastes, in a separate bin at the source of waste generation. This recyclable waste can be handed over to the waste collectors (rag pickers) at the doorstep. The local body may give priority to the source segregation of recyclable wastes by shops, establishments and the household. The details of recyclable waste generations are shown in Fig 4.32 & Table 4.28. The economic worth of recyclables that can earn considerable revenue to the municipality is worked out based on the present market value of each recyclables and its possible revenue to the PMC per day is given in Table 4.29.

Table 4.28:- Recyclable waste generation per day (kg)

Year	Paper	Plastic	Wood	Tyres	Glass & Metal
2007	1755	1755	1755	702	351
2016	1945	1945	1945	778	389
2031	2310	2310	2310	924	462

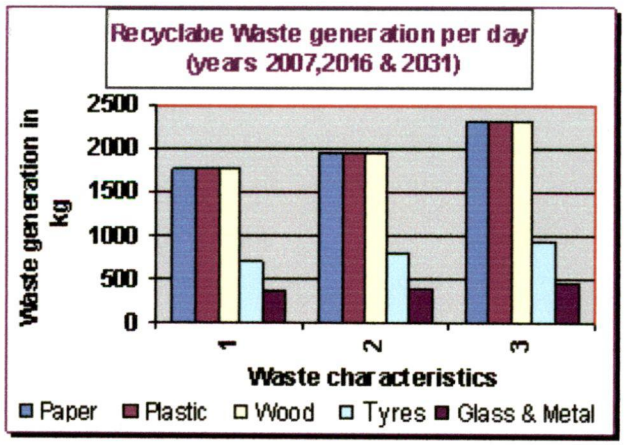


Fig: - 4.32 Recyclable Waste Generation

Table 4.29:- Market values of the Recyclables and Anticipated revenue per day (2007)

Sl.No	Items	Market value Per kg in Rs	Recyclables from MSW in kg	Total revenue from recyclables in Rs
1	Paper	5.00 to 10.00	1755	8775
2	Plastic	6.00 to 12.00	1755	10530
3	Wood	1.50 to 5.00	1755	2633
4	Tyres	3.00 to 6.00	702	2106
5	Glass & Metal	5.00 to 10.00	351	1755
			Total	25799

It is very difficult to achieve 100% collection of recyclables from the entire waste in the beginning due to the fact that there is no segregation of waste; also the rag pickers are collecting the valuable recyclable materials. Therefore assuming a collection of recyclable materials as 40% by segregation (Senthilkumar et.al, 2007), it is estimated that the worth of recyclables present in the MSW of Pudukkottai town is Rs 10320/day.

(x) *Provision of litterbins on streets, public places etc*

To ensure that streets and public places are not littered with waste materials such as used cans, cartons of soft drinks, used bus tickets, wrappers of chocolates or empty cigarette cases.

Litter bins shall be provided on important streets like sathyamoorthy road, east main street, south main street, west main street and north main street and also markets, public places, bus and railway stations, large commercial complexes, etc. at a distance ranging from 25 to 250 metres. Such facilities of litterbins can be created at no cost to local body by involving the private sector and giving them advertisement rights on the bins for a specified period or by allowing them to put their names on the bins as a sponsor. This location shall be reviewed time to time.

4.4.3 Primary collection of Wastes

Primary collection system is necessary to ensure that waste stored at source is collected regularly and it is not disposed off on the streets, drains, water bodies, etc.

(i) *Collection from Households*

Doorstep collections of waste through handcarts is in operation by PMC. The available pushcarts are 144 numbers at the capacity of 0.40cu.m (0.9m x 0 .75m x 0.60m) each. In place of this use handcarts having 4 detachable containers of capacity of 0.06 cu.m each are proposed. The polyethylene container having size of 390 mm x 320 mm at the top and 320 mm x 250 mm at bottom with overall height of 600 mm will be used for transferring solid waste to the community waste storage sites. The requirement is computed for the year 2016 as given in Table 4.30. There is another 1297numbers of containers and 180numbers of handcarts are required for the collection of waste from households to waste storage containers. Community bins for collection waste from authorized/unauthorized slums are proposed.

(ii) *Collection of wastes from Societies/Complexes*

It may be made compulsory for the management of the societies, complexes and multi-storied builders, to keep community bins or containers in which dry and wet waste must be separately stored by there residents. Such bins should be placed at easily approachable locations to facilitate convenient collection by the municipal staff or private party.

(iii) *Collection of Duly Segregated Recyclable/Non-bio-degradable Waste*

Recyclable waste has a value. Rag pickers are exposed to health risks as they put their bare hands in contaminated waste. This system can be improved by introducing a system of collecting recyclable waste from the doorsteps changing the roll of rag pickers to that of waste collectors. This informal sector could thus be organized through NGOs, upgraded and given an opportunity to earn their living through doorstep collection of unsoiled recyclable waste. NGOs to be involved to organize the rag pickers and convert them into doorstep waste-collectors to improve their quality of life and to reduce their health risk. This will also increase their income levels.

Table 4.30:- Containers and Handcarts required in 2016

Ward. No	Waste Generation in cu.m	Containers in Nos	Handcarts in Nos
1	2.77	46	12
2	2.11	35	9
3	2.49	41	10
4	2.24	37	9
5	1.75	29	7
6	1.45	24	6
7	1.27	21	5
8	1.79	30	7
9	2.44	41	10
10	2.3	38	10
11	1.67	28	7
12	2.9	48	12
13	3.02	50	13
14	2.68	45	11
15	1.33	22	6
16	1.07	18	4
17	1.13	19	5
18	1.61	27	7
19	2.63	44	11
20	2.54	42	11
21	2.21	37	9
22	2.93	49	12
23	1.43	24	6
24	0.99	16	4
25	0.92	15	4
26	1.12	19	5
27	1.48	25	6
28	1.94	32	8
29	1.25	21	5
30	2.12	35	9
31	1.61	27	7
32	1.36	23	6
33	2.46	41	10
34	1.15	19	5
35	2.1	35	9
36	1.56	26	6
37	2.54	42	11
38	4.42	74	18
39	3.04	51	13
TOTAL	77.81	1297	324

(iv) *Collection of bio-medical waste*

Collection of bio-medical waste shall be done in accordance with the rules/directions contained in the Ministry of Environment & Forests, Govt. of India Notification dated 20th July 1998 as the liability for safe disposal of biomedical waste is on such waste producer and the local body as such is not directly responsible to provide any service.

(v) *Collection of hotel and restaurant waste*

Hotels and restaurants may make their own arrangements for collection of waste through their own association, or PMC may extend help in primary collection of such waste by deploying their own manpower and machinery for door step collection of such waste on full-cost-recovery basis. The cost recovery may be planned according to the classification of hotels/ restaurants made on the above basis and decided in consultation with them.

(vi) *Collection of waste from Vegetable, fruit, meat and fish markets etc.*

Large containers of capacity of 2.5 cu.m kept in the fruit and vegetable markets should be removed during non-peak hours and the waste from meat and fish markets should be collected through closed pick-up vehicle service by engaging a contractor, or departmentally as deemed expedient by the local body.

(vii) *Collection of waste from Marriage halls, Community halls etc.*

The separate arrangement shall be made for collection of waste from marriage halls, community halls, etc. daily on a full-cost recovery basis. This service may be provided preferably through a contractor or departmentally as the local body deem fit. The charges shall be levied.

(viii) *Collection of construction and demolition waste*

PMC shall prescribe the cess for the collection, transportation and disposal of construction waste and debris and notify the same to the people. Such amount may be deposited at the time when the building permission is being sought.

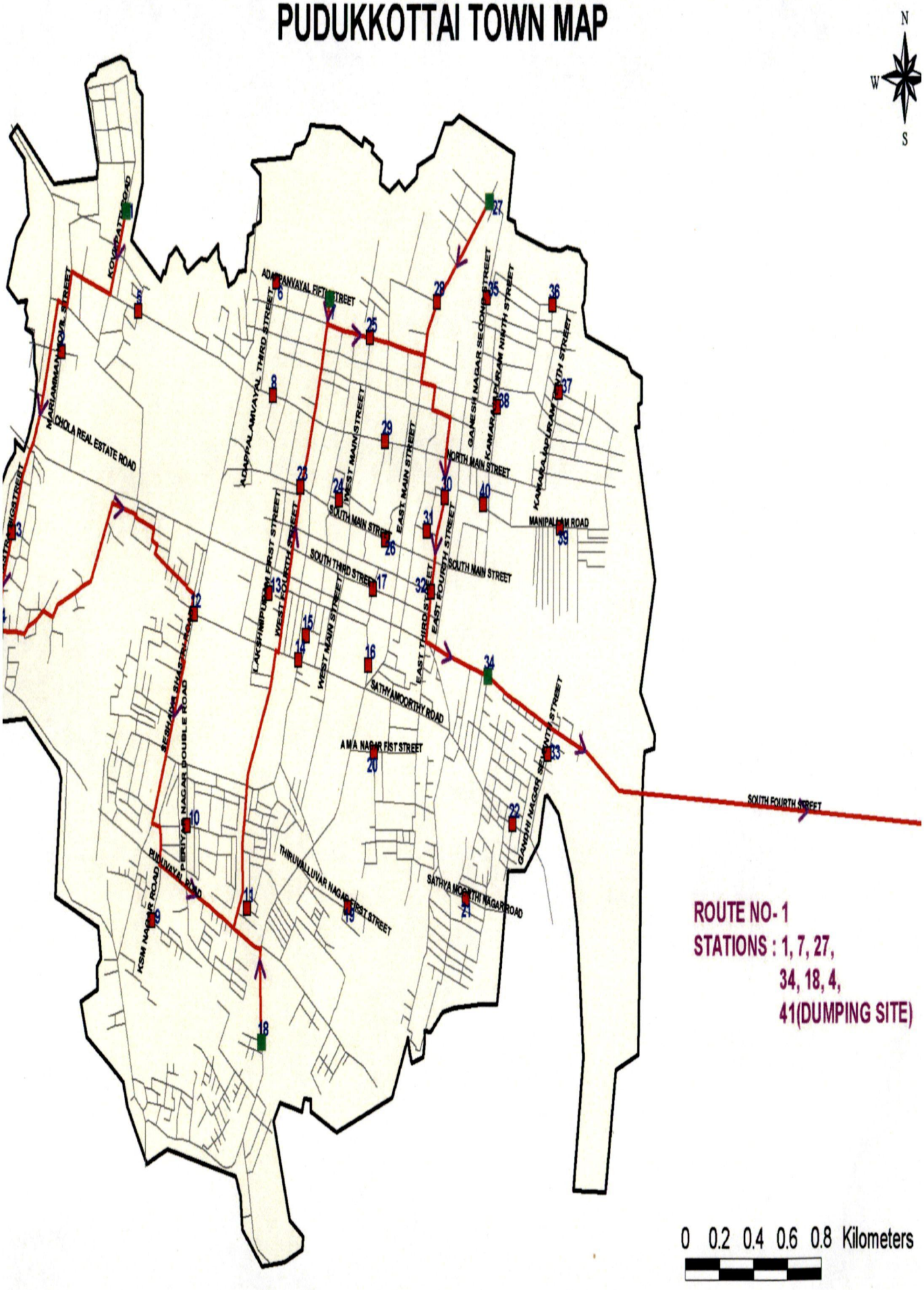
4.4.4 Waste storage Containers

In Pudukkottai town, open waste storage sites are inefficient, unhygienic and unscientific, posing a serious threat to the public health and environment. This waste also necessitates multiple handling till it is finally disposed off. Waste Storage containers should be at a distance not exceeding 250 meters from the place of work of the sweepers. The density of Indian waste is generally 500kg/cu.m (Municipal Solid Waste Management manual, 2000). So containers of 1cu.m volume would be required per 500 kilograms of waste depending on the quantity of waste expected to be received at the waste storage depot each day. There are 40 dumper placer bins of 2.5cu.m capacity of each is required for Pudukkottai town. And also additional 4nos of dumper placer bins required for replacement of the waste filled bins.

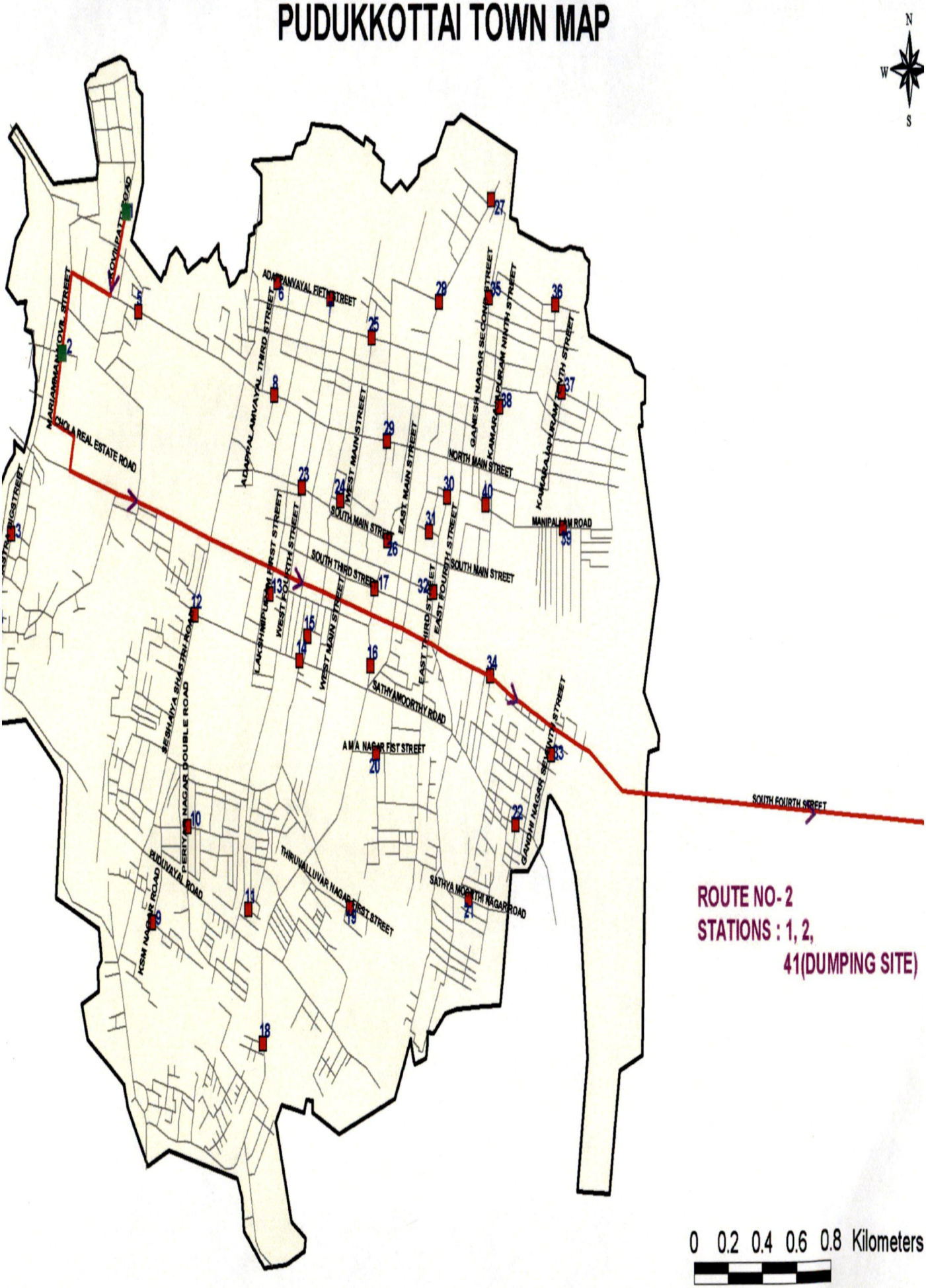
4.4.5 Transportation of Wastes

PMC have limited fleet of vehicles and most of them are old necessitating frequent repairs with the result the transportation of waste does not take place regularly. Manual loading should be discouraged and phased out expeditiously and replaced by direct lifting of containers through hydraulic system or direct loading of waste into transport vehicles. For Pudukkottai town 2nos of dumper placer is required to transfer all the wastes from waste storage containers to dumping yard. The carrying capacity of each dumper placer is 2nos of 2.5m^3 containers. This is the suitable vehicle for the condition and width of the road in Pudukkottai town. The transportation routes have been designed in network analysis using with Geographic Information System (GIS) software. The optimal route (on the boundary of area) and shortest routes from waste storage points to disposal sites are analysed with this software. The route maps are shown in plate nos 4.1 to 4.21 and the details are given in the Annexure III. The total distance covered from all the waste storage points to dumping yard is calculated as 178km up and down. As per the calculation requirement of diesel is 36 litres per day.

PUDUKKOTTAI TOWN MAP



PUDUKKOTTAI TOWN MAP



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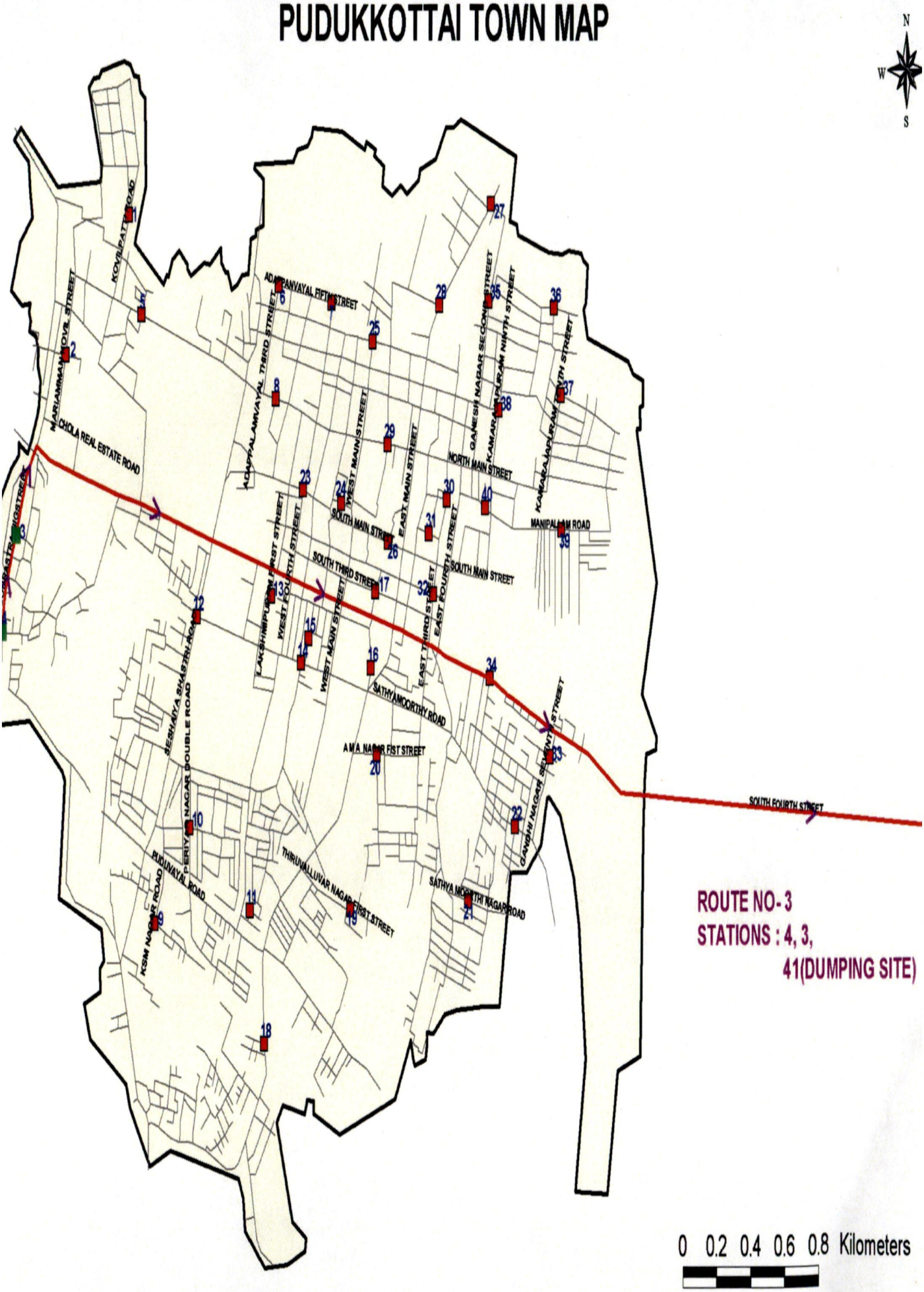

PUDUKKOTTAI TOWN MAP

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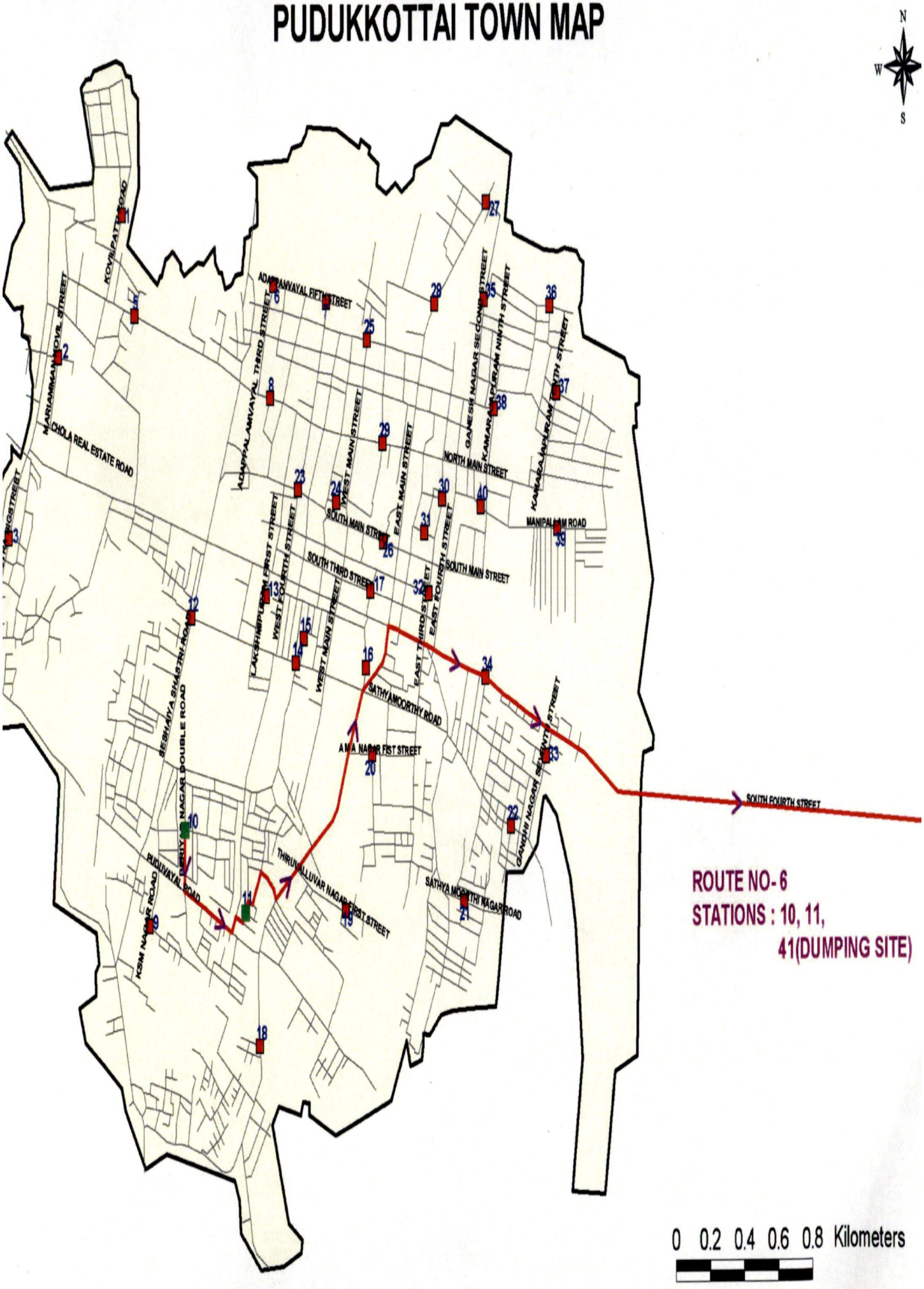
PUDUKKOTTAI TOWN MAP



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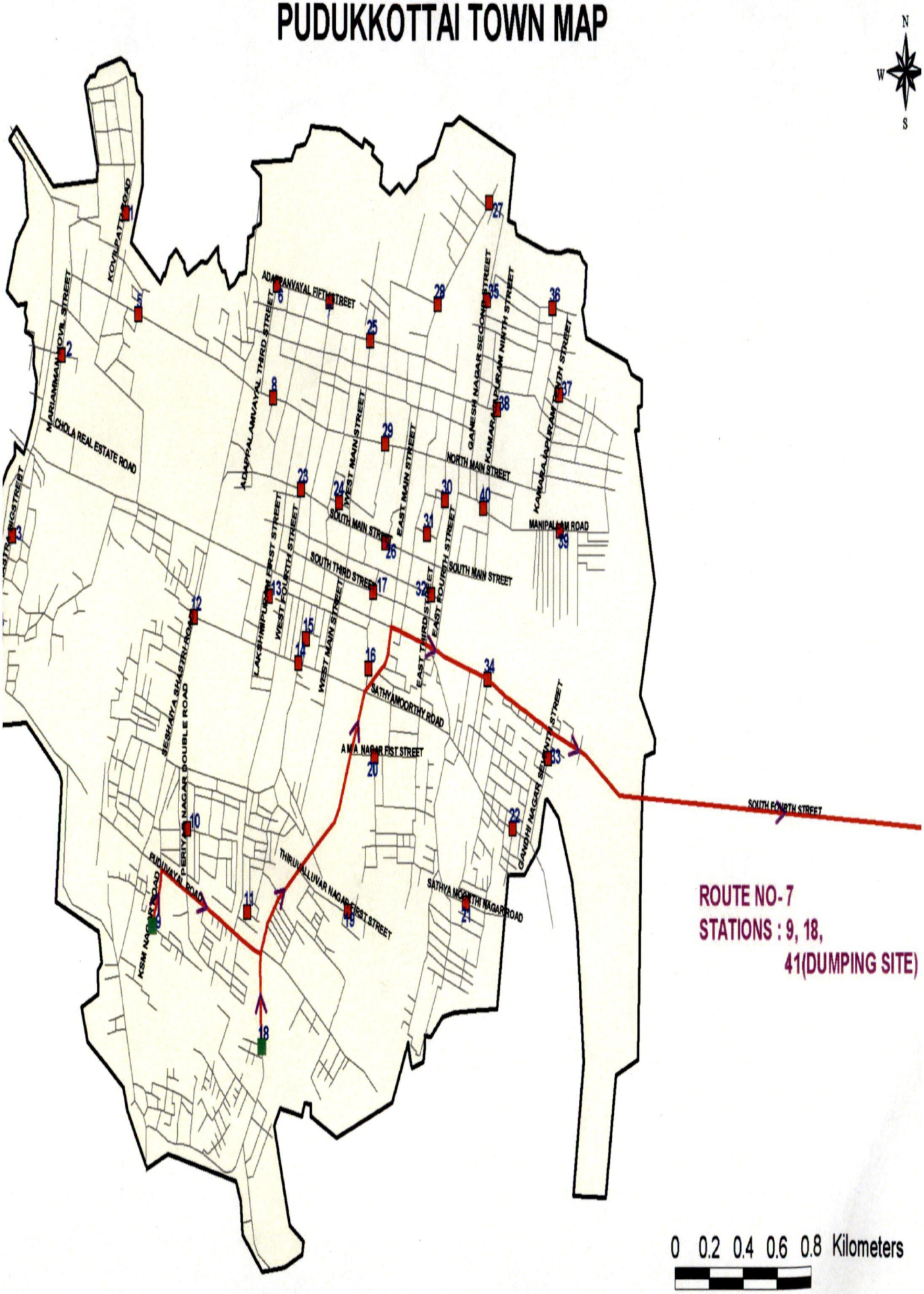

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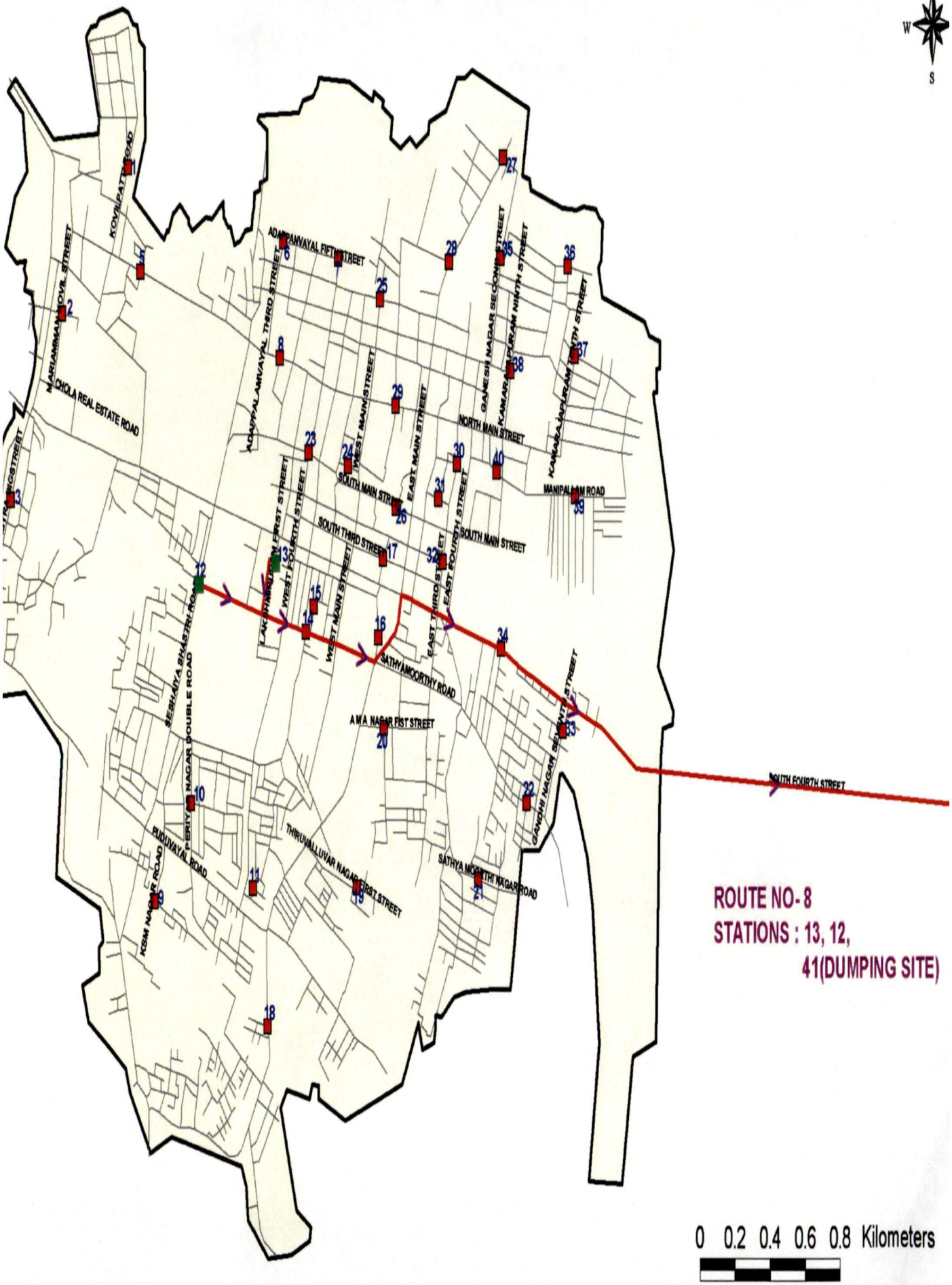

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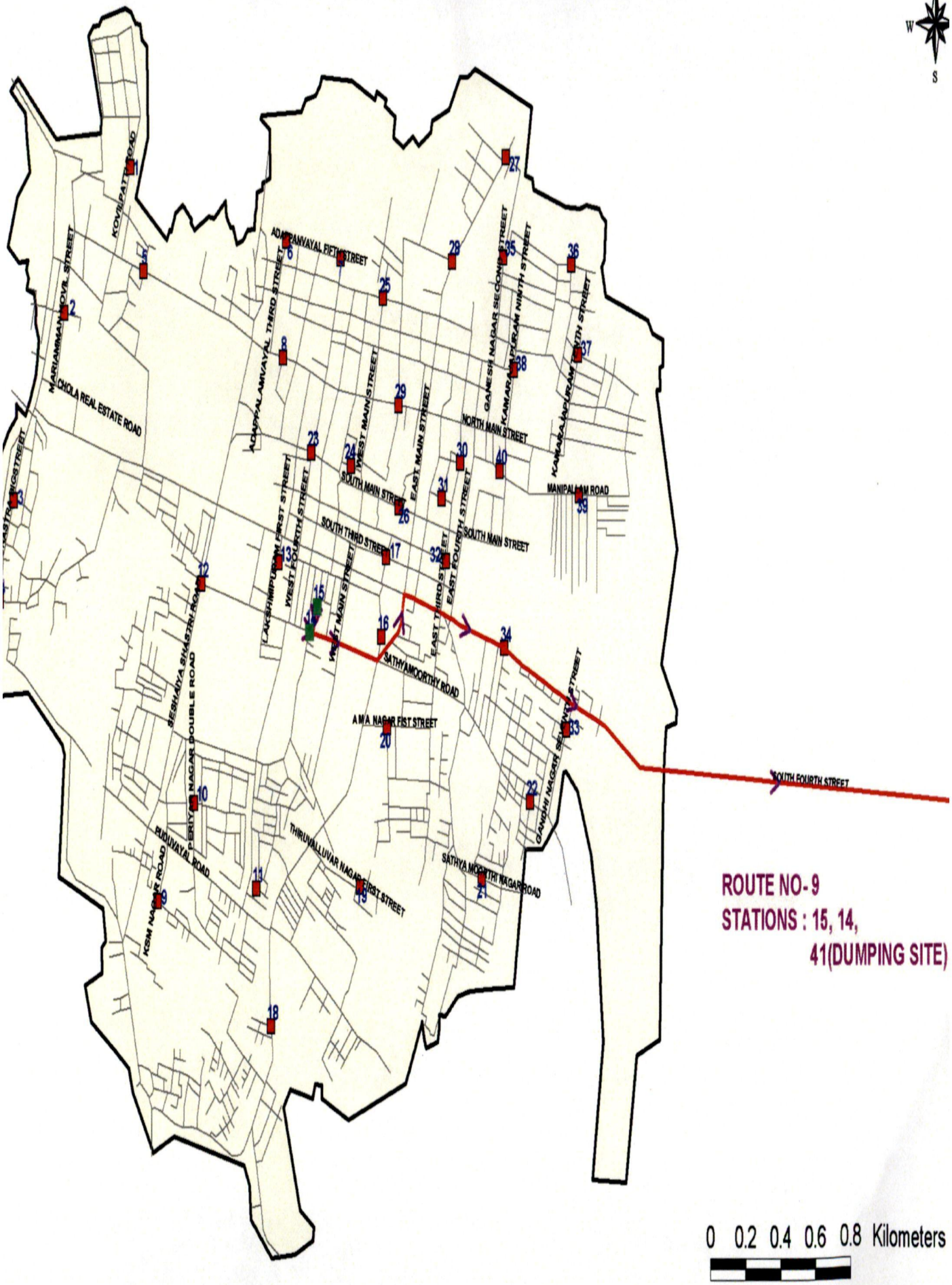

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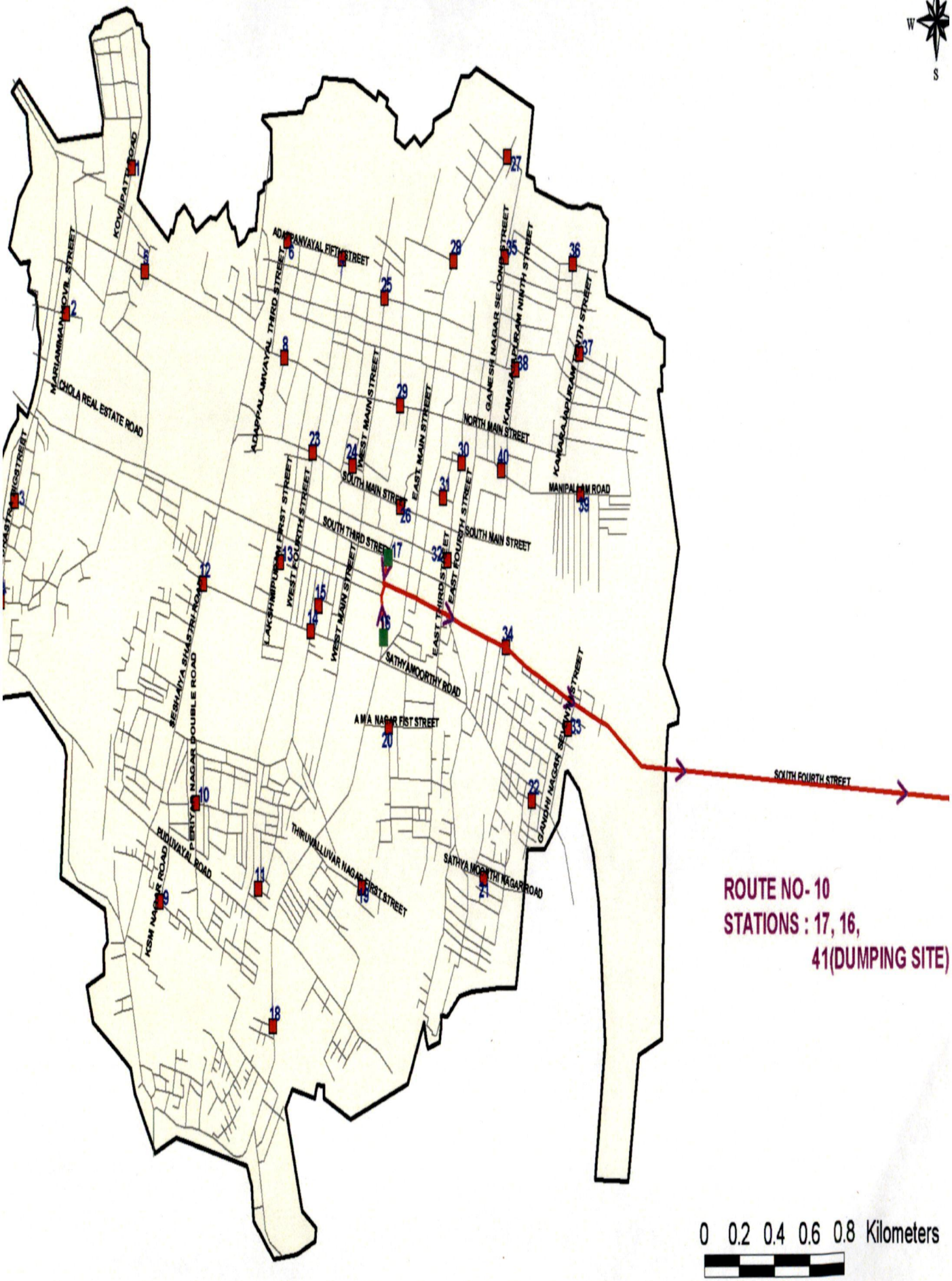

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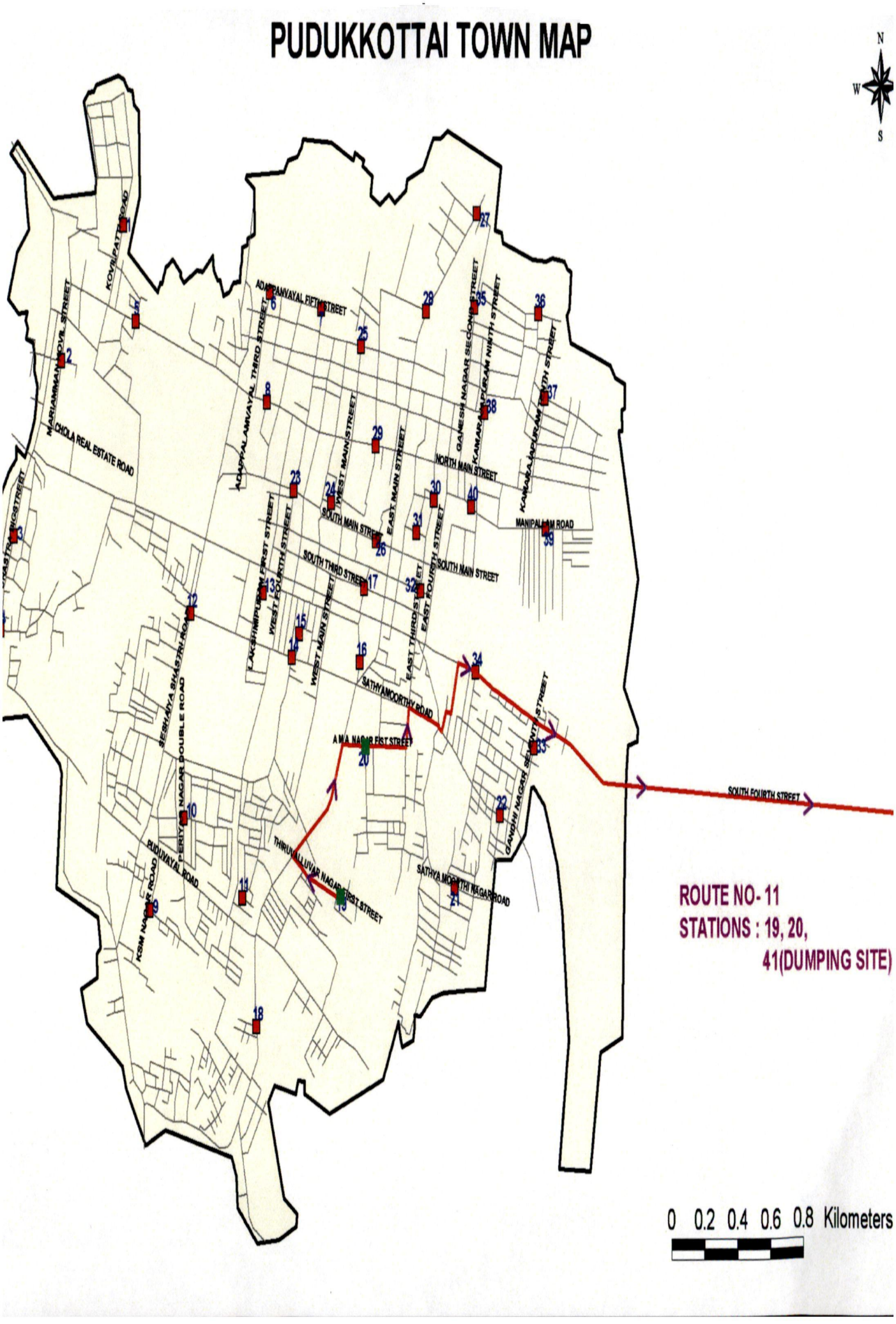

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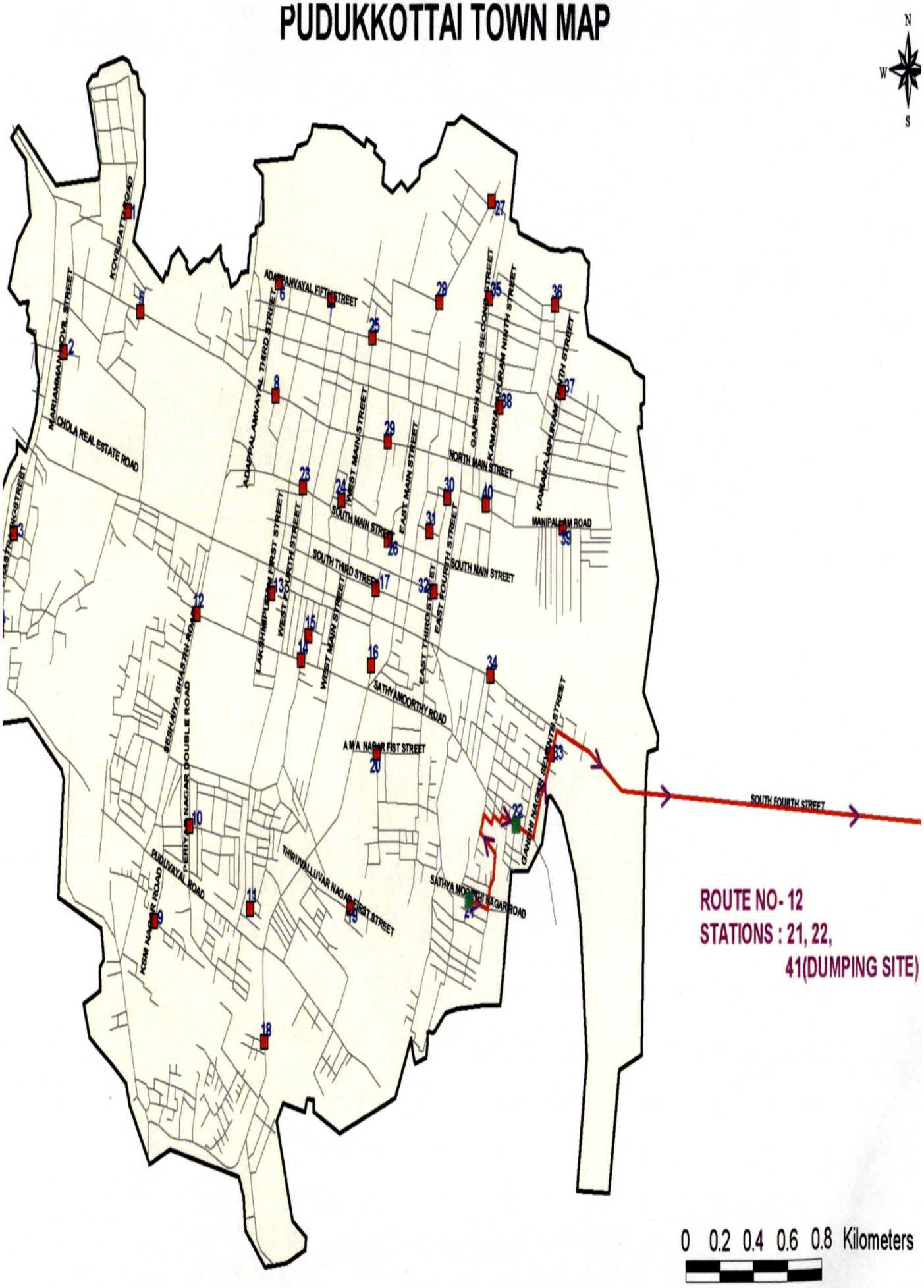

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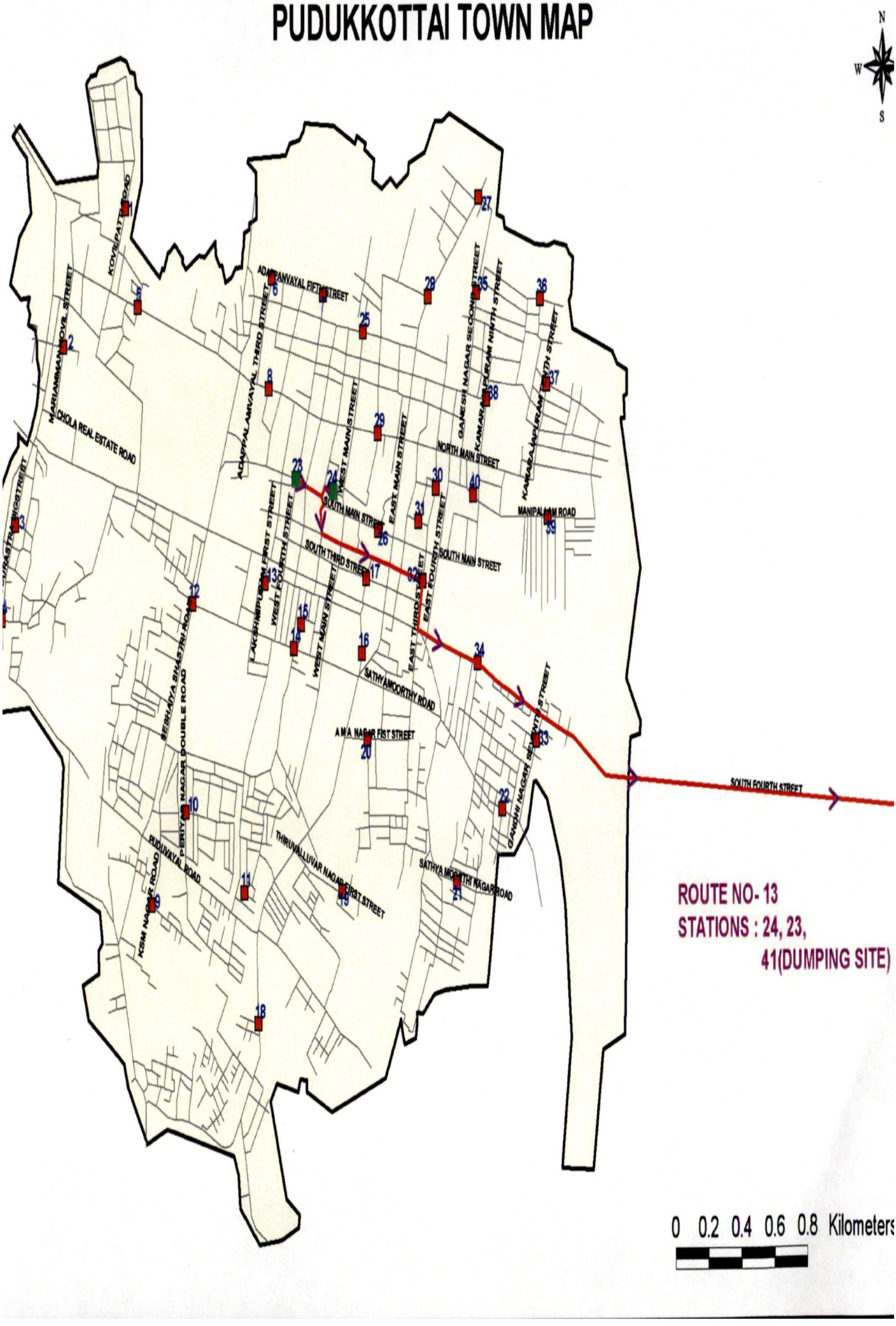

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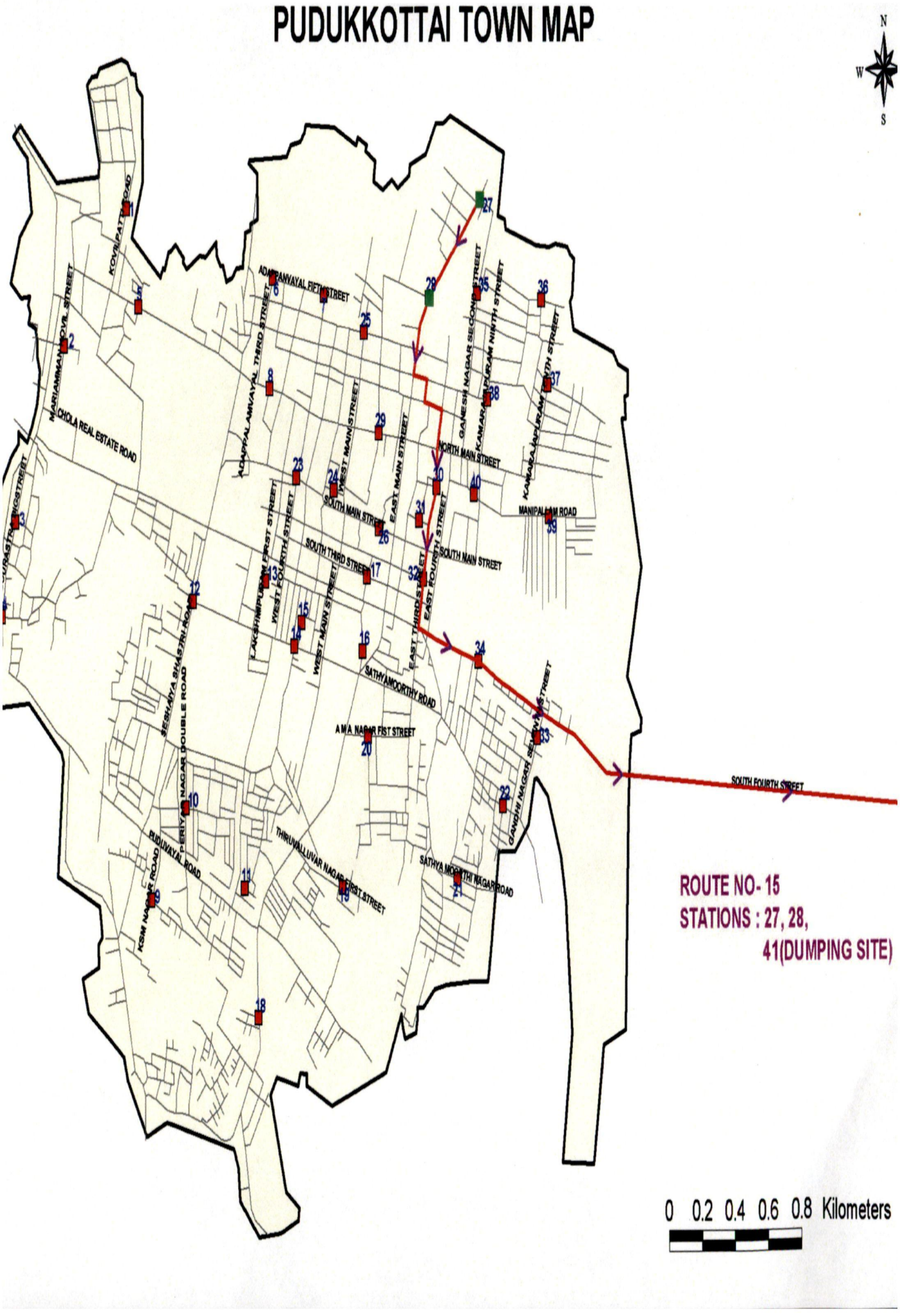

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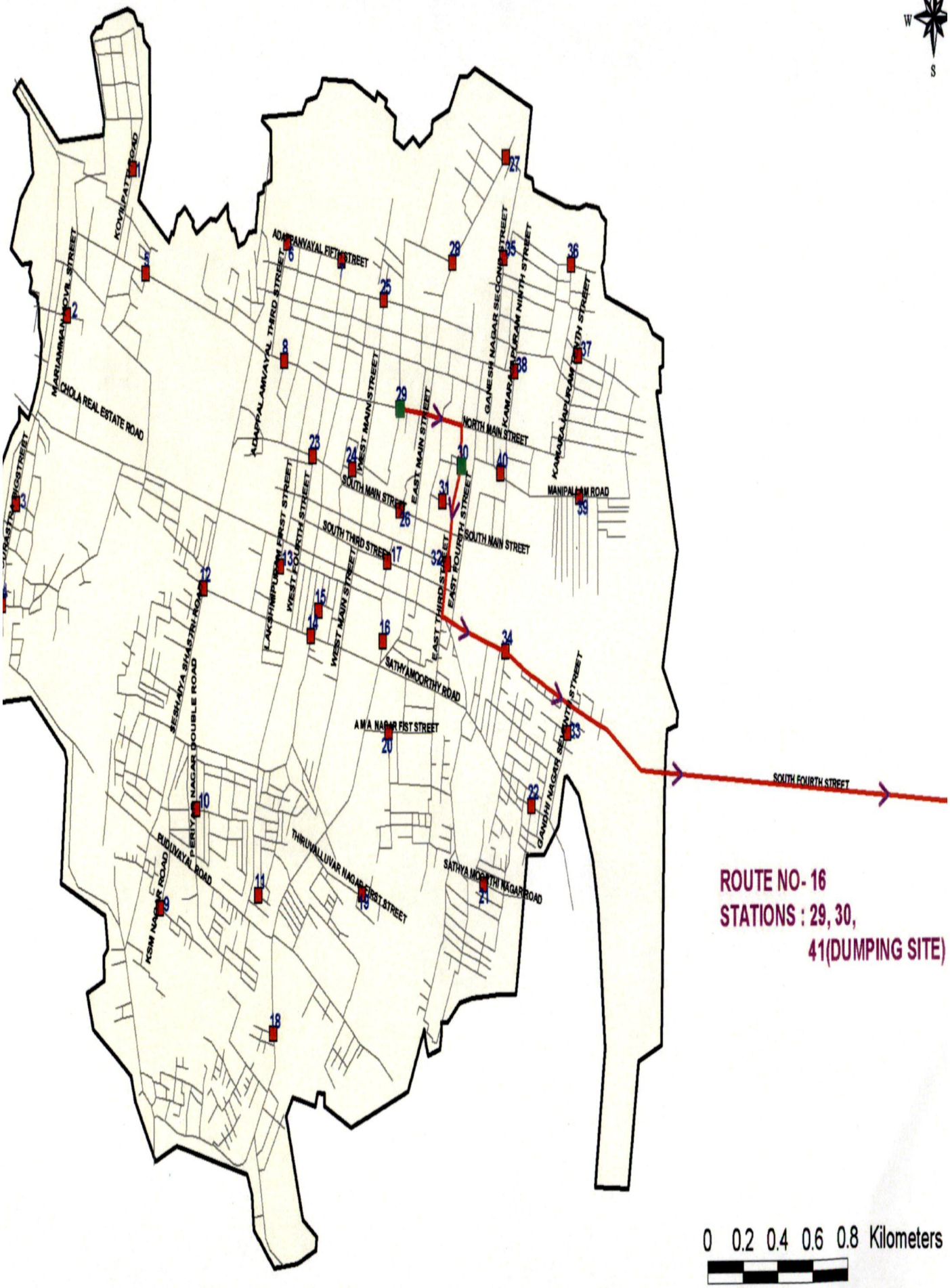

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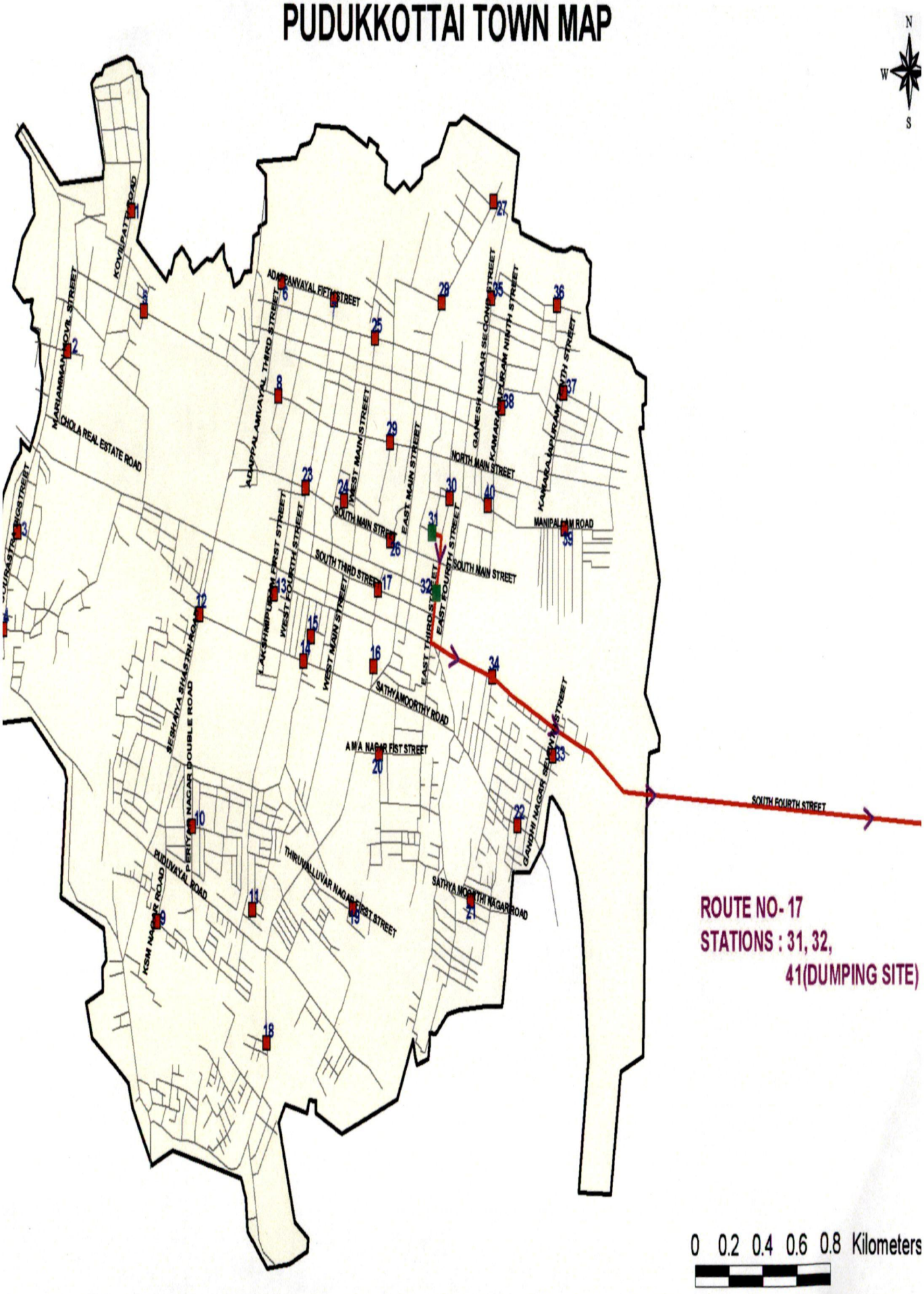

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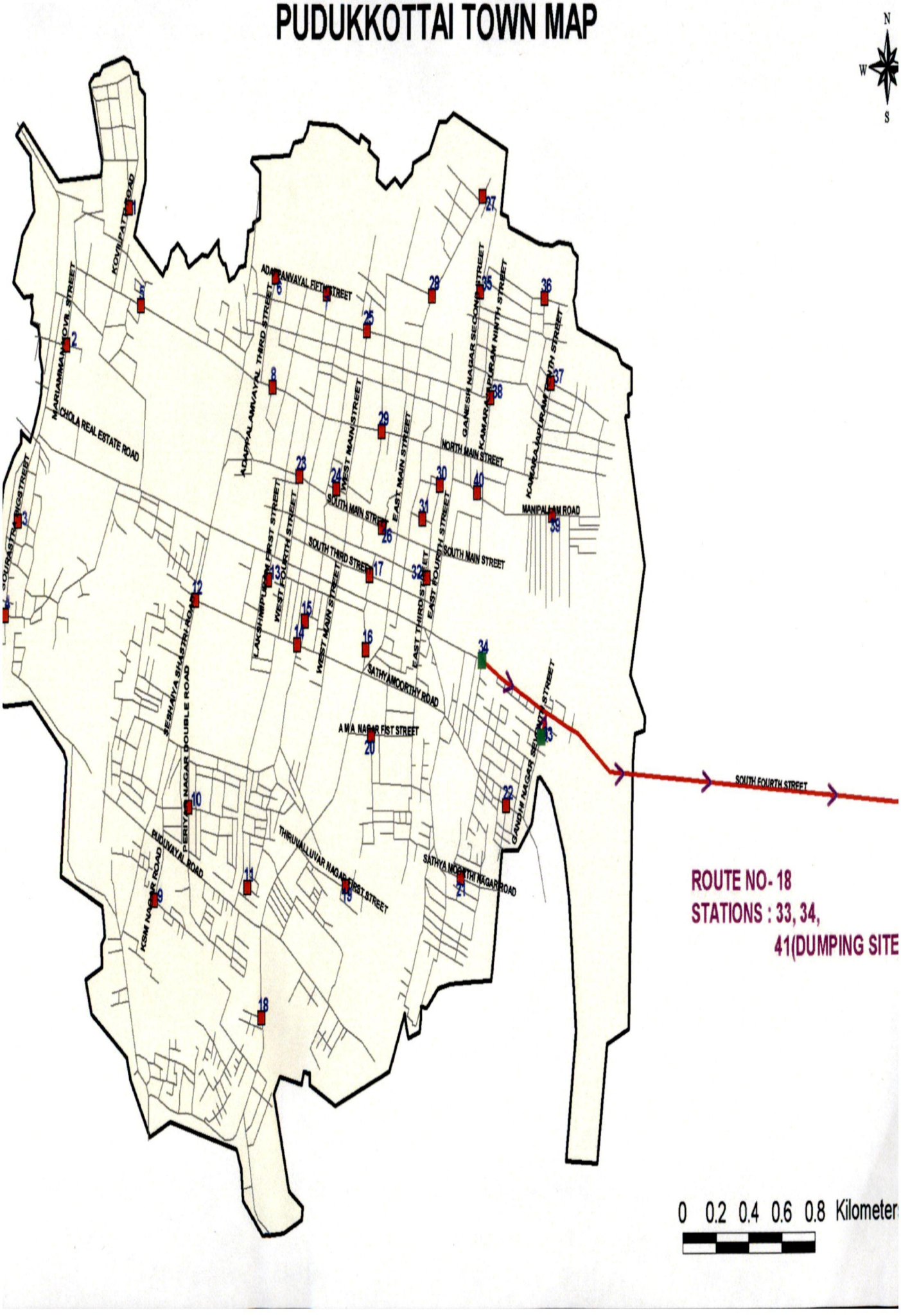

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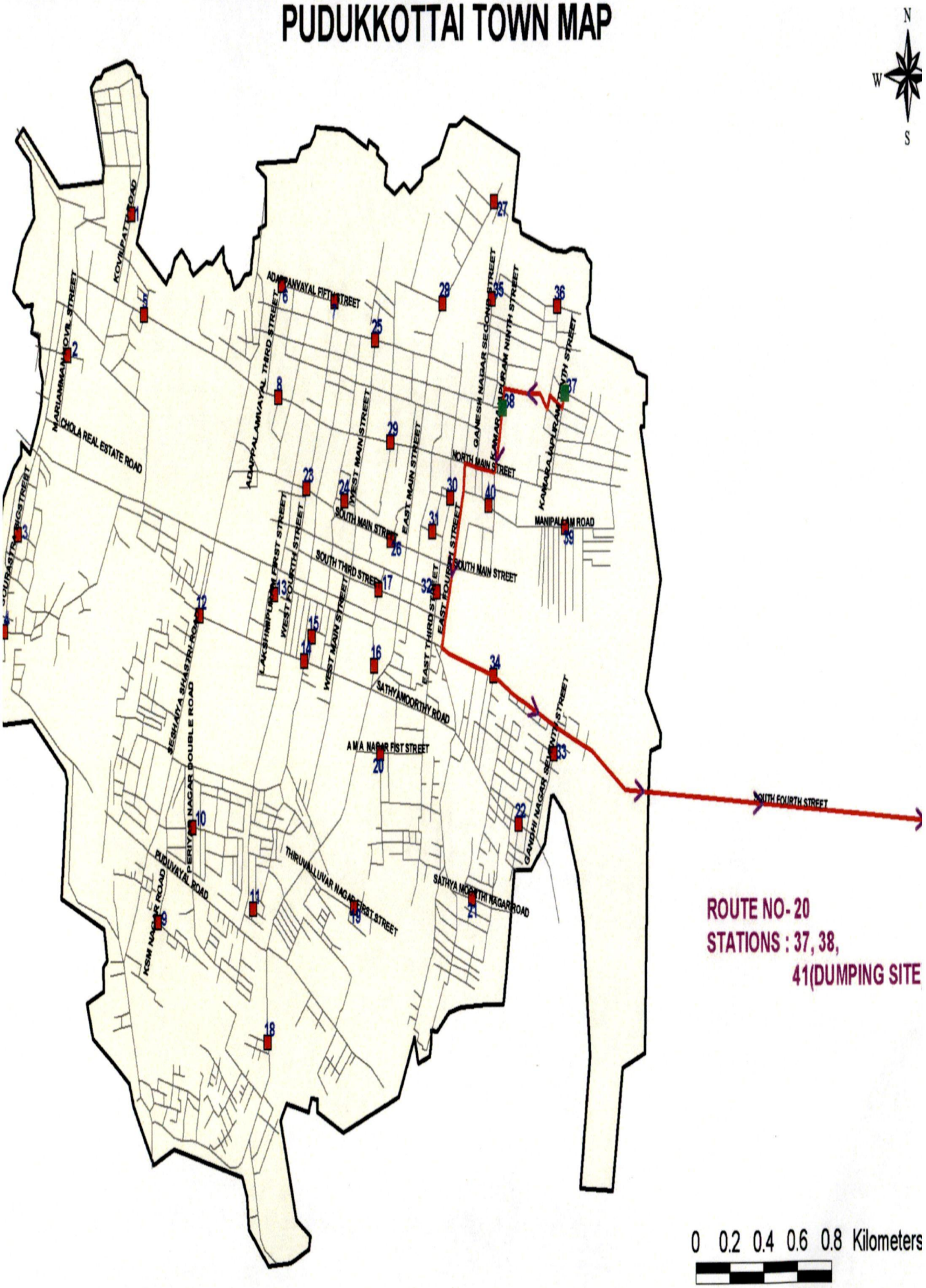

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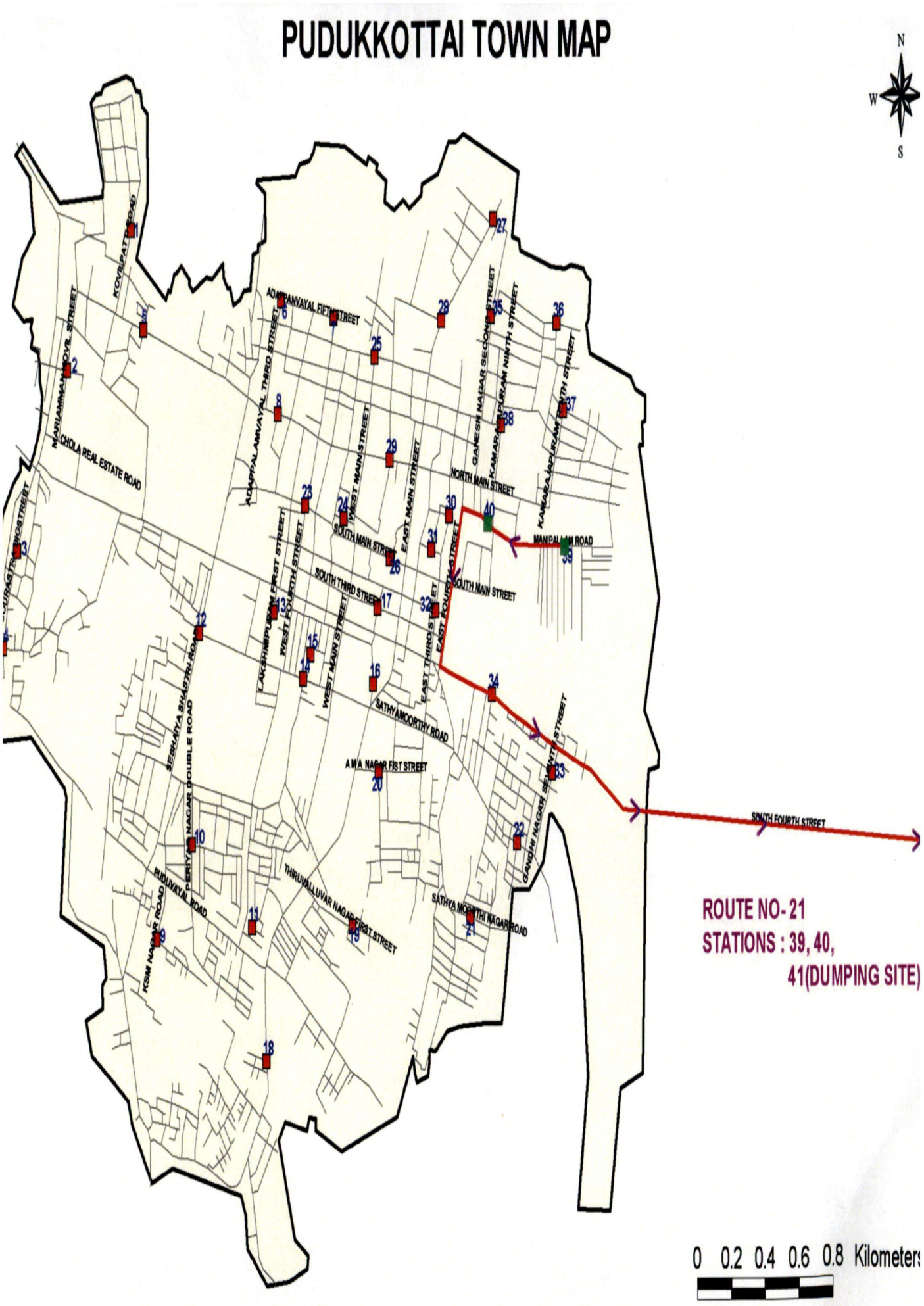


4.4.6 Treatment and disposal of solid wastes

For biodegradable waste aerobic composting, anaerobic composting and vermi composting of waste is proposed.

4.4.6.1 *Aerobic Composting*

It is done as windrow composting. The size of the windrow to be 3m long x 2m wide x 1.5m high, with a total volume not exceeding 9.0 cu.m. The windrow would be turned on 6th & 11th days outside to the centre to destroy insect's larvae and to provide aeration. On 16th day, windrow would be broken down and passed through manually operated rotary screens of about 25mm square mesh to remove the oversize contrary material. The screened compost is stored for about 30 days in heaps about 2m wide x 1.5m high and up to 20m long to ensure stabilization before sale. Various types of equipment such as front end loaders are required for turning of windrows. At the end of the 3 to 4 weeks period, the material is known as green or fresh compost wherein the cellulose has not been fully stabilized. It is hence stored in large sized windrows for 1-2 months either at the plant or the farms. At the end of the storage period, it is known as ripe compost. The area requirement for composting plant is about 2acres.

(i) *Properties of Compost*

The compost prepared from MSW should be black brown or at least black in colour. It should be crumbly in nature with an earthy odour. The pH should be neutral though slightly acidic or alkaline pH within the range of 6.5 to 7.5. The Nitrogen, Phosphorous and Potassium (NPK) contents should be more than one percent each. The C/N ratio should be in between 15 to 20. For safe application of compost, the standards are given in Table 4.31.

Table 4.31:- Standards for Compost

parameter	Maximum acceptable concentration (ppm)
Arsenic	20
Cadmium	20
Chromium	300
Copper	500
Lead	500
Mercury	10
Zinc	100

4.4.6.2 *Anaerobic composting*

For anaerobic composting a fully automatic MSW anaerobic composting processing plant is proposed. The mechanical separation of non-degradable materials like plastics is the specialty of this process, which makes it highly feasible in comparing to other projects. The process diagram is given in Fig 4.40 as per the National Small Industries Corporation (Govt. of India enterprises), Cochin. National Small Industries Corporation, Cochin suggested that from 40 tons of solid waste 10 tons of compost bio manure is produced per day. The area requirement of plant is 2- 3 acres. The main attraction of biomethanation technology is the energy-generating gas during process of treatment, which is a good source of revenue, so that they prove to be commercially viable.

(i) ***The approximate power generation calculation***

In bio-chemical conversion, only the biodegradable fraction of the organic matter can contribute to the energy output:

Total waste quantity: 12 (tons) Bio degradable

Total Organic / Volatile Solids: VS = 52 %,

Organic bio-degradable fraction: approx. 66% of VS = 0.34 x 12

Typical digestion efficiency = 60 %

Typical bio-gas yield: B (m^3) = 0.80 m3 / kg. of

VS destroyed = 0.80 x 0.60 x 0.34 x 12 x1000 = 1958m^3

Calorific Value of bio-gas = 5000 kcal/m^3 (typical)

Energy recovery potential (kWh) = 1958 x 5000 / 860 = 11384 kWh

Power generation potential (kW) = 110384/24 = 474 kW

Typical Conversion Efficiency = 30%

Net power generation potential (kW) = 474 x 0.30 = 142 kW

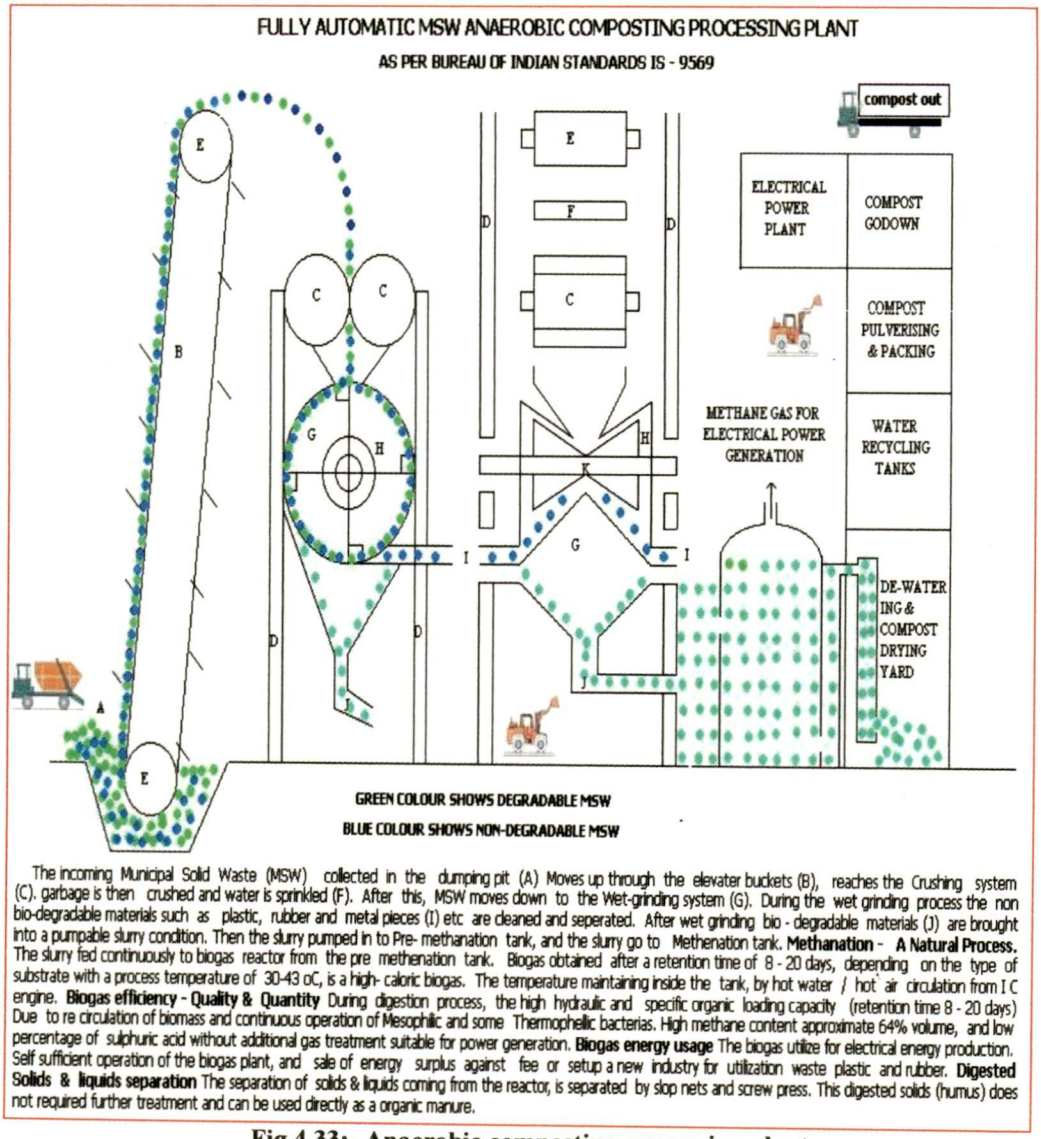


Fig 4.33:- Anaerobic composting processing plant

4.4.6.3 *Vermi Composting*

Vermicomposting is the result of combined activity of microorganisms and earthworms. Many species of earthworms are available in the processing of organic waste of which the most commonly used are *Eisenia fetida, Eudrilus eugeniae, Lumbricus rubelles, Periyonix excavatus and Periyonix hawayane*. *Eudrilus eugeniae* is the species suggested surviving in our environment which has a better consumption rate of 2000-5000mg substrate/g and reproduction rate compared with other earthworms (Monson et.al, 2007).

Use of this method for wastes from individual houses, housing colonies, slums, and apartments etc. where the waste is mainly organic in nature and where the quantities are less and can be manually handled. Minimum three persons are required for handling one ton of waste including segregation. The cost of the project is 107.50 lakhs including sheds, tubs, manure storage building, receiving and segregation platform, machineries and infrastructure facilities etc.

4.4.6.4 *The designs of a landfill*

Landfill capacity, Landfill height, and Landfill area

(a) Current waste generation per year = 14 tons (Inert & soil)

(b) Estimated waste generation after 16 years = 17tons

(c) Total waste generation in 16 years = 0.5(14+17) X 365 X 16 = 90520 tons

(d) Total Waste volume (density 0.90 ton/cu.m as per TNAU lab result)

$= 90520/0.90 = 100578\ m^3$

(e) Volume of daily cover = 0.1 X100578 = 10058 m^3

(f) Volume of liner and cover systems = 0.125 X 100578 = 12572 m^3

(g) Estimate of landfill volume Ci = (100578+ 10058 + 12572– 10058) = 113150 m^3

(h) Shape of Landfill – Rectangular in plan (length: width = 2:1)

(i) Possible Maximum Landfill Height = 20m

(j) Area required = 113150/20 = 5658sq.m

(k) Approximate plan dimensions = 55m X 110m = 1.50 acres.

The following mitigation measures are proposed to reduce the adverse impacts are

For prevention of ground water pollution leachate control and treatment shall be required. For this the site will be properly drained so that rain water does not enter the landfill. The liner system shall be provided at the bottom of the landfill. The minimum requirement for a single composite liner system are (i) A Leachate drainage layer 30cm thick made of granular soil having permeability (K) greater than 10^{-2} cm/sec. (ii) A protection layer 20cm to 30cm thick. (iii) A compacted clay barrier of 1m thickness having permeability of less than 10^{-7} cm/sec. The liner system adopted at landfill must satisfy the minimum requirements published by regulatory agencies (MoEF/CPCB).

The equipment is required at a landfill site are Buldozers 1no, Loader1no, Excavator1no, Compactor1no, and Water tanker 1no, Tractor Trailer / Tipper1no. The arterial roads are to be minimum width of 3.5m along the periphery. All around the landfill site fencing to be done. Surface water drains are to be constructed adjacent to arterial road along periphery. Leachate holding tank, Leachate treatment facility, Surface water sedimentation tank, Gas flaring facility, Street light facilities are must be provided. The cross- section of landfill site is shown in Fig 4.34. The surface water drains are designed and sectional view of cells, lifts and final cover were shown in layout Fig 4.35 and 4.36.

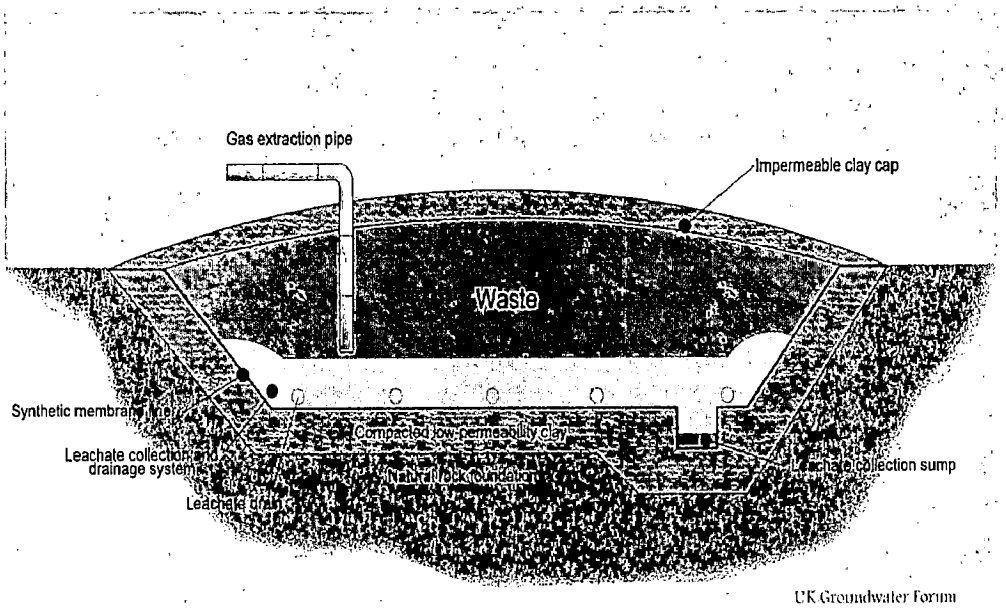


Fig 4.34:- Cross section of landfill (source: www. groundwateruk.org, 2007)

(a) Design of storm water drain

The expected peak discharge in the drain using rational formula (Garg, 2004),

$$Qp = \frac{1}{36} Kp_c . A$$

Qp = Peak rate of runoff in cumecs

K = Co- efficient of runoff (0.4425)

A = Catchment area in hectare (5.76)

p_c = Rainfall intensity (1.82 cm/hr)

$$Qp = \frac{1}{36} \times 0.4425 \times 1.82 \times 5.32$$

$$= 0.12 \text{ cumecs}$$

For designing drains the Manning's formula is used,

$$Q = \frac{1}{N} \times A\, R^{2/3} \times S^{1/2}$$

Q = Discharge in cumecs

N = Manning's co - efficient

A = Area of drains

R = Wetted perimeter (A/P)

S = Slope 1 in 500

$$0.12 = \frac{1}{0.015} \times D^2 \times (D^2/3D)^{2/3} \times (.002)^{1/2}$$

$$0.12 = \frac{1}{0.015} \times (1/3)^{2/3} \times (D)^{8/3} \times (.002)^{1/2}$$

$$D^{8/3} = \frac{0.12}{66.67 \times 0.4789 \times (0.002)^{1/2}}$$

$$D^{8/3} = 0.0840$$

Depth = 0.40m.

The size of the drain is 0.40m x 0.45m

LAYOUT OF DISPOSAL SITE

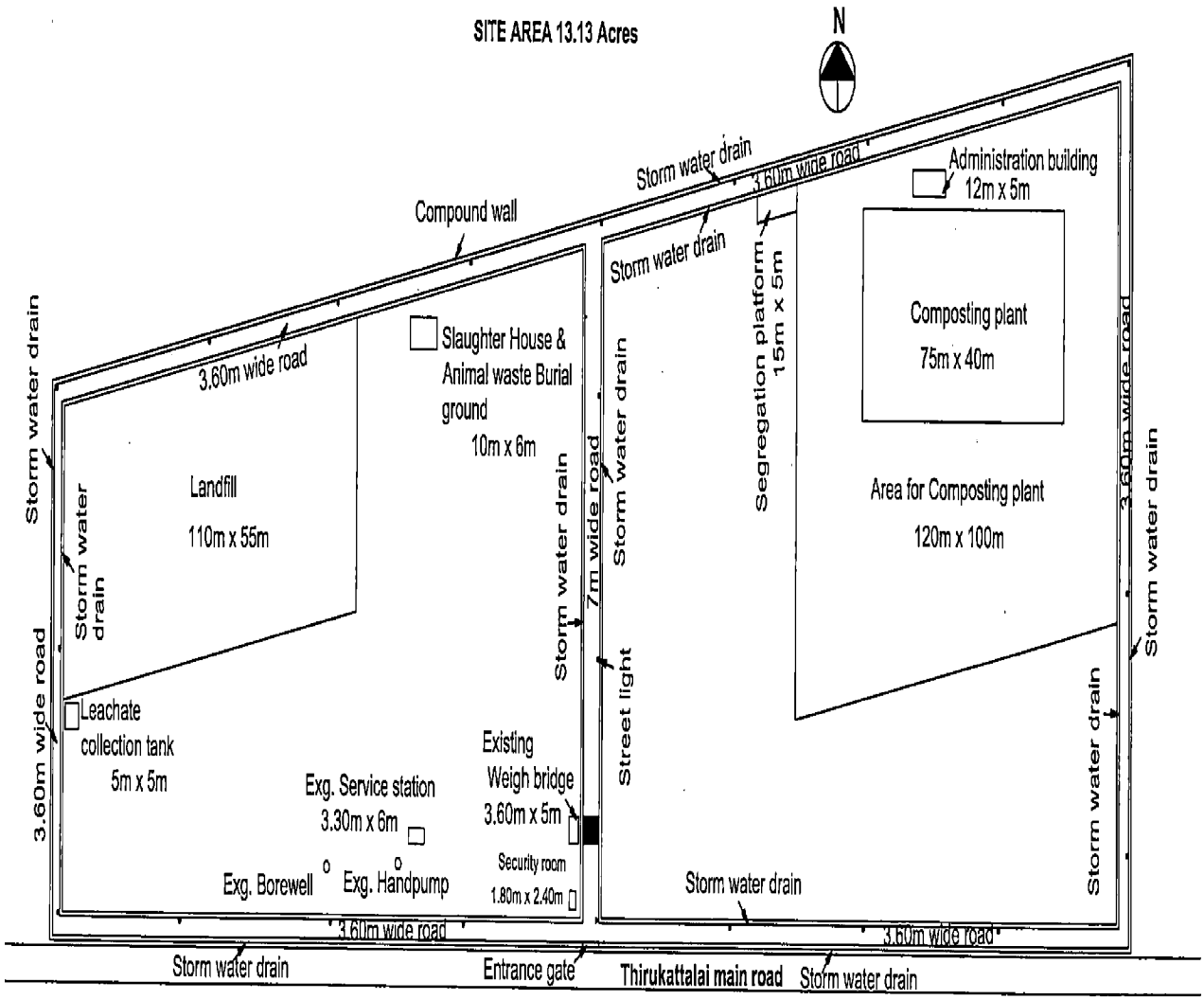


Fig:- 4.35 Layout of disposal site

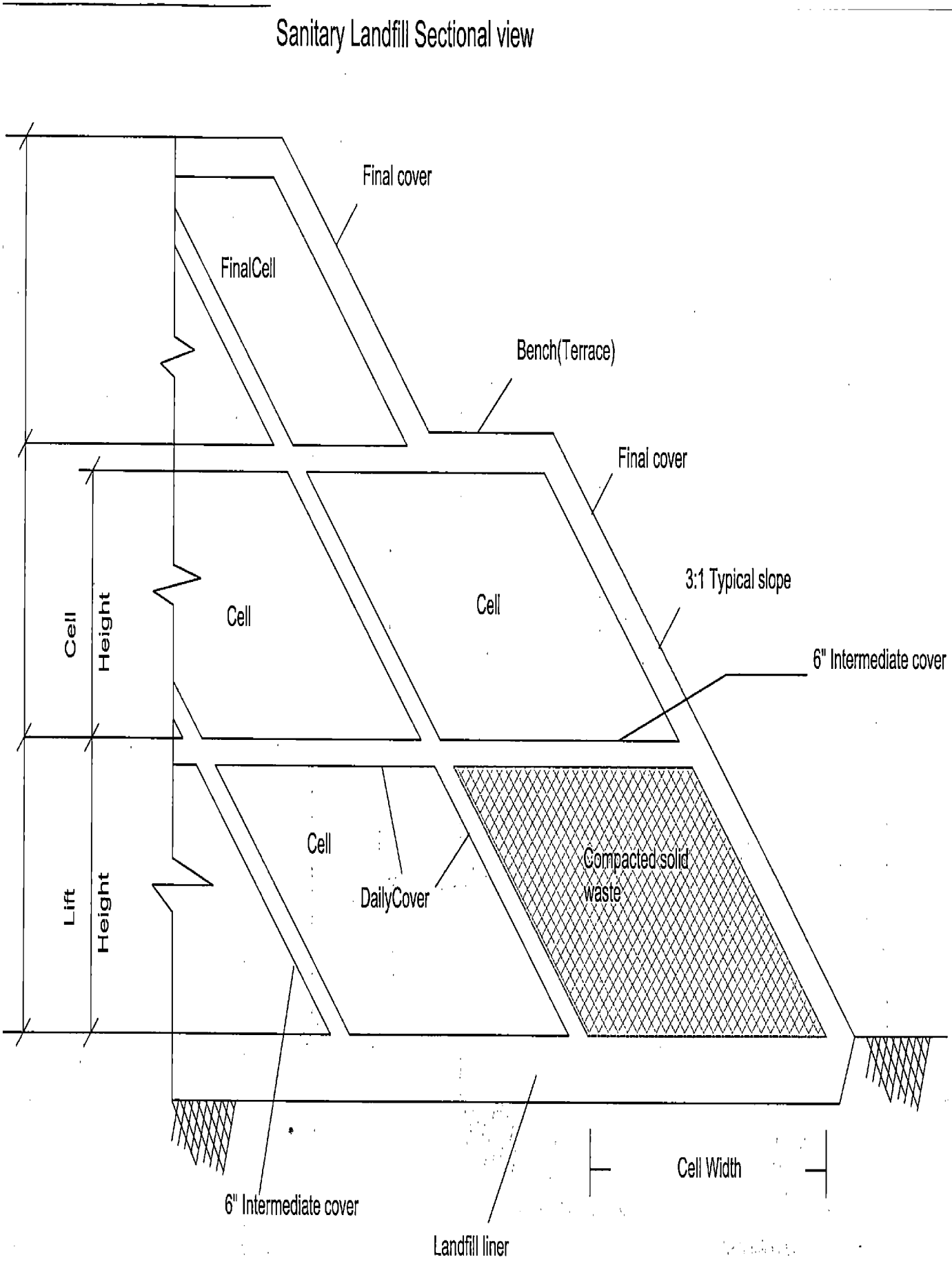


Fig 4.36:- Sanitary Landfill sectional view Source: Tchobanoglous et al, 1993

4.4.7 Public and Private Participation

(i) ***Public Participation***

Identification of problems of waste management may be done through site visits and consultation with local population at the time when the community is available for interaction. In this exercise the local councilors, local leaders, NGOs can be invited to participate. People's Participation is Essential in the Following Areas;

- Reduce, Reuse& Recycling (R R R) of waste.
- Not to throw the waste/litter on the streets drains, open spaces, water bodies, etc.
- Storage of organic/bio-degradable and recyclable waste separately at source.
- Primary collection of waste
- Community storage/collection of waste in flats, multi-storied buildings, societies, commercial complexes, etc.
- Pay adequately for the services provided.

The communication material developed should be utilized in public awareness programmes through variety of approaches such as Group education, Mass education, Use of print media, Use of local Cable TV, Display of slides in Cinema theaters, Using hand bills, Use of Hoarding, Use of School children, Women Associations, Resident Associations, NGOs etc. The allocation of funds in every budget is essential for conducting public awareness programmes.

(ii) ***Private Participation***

The local body may attempt Private sector Participation or Public Private Partnerships. Private sector Participation shall be considered in Collection of Hotel wastes, Market wastes mainly in ward 16, 17, 18, 25, 26 & 34 respectively. Door to Door collection shall be through private body. Setting up and operation & maintenance of waste disposal facility, setting up and operation and maintenance of waste treatment plants can also be done on contractual basis. An arrangement of BOO (Build, Own and Operate), BOOT (Build, Own, Operate and Transfer) or any other arrangement which may be transparent and beneficial to local body.

National Small Industries Corporations Ltd (NSIC), Cochin is a body which can set up a treatment plant for Pudukkottai town based on DBOT (Design Build Operate and Transfer), Turnkey and DBOLT (Design Build Operate Lease and Transfer).

4.4.8 Institutional aspects

Institutional strengthening can be done by adequately decentralizing the administration, delegating adequate powers at the decentralized level inducting professionals into the administration and providing adequate training to the existing staff. Street sweepers required for this town is 336 nos. The calculation is made in one person can sweep 500RM including household waste collection. The local body may also encourage NGOs or co-operative of rag pickers to enter this field and organize rag pickers in doorstep collection of waste and provide them an opportunity to improve their working conditions and income. The proposed Staffing arrangement for PMC as per SWM manual is shown in Fig 4.37.

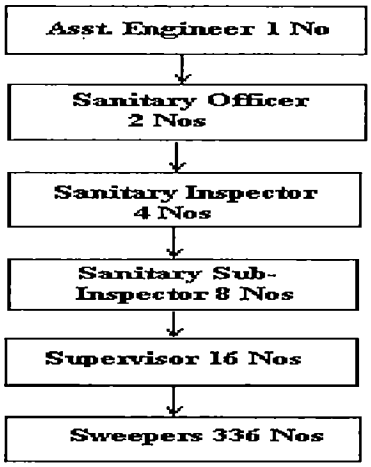
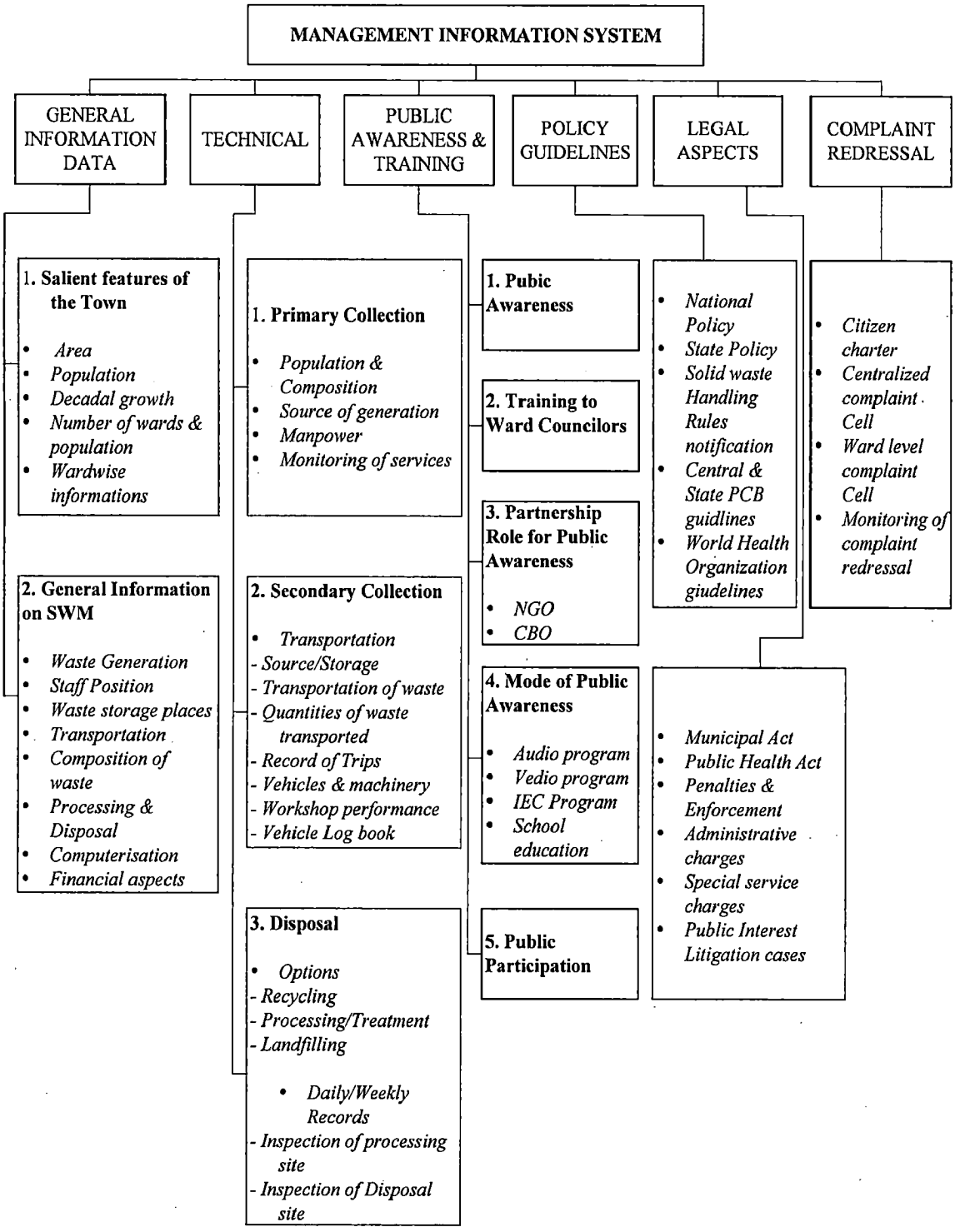


Fig 4.37:- Staffing arrangement for proposed SWM

4.4.9 Management Information System (MIS)

MSW management practice is the key to keep a city clean. This requires collection of critical information which is effectively used for taking corrective measures as well as proper planning for future is shown as a flow chart. Computerisation of such information helps at all the levels of administration to work not harder, increases the level of job satisfaction, and also to establish strong and reliable information data base necessary to facilitate the decision making and monitoring process for management.


MANAGEMENT INFORMATION SYSTEM
GENERAL INFORMATION DATA
TECHNICAL
PUBLIC AWARENESS & TRAINING
POLICY GUIDELINES
LEGAL ASPECTS
COMPLAINT REDRESSAL
1. Salient features of the Town
• Area
• Population
• Decadal growth
• Number of wards & population
• Wardwise informations
2. General Information on SWM
• Waste Generation
• Staff Position
• Waste storage places
• Transportation
• Composition of waste
• Processing & Disposal
• Computerisation
• Financial aspects
1. Primary Collection
• Population & Composition
• Source of generation
• Manpower
• Monitoring of services
2. Secondary Collection
• Transportation
- Source/Storage
- Transportation of waste
- Quantities of waste transported
- Record of Trips
- Vehicles & machinery
- Workshop performance
- Vehicle Log book
3. Disposal
• Options
- Recycling
- Processing/Treatment
- Landfilling
• Daily/Weekly Records
- Inspection of processing site
- Inspection of Disposal site
1. Pubic Awareness
2. Training to Ward Councilors
3. Partnership Role for Public Awareness
• NGO
• CBO
4. Mode of Public Awareness
• Audio program
• Vedio program
• IEC Program
• School education
5. Public Participation
• National Policy
• State Policy
• Solid waste Handling Rules notification
• Central & State PCB guidlines
• World Health Organization giudelines
• Municipal Act
• Public Health Act
• Penalties & Enforcement
• Administrative charges
• Special service charges
• Public Interest Litigation cases
• Citizen charter
• Centralized complaint Cell
• Ward level complaint Cell
• Monitoring of complaint redressal

4.4.10 Cost Estimate and Cess calculation

The cost estimate for the proposed SWM is prepared based on PMC, local market rates and information provided by manufacturers. The price and the operating cost of the plant are obtained from the information as provided by National Small Industries Corporations Ltd (NSIC), Cochin. The capital investment required for proposed SWM in Pudukkottai town is Rs. 644.00 lakhs and the details are shown in Table 4.32. In Table 4.33, the annual Operation & Maintenance cost (Rs. 245.95 lakhs) and the details are given. In Table 4.34, the expected revenue from the 12th finance commission grant, plant, recyclables and cess from shopping centers, marriage halls, cinema theatres, hotels & restaurants and households (Rs. 265.85 lakhs) are given. Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT) sharing of funds would be in the ratio of 80:10 between Central Government & State Government (www. Urbanindia.nic.in, 2005) and the balance 10% i.e., Rs. 64.40 lakhs could be raised by the PMC from the Tamilnadu Urban Finance and Infrastructure Development Corporation Ltd (TUFIDCO) at the rate of interest is 8% per annum and the amount to be paid in the period of 10 years.

(i) ***Estimation of the capital investment for the Proposed SWM***

The capital investment calculated for the proposed SWM shown in Table 4.32.

Table 4.32:- Estimation of the capital investment for the Proposed SWM

Item no	Item in short	Rs (in Lakhs)
1	**Anaerobic composting processing plant** a) MSW feeding stainless steel system b) MSW plastic separating and degradable size reduction stainless steel plant 1ton/hr capacity c) Stainless steel slurry pump 1ton/hr capacity d) Electric compost turning stainless steel machine e) Compost pulverizing and plastic separating machine 300kg/hr capacity f) Compost briquetting stainless steel machine 300kg/hr g) Electric / Diesel loader (mini JCB) h) Waste water recycling stainless steel system	368.00

Contd....

2	**Civil works** a) 3000 sq.m totally R.C.C floor, enclosed, electrified, G.I sheet or fiberglass roof building for installation of plant & machinery with stainless steel solar water heaters & stainless steel filters, tanks etc. b) 60 sq.m R.C.C floor, G.I sheet roof, electrified shed for office room, workers rest room, toilet etc. c) Land development & basic infrastructure cost, green belt etc.	143.00
3	Disposal site Roads (124m x 7m) @Rs. 800/sq.m Roads (1078m x 3.6m) @Rs. 500/sq.m	26.35
4	Storm water drains (2378RM) @Rs. 800/RM	19.02
5	Street lights (22 numbers) @Rs. 5000/each	1.10
6	Compound Wall (1110m) @Rs. 1000RM	11.10
7	Sanitary Landfill (L.S)	5.00
8	Tree plantation (2000nos) @Rs. 50/each	1.00
9	Culverts (62 sq.m) @Rs. 750/ sq.m	2.17
10	Receiving platform (75 sq.m) @Rs. 750/ sq.m	0.56
11	**Vehicles**	
	a) Dumper placer (2 numbers) @Rs.15.80/ each	31.60
	b) Handcarts (180 numbers) (@Rs. 2000/each)	3.60
12	**Collection & storage bins**	
	a) 2.5 cu.m metallic containers (44 numbers) @Rs. 40000/each b) 0.06 cu.m polyethylene containers (1297 numbers) @Rs. 1000/each	17.60 12.97
	Miscellaneous expenses(wheel barrow, trolley, first aid box & fire extinguisher etc)	0.93
	Total	644.00

(ii) ***Estimation of the Annual O&M Cost for the Proposed SWM***

The annual operating and maintenance cost for the proposed SWM is calculated as shown in Table 4.33.

Table 4.33:- Estimation of Annual O&M Cost for the Proposed SWM

Item No.	Item in short	Rs (in Lakhs)
1	**Operating Cost for plant**	
	(a) Labour charges (35numbers/day) @Rs. 150 each/day	19.16
	(b) Electricity (700KW/day) @Rs. 4/kW	10.22
2	Maintenance cost of building, equipments, vehicles etc (L.S)	2.00
3	**Salaries**	
	(a) Assistant Engineer (1number) @Rs. 12,000pm	1.44
	(b) Sanitary Officer (2numbers) @Rs. 10,000pm	2.40
	(c) Sanitary Inspector (4numbers) @Rs. 8,000pm	3.84
	(d) Sanitary Sub Inspector (8 numbers) @Rs. 7,000pm	6.72
	(e) Supervisor (16numbers) @Rs. 5,000pm	9.60
	(f) Drivers (4numbers) @Rs. 5000pm	2.40
	(g) Sweeper336numbers @Rs. 4500pm	181.44
4	Fuel expenses (36 litres/day) @Rs. 36/litre	4.73
5	Public Participation Programme (L.S)	2.00
	Total	245.95

(iii) ***Expected Revenue***

The annual expected revenue from the plant & recyclables and cess calculations are given in Table 4.34.

Table 4.34:- Annual Expected revenue

Item No.	Item in short	Rs (in Lakhs)
1	Bio manure (10tons/day) @Rs. 2000/ton	73.00
2	Recyclables (Rs. 10320/day)	37.67
3	Power generation from plant (142kW/day) @Rs. 4/kW	2.07
4	Funds from 12th Finance Commission (Grant)	32.00
5	Shopping Centers (53 numbers) @Rs. 30 each per day	5.80
6	Marriage halls (39 numbers) @Rs. 100 for 80 days only	3.12
7	Hotels & Restaurants (29 numbers) @Rs. 25 each per day	2.65
8	Night canteens & Food stalls (68 numbers) @Rs. 15 each per day	3.72
9	Cinema theatres (4 numbers) @Rs.41each per day	0.60
10	Small shops (890 numbers) @Rs. 5 each per day	16.24
11	Households (23830 numbers) @Rs. 1 house per day	86.98
	Total	265.85

(iv) ***Calculation of Benefit Cost ratio & Internal Rate of Return***

The annual repayment of capital Rs. 9.59 lakhs per year is calculated and the details are given below (Eugene, 1976).

$$A = \frac{Pi\,(1+i)^n}{(1+i)^n - 1}$$

A= Annual Payment (or) Annuity

P= Capital (Rs. 64.40 lakhs)

i= interest rate per annum (8%)

n= number of periods in years (10 years)

$$A = \frac{64.40 \times 0.08\,(1+0.08)^{10}}{(1+0.08)^{10} - 1} = \text{Rs. } 9.59 \text{ lakhs per year}$$

The calculation of Benefit Cost ratio (1.00) & Internal Rate of Return (9.5%) are given in Table 4.35 & 4.36. The Net Present Value (NPV) has been calculated as Rs. 3.68 lakhs. No monetary benefit can be shown for the health improvement in turn improving the efficiency of the people, reduction is the illness (cost of treatment) and saving of man hour (which are lost due to illness). In addition the equipment in use in SWM has a shorter life as compared to other municipal services such as water supply and sewerage, a continuous investment also required. Hence the revision of the tax rate every 3 to 5 years shall be considered.

Table 4.35:- Benefit Cost Ratio

Year	Capital Rs (in lakhs)	Expenditure* Rs (in lakhs)	Revenue Rs (in lakhs)	Discount Factor 8%	Present worth banefit Rs (in lakhs)	Present worth expenditure Rs (in lakhs)
1	64.4	64.4	.....	0.9259	.....	59.63
2	.....	252.91	263.85	0.8573	226.21	216.83
3	.....	252.91	263.85	0.7938	209.45	200.76
4	.....	252.91	263.85	0.7350	193.94	185.89
5	.....	252.91	263.85	0.6806	179.57	172.12
6	.....	252.91	263.85	0.6302	166.27	159.37
7	.....	252.91	263.85	0.5835	153.95	147.57
8	.....	252.91	263.85	0.5403	142.55	136.64
9	.....	252.91	263.85	0.5002	131.99	126.52
10	.....	252.91	263.85	0.4632	122.21	117.14
				TOTAL	1526.15	1522.47

Net Present Value (NPV) = Rs.1526.15 – Rs.1522.47 = Rs.3.68 lakhs

Benefit Cost ratio (B/C) = 1526.15/1522.47 = 1.00

Table 4.36:- Internal Rate of Return (IRR)

Year	Capital Rs (in lakhs)	Expenditure* Rs (in lakhs)	Revenue Rs (in lakhs)	D.F 9.5%	Present worth banefit Rs (in lakhs)	Present worth expenditure Rs (in lakhs)
1	64.4	64.4	.....	0.9132	.....	58.81
2	.....	252.91	263.85	0.8340	220.05	210.93
3	.....	252.91	263.85	0.7617	200.96	192.63
4	.....	252.91	263.85	0.6956	183.53	175.92
5	.....	252.91	263.85	0.6352	167.60	160.66
6	.....	252.91	263.85	0.5801	153.06	146.72
7	.....	252.91	263.85	0.5298	139.78	133.99
8	.....	252.91	263.85	0.4838	127.66	122.36
9	.....	252.91	263.85	0.4418	116.58	111.75
10	.....	252.91	263.85	0.4035	106.47	102.05
	NPV = 0	IRR = 9.5%	B/C = 1	TOTAL	1416	1416

Expenditure* = O & M + Capital + Interest on Capital

Expenditure* = 243.95 + ((64.4+ (64.4*.08))/10 = Rs 252.91 lakhs

CHAPTER 5

CONCLUSIONS

From the study, the following conclusions are drawn:

- In Pudukkottai town, waste generation was found to be 300gm/capita/day.
- At present only 144 nos of pushcarts used for primary collection.
- Totally 46 places are identified as open storage points.
- Presently waste is not handled and disposed off as per the MSWM rules.
- The laboratory test results were indicating the pollution of river kundar, ponds and the ground water contamination in the dumping site.
- A Management Plan is proposed with regard to segregation at the point of generation, collection, transportation, treatment and final disposal at the common facility.
- Two nos. of dumper placer is required for the transportation of MSW. Totally, 44nos of 2.5cu.m capacity of dumper bins, 1297nos of 0.06cu.m of polyethylene detachable containers and 324nos of handcarts designed for primary, secondary collection and storage of wastes.
- The network analysis is made for finding optimal route and shortest routes for transportation of wastes from collection points to disposal sites using GIS software.
- The costs for the capital investment, O & M and revenue from the composting plant & recyclables and cess have been calculated.
- UIDSSMT sharing of funds would be in the ratio of 80:10 between Central Government & State Government.
- The balance 10% i.e., Rs. 64.40 lakhs will be borrowed from the TUFIDCO at the rate of interest is 8% per annum for the period of 10 years. The Annual repayment is calculated as Rs. 9.59 lakhs per year.
- The Benefit Cost ratio (1.00), IRR (9.5%) and NPV Rs. 3.68 lakhs have been calculated.

- Public Private Participation is essential to reduce the burden of PMC as well as the pollution of water bodies.

➢ LIMITATIONS AND FURTHER SCOPE OF WORK

1. Primary data was collected for seven days only. More data collection will improve the study.
2. Household Hazardous waste & Electronic waste generation was not studied due to non-availability of data.
3. Further Scope: An in-depth study of the Household Hazardous waste & Electronic waste generation and disposal facility of both the wastes may be undertaken.

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ANNEXURE I

QUESTIONNAIRE FOR SWM IN PUDUKKOTTAI TOWN

HOUSEHOLD INFORMATION FORM

1. a) State: b) District: c) Town :

   d) Ward: e) Street name:

   f) Town survey no / Door no:

2. Survey conducted from date: to date

3. Name of the house owner:

4. Number of persons in the household: Male: Female:

5. Number of persons in household:

6. Total monthly income of the household:

7. Opinion of the members regarding sanitation in the area/neighborhood

8. Suggestions of the members of the family to improve sanitation in the area

9. How many Domestic helps are engaged by the family?
   Full time Category
   Part time category

10. Is the house cleaned manually/mechanically/both?

11. In a day how many times the house is swept/cleaned?

- Is sweeping and cleaning of the house done by the family members

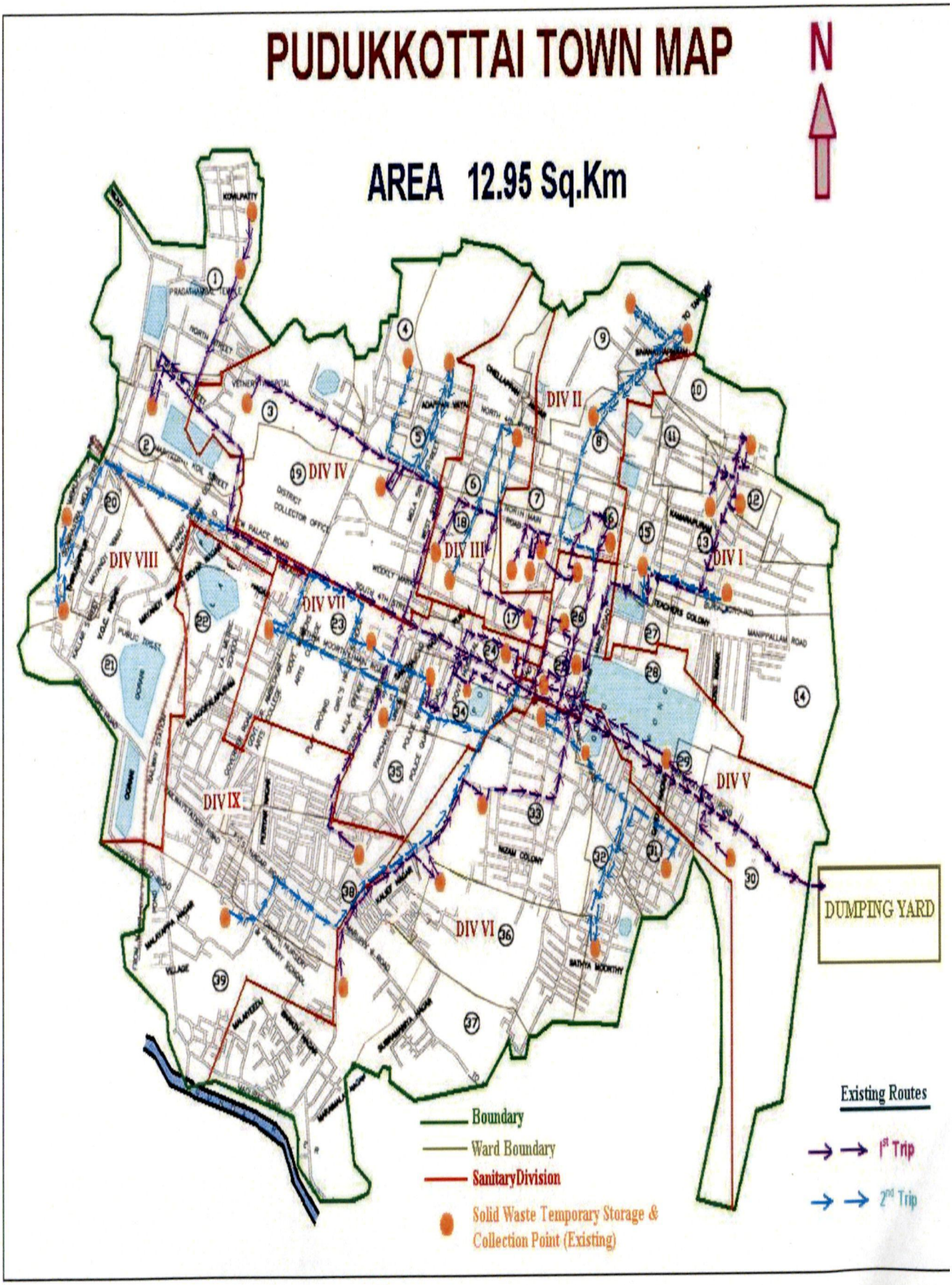
  Yes/no/Sometimes

12. Does the household segregate its waste?

- If yes, to how many categories and why?
- What do they do with their biodegradable waste?
- What do they do with their non-biodegradable waste?
- How and where do they dispose of their biodegradable waste and non-biodegradable waste?
- How and where do they dispose of their hazardous waste? (Like old battery, insecticide/pesticide containers)
- How and where do they dispose of their construction and demolition waste?
- How and where they dispose of their bulky waste? (Like broken wooden furniture)
- How and where they dispose of their electronic waste? (Like broken electrical and electronic equipment, computer waste, etc).

Investigator Supervisor

ANNEXURE II


PUDUKKOTTAI TOWN MAP
N
AREA 12.95 Sq.Km
DIV I
DIV II
DIV III
DIV IV
DIV V
DIV VI
DIV VII
DIV VIII
DIV IX
DUMPING YARD
Boundary
Ward Boundary
SanitaryDivision
Solid Waste Temporary Storage & Collection Point (Existing)
Existing Routes
1st Trip
2nd Trip

ANNEXURE III

PUDUKKOTTAI TOWN

Transportation route details & distance calculation is made using GIS software

Route no: 1

Starting from Stop #1

Turn left onto KOVILPATTI ROAD

Travel on KOVILPATTI ROAD for 0.26 km

Turn right onto NORTH MAIN STREET

Travel on NORTH MAIN STREET for 0.16 km

Travel on for 0.00 km

Continue straight onto NORTH MAIN STREET

Travel on NORTH MAIN STREET for 0.06 km

Turn left onto MARIAMMAN KOVIL STREET

Travel on MARIAMMAN KOVIL STREET for 0.11 km

Travel on for 0.50 km

Turn left onto SOURASTRA BIGSTREET

Travel on SOURASTRA BIGSTREET for 0.59 km

Travel on for 0.00 km passing

Pallivasal on left (0.00 km)

Turn left into Stop #22

Starting from Stop #22

Travel on for 1.70 km

At Pallivasal Turn right onto SESHAIYA SHASTRI ROAD

Travel on SESHAIYA SHASTRI ROAD for 0.51 km

Travel on for 0.16 km

Turn left onto PUDUVAYAL ROAD

Travel on PUDUVAYAL ROAD for 0.64 km

Turn right onto EAST MAIN STREET

Travel on EAST MAIN STREET for 0.28 km

Travel on for 0.00 km passing

Leader chappal on left (0.00 km)

Turn left into Stop #36

Starting from Stop #36

Travel on for 0.00 km

At Leader chappal Turn left onto EAST MAIN STREET

Travel on EAST MAIN STREET for 0.28 km

Turn left onto PUDUVAYAL ROAD

Travel on PUDUVAYAL ROAD for 0.17 km

Travel on for 0.87 km

Turn right onto SATHYAMOORTHY ROAD

Travel on SATHYAMOORTHY ROAD for 0.02 km

Turn left onto WEST FOURTH STREET

Travel on WEST FOURTH STREET for 1.09 km

Turn right onto ADAPPANVAYAL FIFTH STREET

Travel on ADAPPANVAYAL FIFTH STREET for 0.00 km

Turn left into Stop #5

Starting from Stop #5

Turn right onto ADAPPANVAYAL FIFTH STREET

Travel on ADAPPANVAYAL FIFTH STREET for 0.00 km

Turn left onto WEST FOURTH STREET

Travel on WEST FOURTH STREET for 0.07 km

Travel on for 0.57 km

Turn left onto EAST MAIN STREET

Travel on EAST MAIN STREET for 0.60 km

Turn left into Stop #8

Starting from Stop #8

Turn right onto EAST MAIN STREET

Travel on EAST MAIN STREET for 0.68 km passing

Reservoir colony on right (0.00 km)

Travel on for 0.26 km

Turn right onto EAST THIRD STREET
Travel on EAST THIRD STREET for 0.68 km
Turn left onto SOUTH FOURTH STREET
Travel on SOUTH FOURTH STREET for 0.37 km
Travel on for 0.00 km
Turn right into Stop #28

Starting from Stop #28
Travel on for 0.00 km
Turn right onto SOUTH FOURTH STREET
Travel on SOUTH FOURTH STREET for 2.72 km
Turn left into Stop #41

Total distance traveled is 13.37 km

==========

ROUTE NO: 2

Starting from Stop #1

Turn left onto KOVILPATTI ROAD

Travel on KOVILPATTI ROAD for 0.26 km

Turn right onto NORTH MAIN STREET

Travel on NORTH MAIN STREET for 0.16 km

Travel on for 0.00 km

Continue straight onto NORTH MAIN STREET

Travel on NORTH MAIN STREET for 0.06 km

Turn left onto MARIAMMAN KOVIL STREET

Travel on MARIAMMAN KOVIL STREET for 0.24 km

Turn left into Stop #2

Starting from Stop #2

Turn left onto MARIAMMAN KOVIL STREET

Travel on MARIAMMAN KOVIL STREET for 0.21 km

At Mariamman kovil Turn left onto CHOLA REAL ESTATE ROAD

Travel on CHOLA REAL ESTATE ROAD for 0.23 km

Turn left onto SOUTH FOURTH STREET

Travel on SOUTH FOURTH STREET for 5.22 km

Turn left into Stop #41

Total distance traveled is 6.40 km

==========

ROUTE NO: 3

Starting from Stop #22

Travel on for 0.00 km

At Pallivasal Turn left onto SOURASTRA BIGSTREET

Travel on SOURASTRA BIGSTREET for 0.30 km

Turn right into Stop #21

Starting from Stop #21

Turn right onto SOURASTRA BIGSTREET

Travel on SOURASTRA BIGSTREET for 0.29 km

At Municipal School Turn right onto SOUTH FOURTH STREET

Travel on SOUTH FOURTH STREET for 5.45 km

Turn left into Stop #41

Total distance traveled is 6.04 km

==========

ROUTE NO: 4

Starting from Stop #3

Turn right onto NORTH MAIN STREET

Travel on NORTH MAIN STREET for 0.82 km passing

Veterinary Hospital on right (0.00 km)

Travel on for 0.00 km

Turn left into Stop #20

Starting from Stop #20

Travel on for 1.36 km passing

Lena Mahal on left (0.00 km)

Turn right onto EAST THIRD STREET

Travel on EAST THIRD STREET for 0.15 km

Turn left onto SOUTH FOURTH STREET

Travel on SOUTH FOURTH STREET for 3.10 km

Turn left into Stop #41

Total distance traveled is 5.42 km

==========

ROUTE NO: 5

Starting from Stop #4

Turn left onto ADAPPANVAYAL FIFTH STREET

Travel on ADAPPANVAYAL FIFTH STREET for 0.31 km passing

Municipal water House on left (0.00 km)

Turn left into Stop #5

Starting from Stop #5

Turn right onto ADAPPANVAYAL FIFTH STREET

Travel on ADAPPANVAYAL FIFTH STREET for 0.00 km

Turn left onto WEST FOURTH STREET

Travel on WEST FOURTH STREET for 0.07 km

Travel on for 0.65 km

Turn left onto NORTH MAIN STREET

Travel on NORTH MAIN STREET for 0.16 km

Turn right onto EAST MAIN STREET

Travel on EAST MAIN STREET for 0.39 km

Travel on for 0.20 km

Turn right onto EAST THIRD STREET

Travel on EAST THIRD STREET for 0.15 km

Turn left onto SOUTH FOURTH STREET

Travel on SOUTH FOURTH STREET for 3.10 km

Turn left into Stop #41

Total distance traveled is 5.04 km

ROUTE NO: 6

Starting from Stop #38

Turn right onto PERIYAR NAGAR DOUBLE ROAD

Travel on PERIYAR NAGAR DOUBLE ROAD for 0.18 km passing

Jeevan trust on right (0.00 km)

Turn left onto PUDUVAYAL ROAD

Travel on PUDUVAYAL ROAD for 0.30 km

Travel on for 0.10 km

Turn left onto KAMBAN NAGAR ROAD

Travel on KAMBAN NAGAR ROAD for 0.03 km passing

E-governance opposite on left (0.03 km)

Turn left into Stop #37

Starting from Stop #37

Turn left onto KAMBAN NAGAR ROAD

Travel on KAMBAN NAGAR ROAD for 0.04 km

Travel on for 0.26 km

Turn left onto EAST MAIN STREET

Travel on EAST MAIN STREET for 1.08 km

Turn right onto SOUTH FOURTH STREET

Travel on SOUTH FOURTH STREET for 3.31 km

Turn left into Stop #41

Total distance traveled is 5.29 km

==========

ROUTE NO: 7

Starting from Stop #39

Turn right onto KSM NAGAR ROAD

Travel on KSM NAGAR ROAD for 0.18 km

Turn right onto PUDUVAYAL ROAD

Travel on PUDUVAYAL ROAD for 0.63 km

Turn right onto EAST MAIN STREET

Travel on EAST MAIN STREET for 0.28 km

Travel on for 0.00 km passing

Leader chappal on left (0.00 km)

Turn left into Stop #36

Starting from Stop #36

Travel on for 0.00 km

At Leader chappal Turn left onto EAST MAIN STREET

Travel on EAST MAIN STREET for 1.55 km

Turn right onto SOUTH FOURTH STREET

Travel on SOUTH FOURTH STREET for 3.31 km

Turn left into Stop #41

Total distance traveled is 5.94 km

==========

ROUTE NO: 8

Starting from Stop #24
Travel on for 0.20 km passing
Hanifa Complex rear side on left (0.00 km)
Turn right onto SATHYAMOORTHY ROAD
Travel on SATHYAMOORTHY ROAD for 0.36 km
Turn right onto SESHAIYA SHASTRI ROAD
Travel on SESHAIYA SHASTRI ROAD for 0.00 km
Turn right into Stop #23

Starting from Stop #23
Turn left onto SESHAIYA SHASTRI ROAD
Travel on SESHAIYA SHASTRI ROAD for 0.00 km
Turn left onto SATHYAMOORTHY ROAD
Travel on SATHYAMOORTHY ROAD for 1.01 km
Turn left onto EAST MAIN STREET
Travel on EAST MAIN STREET for 0.26 km
Turn right onto SOUTH FOURTH STREET
Travel on SOUTH FOURTH STREET for 3.31 km
Turn left into Stop #41

Total distance traveled is 5.14 km

ROUTE NO: 9

Starting from Stop #25

Travel on for 0.08 km

At Palaniappa lodge opposite Turn right onto SATHYAMOORTHY ROAD

Travel on SATHYAMOORTHY ROAD for 0.02 km

Turn left into Stop #34

Starting from Stop #34

Turn right onto SATHYAMOORTHY ROAD

Travel on SATHYAMOORTHY ROAD for 0.39 km passing

Bus stand on right (0.00 km)

Turn left onto EAST MAIN STREET

Travel on EAST MAIN STREET for 0.26 km

Turn right onto SOUTH FOURTH STREET

Travel on SOUTH FOURTH STREET for 3.31 km

Turn left into Stop #41

Total distance traveled is 4.06 km

ROUTE NO: 10

Starting from Stop #40

Turn left onto SOUTH THIRD STREET

Travel on SOUTH THIRD STREET for 0.00 km

Travel on for 0.08 km

Turn left onto SOUTH FOURTH STREET

Travel on SOUTH FOURTH STREET for 0.01 km

Turn right onto KUMUNTHAMKULAM ROAD

Travel on KUMUNTHAMKULAM ROAD for 0.16 km

Turn left into Stop #33

Starting from Stop #33

Turn right onto KUMUNTHAMKULAM ROAD

Travel on KUMUNTHAMKULAM ROAD for 0.16 km

Turn right onto SOUTH FOURTH STREET

Travel on SOUTH FOURTH STREET for 3.43 km

Turn left into Stop #41

Total distance traveled is 3.83 km

==========

ROUTE NO: 11

Starting from Stop #35

Turn right onto THIRUVALLUVAR NAGAR FIRST STREET

Travel on THIRUVALLUVAR NAGAR FIRST STREET for 0.32 km

Turn right onto EAST MAIN STREET

Travel on EAST MAIN STREET for 0.47 km

Turn right onto A M A NAGAR FIST STREET -

Travel on A M A NAGAR FIST STREET for 0.14 km passing

Prahadambal school rear side on left (0.14 km)

Turn left into Stop #32

Starting from Stop #32

Turn left onto A. M. A NAGAR FIST STREET

Travel on A.M A NAGAR FIST STREET for 0.24 km

Travel on for 0.12 km

Turn right onto SATHYAMOORTHY ROAD

Travel on SATHYAMOORTHY ROAD for 0.21 km

Travel on for 0.26 km

Turn right onto SOUTH FOURTH STREET

Travel on SOUTH FOURTH STREET for 2.83 km

Turn left into Stop #41

Total distance traveled is 4.60 km

==========

ROUTE NO: 12

Starting from Stop #31

Turn right onto SATHYA MOORTHI NAGAR ROAD

Travel on SATHYA MOORTHI NAGAR ROAD for 0.11 km passing

Maharaj mahal on right (0.00 km)

Travel on for 0.49 km

Turn right onto SATHYAMOORTHY ROAD

Travel on SATHYAMOORTHY ROAD for 0.08 km passing

Usilangulam 5th street on left (0.08 km)

Turn left into Stop #30

Starting from Stop #30

Turn left onto SATHYAMOORTHY ROAD

Travel on SATHYAMOORTHY ROAD for 0.11 km

Turn left onto GANDHI NAGAR SEVENTH STREET

Travel on GANDHI NAGAR SEVENTH STREET for 0.35 km

Turn right onto SOUTH FOURTH STREET

Travel on SOUTH FOURTH STREET for 2.31 km

Turn left into Stop #41

Total distance traveled is 3.45 km

==========

ROUTE NO: 13

Starting from Stop #18

Turn right onto SOUTH SECOND STREET

Travel on SOUTH SECOND STREET for 0.05 km

At Westnainari kulam Turn left onto

Travel on for 0.20 km

Turn right into Stop #19

Starting from Stop #19

Travel on for 0.91 km

Turn right onto EAST THIRD STREET

Travel on EAST THIRD STREET for 0.15 km

Turn left onto SOUTH FOURTH STREET

Travel on SOUTH FOURTH STREET for 3.10 km

Turn left into Stop #41

Total distance traveled is 4.40 km

ROUTE NO: 14

Starting from Stop #6

Travel on for 0.00 km

Turn left onto WEST MAIN STREET

Travel on WEST MAIN STREET for 0.14 km

Travel on for 0.00 km

Turn right onto WEST MAIN STREET

Travel on WEST MAIN STREET for 0.42 km

Turn left onto SOUTH MAIN STREET

Travel on SOUTH MAIN STREET for 0.21 km

Travel on for 0.00 km

Turn right into Stop #17

Starting from Stop #17

Travel on for 0.00 km

Turn left onto SOUTH MAIN STREET

Travel on SOUTH MAIN STREET for 0.09 km

Travel on for 0.00 km

Turn right onto EAST MAIN STREET

Travel on EAST MAIN STREET for 0.09 km

Travel on for 0.20 km

Turn right onto EAST THIRD STREET

Travel on EAST THIRD STREET for 0.15 km

Turn left onto SOUTH FOURTH STREET

Travel on SOUTH FOURTH STREET for 3.10 km

Turn left into Stop #41

Total distance traveled is 4.41 km

==========

ROUTE NO: 15

Starting from Stop #8

Turn right onto EAST MAIN STREET

Travel on EAST MAIN STREET for 0.43 km passing

Reservoir colony on right (0.00 km)

Travel on for 0.00 km passing

Othatheru on right (0.00 km)

Turn right into Stop #7

Starting from Stop #7

Travel on for 0.00 km passing

Othatheru on left (0.00 km)

Turn right onto EAST MAIN STREET

Travel on EAST MAIN STREET for 0.26 km

Travel on for 0.26 km

Turn right onto EAST THIRD STREET

Travel on EAST THIRD STREET for 0.68 km

Turn left onto SOUTH FOURTH STREET

Travel on SOUTH FOURTH STREET for 3.10 km

Turn left into Stop #41

Total distance traveled is 4.72 km

ROUTE NO: 16

Starting from Stop #16

Turn left onto NORTH MAIN STREET

Travel on NORTH MAIN STREET for 0.35 km

Turn right onto EAST THIRD STREET

Travel on EAST THIRD STREET for 0.12 km

Turn left into Stop #15

Starting from Stop #15

Turn left onto EAST THIRD STREET

Travel on EAST THIRD STREET for 0.44 km

Turn left onto SOUTH FOURTH STREET

Travel on SOUTH FOURTH STREET for 3.10 km

Turn left into Stop #41

Total distance traveled is 4.01 km

==========

ROUTE NO: 17

Starting from Stop #27
Turn left onto PANDURANGA LANE
Travel on PANDURANGA LANE for 0.06 km
Turn right onto EAST THIRD STREET
Travel on EAST THIRD STREET for 0.17 km
Travel on for 0.00 km passing
South 3rd & East 3rd street junction on left (0.00 km)
Turn left into Stop #26

Starting from Stop #26
Travel on for 0.00 km
Turn left onto EAST THIRD STREET
Travel on EAST THIRD STREET for 0.15 km
Turn left onto SOUTH FOURTH STREET
Travel on SOUTH FOURTH STREET for 3.10 km
Turn left into Stop #41

Total distance traveled is 3.47 km

ROUTE NO: 18

Starting from Stop #29

Travel on for 0.00 km

Turn left onto GANDHI NAGAR SEVENTH STREET

Travel on GANDHI NAGAR SEVENTH STREET for 0.08 km

Turn left onto SOUTH FOURTH STREET

Travel on SOUTH FOURTH STREET for 0.42 km

Travel on for 0.00 km

Turn right into Stop #28

Starting from Stop #28

Travel on for 0.00 km

Turn right onto SOUTH FOURTH STREET

Travel on SOUTH FOURTH STREET for 2.72 km

Turn left into Stop #41

Total distance traveled is 3.22 km

==========

ROUTE NO: 19

Starting from Stop #9
Turn left onto GANESH NAGAR SECOND STREET
Travel on GANESH NAGAR SECOND STREET for 0.00 km
At Vattam pallam Turn right onto KAMARAJAPURAM THIRTY FOURTH STREET
Travel on KAMARAJAPURAM THIRTY FOURTH STREET for 0.46 km
Turn left into Stop #10

Starting from Stop #10
Turn right onto KAMARAJAPURAM THIRTY FOURTH STREET
Travel on KAMARAJAPURAM THIRTY FOURTH STREET for 0.07 km
Travel on for 0.44 km
Turn left onto KAMARAJAPURAM NINTH STREET
Travel on KAMARAJAPURAM NINTH STREET for 0.25 km
Travel on for 0.00 km
Turn right onto NORTH MAIN STREET
Travel on NORTH MAIN STREET for 0.18 km
Turn left onto EAST FOURTH STREET
Travel on EAST FOURTH STREET for 0.57 km
Turn left onto SOUTH FOURTH STREET
Travel on SOUTH FOURTH STREET for 3.04 km
Turn left into Stop #41

Total distance traveled is 5.00 km

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ROUTE NO: 20

Starting from Stop #11

Travel on for 0.00 km

Turn right onto KAMARAJAPURAM TENTH STREET

Travel on KAMARAJAPURAM TENTH STREET for 0.05 km

Travel on for 0.39 km

Turn left onto KAMARAJAPURAM NINTH STREET

Travel on KAMARAJAPURAM NINTH STREET for 0.06 km

Turn left into Stop #12

Starting from Stop #12

Turn left onto KAMARAJAPURAM NINTH STREET

Travel on KAMARAJAPURAM NINTH STREET for 0.20 km

At Kamarajapuram 9th street & North 3rd street j Continue straight onto

Travel on for 0.00 km

Turn right onto NORTH MAIN STREET

Travel on NORTH MAIN STREET for 0.18 km

Turn left onto EAST FOURTH STREET

Travel on EAST FOURTH STREET for 0.57 km

Turn left onto SOUTH FOURTH STREET

Travel on SOUTH FOURTH STREET for 3.04 km

Turn left into Stop #41

Total distance traveled is 4.48 km

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ROUTE NO: 21

Starting from Stop #13
Travel on for 0.00 km
At V.O.C hall Turn left onto MANIPALLAM ROAD
Travel on MANIPALLAM ROAD for 0.46 km passing
Raj hall on right (0.46 km)
Turn right into Stop #14

Starting from Stop #14
Turn right onto MANIPALLAM ROAD
Travel on MANIPALLAM ROAD for 0.16 km
Turn left onto EAST FOURTH STREET
Travel on EAST FOURTH STREET for 0.48 km
Turn left onto SOUTH FOURTH STREET
Travel on SOUTH FOURTH STREET for 3.04 km
Turn left into Stop #41

Total distance traveled is 4.14 km