Kingdom of Cambodia
Nation Religion King

Ministry of Public Works and Transport
General Directorate of Public Works
Sewerage Management and Construction Department

Wastewater System Operation and Maintenance Guideline

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

Global Green Growth Institute

2018

Wastewater System Operation and Maintenance Guideline

អារម្ភកថា

ប្រទេសកម្ពុជាទទួលបាននូវកំណើនសេដ្ឋកិច្ចដ៏រឹងមាំក្នុងរយៈពេលពីរទសវត្សរ៍កន្លងមកនេះ ដែលបានជួយធ្វើឱ្យមានការរីកចម្រើនគួរឱ្យកត់សម្គាល់លើសេវាទឹកស្អាត និងអនាម័យ ជាពិសេសនៅក្នុងតំបន់ទីក្រុង។ តំបន់ទីក្រុងនៅប្រទេសកម្ពុជាមានប្រជាជនរស់នៅប្រហែល ២១,៧ ភាគរយ នៃចំនួនប្រជាជនសរុបក្នុងឆ្នាំ២០១៨ ហើយចំនួននេះ ត្រូវបានគេរំពឹងថានឹងកើនឡើងទ្វេដងនៅឆ្នាំ២០៣០។ ការកើនឡើងយ៉ាងឆាប់រហ័សនេះបង្កើតឱ្យមានតម្រូវការកាន់តែច្រើនសម្រាប់ហេដ្ឋារចនាសម្ព័ន្ធ និងសេវាសាធារណៈ ហើយការធ្វើឱ្យប្រសើរឡើងនូវហេដ្ឋារចនាសម្ព័ន្ធ និងការវិនិយោគ គឺជាគន្លឹះក្នុងការរក្សានូវការអភិវឌ្ឍក្នុងវិស័យហេដ្ឋារចនាសម្ព័ន្ធ និងនគរូបនីយកម្មកម្ពុជា។

ក្នុងចំណោមវិស័យសំខាន់ៗ វិស័យដែលត្រូវផ្តោតការយកចិត្តទុកដាក់ខ្ពស់ដើម្បីរក្សានូវនិរន្តរភាពនៃការអភិវឌ្ឍ គឺការគ្រប់គ្រងទឹកកខ្វក់។ មានបញ្ហាប្រឈមជាច្រើននៅក្នុងវិស័យនេះ រួមមាន វិសាលភាពគ្របដណ្តប់ប្រព័ន្ធលូបង្ហូរមិនគ្រប់គ្រាន់ដែលមានតិចជាង ៥% និងអត្រានៃការតភ្ជាប់ប្រព័ន្ធលូបង្ហូរមានកំរិតទាប ជាពិសេសតំបន់ដែលស្ថិតនៅក្រៅតំបន់ស្នូលនៃរាជធានីភ្នំពេញ ជាមួយនឹងការយល់ដឹងផ្នែកបច្ចេកទេសទៅលើដំណោះស្រាយបញ្ហាទឹកកខ្វក់នៅមានកំរិត។ កង្វះខាតទូទៅនៃការរៀបចំផែនការគ្រប់គ្រងទឹកកខ្វក់ និងសម្ភារៈផ្សេងៗបានបណ្តាលឱ្យមានការបង្ហូរទឹកកខ្វក់ដោយផ្ទាល់ទៅក្នុងបរិស្ថានដែលមិនត្រូវបានធ្វើប្រព្រឹត្តកម្ម បង្កឱ្យមានការបំពុលបរិស្ថាន និងគ្រោះថ្នាក់ធ្ងន់ធ្ងរដល់សុខភាព។ ដូច្នេះ វិស័យទឹកកខ្វក់ ត្រូវបានរាជរដ្ឋាភិបាលនៃព្រះរាជាណាចក្រកម្ពុជាចាត់ទុកថាជាវិស័យអាទិភាពខ្ពស់មួយដូចបានចែងក្នុងយុទ្ធសាស្ត្រចតុកោណ ដំណាក់កាលទី ៤ របស់រាជរដ្ឋាភិបាលនីតិកាលទី ៦ នៃរដ្ឋសភា (ការអភិវឌ្ឍប្រកបដោយចីរភាព និងបរិយាប័ន្ន, ការពង្រឹងការគ្រប់គ្រងនគរូបនីយកម្ម និងការរៀបចំផែនការមេអភិវឌ្ឍហេដ្ឋារចនាសម្ព័ន្ធទីក្រុង និងទីប្រជុំជនសំខាន់ៗ សម្រាប់ការគាំទ្រការអភិវឌ្ឍ ផ្លូវថ្នល់ ផ្លូវដែក និងផ្លូវទឹក ក៏ដូចជាប្រព័ន្ធផ្គត់ផ្គង់អគ្គិសនី និងទឹកស្អាត ជាពិសេស **ប្រព័ន្ធលូ និងប្រព័ន្ធប្រព្រឹត្តកម្មទឹកកខ្វក់**)។

ការអភិវឌ្ឍប្រព័ន្ធទឹកកខ្វក់មិនត្រឹមតែត្រូវការហេដ្ឋារចនាសម្ព័ន្ធប៉ុណ្ណោះទេ ប៉ុន្តែថែមទាំងត្រូវការនូវដំណើរការប្រតិបត្តិការ និងការថែទាំផ្អែកលើមូលដ្ឋានច្បាស់លាស់ ការអប់រំក្នុងសហគមន៍ ការយល់ដឹងពីលក្ខណៈបច្ចេកទេស និងការត្រួតពិនិត្យផ្នែកច្បាប់។ លើសពីនេះទៅទៀត បើគ្មានការយកចិត្តទុកដាក់ផ្នែកប្រតិបត្តិការ និងការថែទាំត្រឹមត្រូវនោះទេ ហេដ្ឋារចនាសម្ព័ន្ធអាចនឹងងាយខូចខាតដល់កំរិតមួយដែលមិនអាចជួសជុលបាន ឬមិនអាចប្រើប្រាស់ទៅតាមសក្តានុពលពេញលេញរបស់វាបាន។ ដូចនេះវាជាការចាំបាច់តម្រូវឱ្យមានប្រតិបត្តិករដែលមានជំនាញបច្ចេកទេសច្បាស់លាស់ និងការបណ្តុះបណ្តាល ហើយមន្ត្រីរាជរដ្ឋាភិបាលចាំបាច់ត្រូវគ្រប់គ្រងដំណើរការ ថែទាំ ជួសជុល ត្រួតពិនិត្យ និងអង្កេតតាមដានលើប្រតិបត្តិករ និងហេដ្ឋារចនាសម្ព័ន្ធរបស់ប្រព័ន្ធប្រព្រឹត្តកម្មទឹកកខ្វក់នេះ។

ខ្ញុំពិតជាមានសេចក្តីសោមនស្សរីករាយ ដែលសៀវភៅគោលការណ៍ណែនាំស្តីពីប្រតិបត្តិការ និងការថែទាំប្រព័ន្ធទឹកកខ្វក់នេះ ត្រូវបានបង្កើតឡើងសម្រាប់គោលបំណងលើកកម្ពស់ការគ្រប់គ្រងទឹកកខ្វក់ ទាំងជាភាសាខ្មែរ និងភាសាអង់គ្លេស ដែលនឹងផ្តល់នូវការផ្សព្វផ្សាយយ៉ាងទូលំទូលាយនៅទូទាំងប្រទេស។ សៀវភៅគោលការណ៍ណែនាំនេះ ត្រូវបានបែងចែកជា **បីជំពូក** សម្រាប់ការងារការគ្រប់គ្រងទឹកកខ្វក់៖ ជំពូកទី១ ស្តីពី **ប្រព័ន្ធលូបង្ហូរ** ជំពូកទី២ ស្តីពី **លក្ខណៈរបស់អាង/ស្រះប្រព្រឹត្តកម្មទឹកកខ្វក់តាមបែបធម្មជាតិ** ដែលជាទូទៅជាវិធីសាស្ត្រសមស្របបំផុតនៃការធ្វើប្រព្រឹត្តកម្មទឹកកខ្វក់ចេញពីលំនៅដ្ឋាន និងទឹកកខ្វក់ក្នុងទីក្រុង។ ជំពូកចុងក្រោយ គឺផ្តោតការយកចិត្តទុកដាក់លើ **ការត្រួតពិនិត្យគុណភាពទឹក** ក្រោយពីប្រព្រឹត្តកម្មរួច។ សៀវភៅគោលការណ៍ណែនាំនេះ ផ្តល់នូវព័ត៌មានបច្ចេកទេសលម្អិតស្តីពីវិធីសាស្ត្រនៃការត្រួតពិនិត្យ ការសម្អាត ការជួសជុល ការតាមដាន ការយកសំណាកទឹក និងបច្ចេកទេសតេស្ត ដែលជាតម្រូវការចាំបាច់ បំផុតសម្រាប់ប្រតិបត្តិការ និងការថែទាំប្រកបដោយប្រសិទ្ធភាពនៃប្រព័ន្ធប្រព្រឹត្តកម្មទឹកកខ្វក់។

សៀវភៅមគ្គុទេសក៍ស្តីពីប្រព័ន្ធលូបង្ហូរ និងប្រព័ន្ធប្រព្រឹត្តកម្មទឹកកខ្វក់ ដែលបានបោះពុម្ពផ្សាយដោយក្រសួងអភិវឌ្ឍន៍ទីក្រុងនៃប្រទេសឥណ្ឌា ដោយសហការជាមួយទីភ្នាក់ងារសហប្រតិបត្តិការអន្តរជាតិជប៉ុន (JICA) ត្រូវបានយកមកប្រើប្រាស់ជាឯកសារយោងសម្រាប់ការផលិតសៀវភៅគោលការណ៍ណែនាំនេះ។

ជាចុងក្រោយនេះ ខ្ញុំសូមកោតសរសើរ និងវាយតម្លៃខ្ពស់ចំពោះនាយកដ្ឋានសំណង់ប្រព័ន្ធចម្រោះទឹកកខ្វក់ ដែលជានាយកដ្ឋានក្រោមឱវាទអគ្គនាយកដ្ឋានសាធារណការ នៃក្រសួងសាធារណការ និងដឹកជញ្ជូន និងមានការកិច្ចសហការជាមួយទីភ្នាក់ងារសហប្រតិបត្តិការអន្តរជាតិអាឡឺម៉ង់ (GIZ) និងវិទ្យាស្ថានអភិវឌ្ឍន៍បៃតងសកល (GGGI) សម្រាប់ការរៀបចំឯកសារដ៏មានសារៈសំខាន់នេះឡើង។ ខ្ញុំជឿជាក់ថាវានឹងក្លាយជាមគ្គុទេសក៍ដ៏មានគុណប្រយោជន៍ដល់អ្នកដែលពាក់ព័ន្ធ នៅក្នុងការងារគ្រប់គ្រងទឹកកខ្វក់នៅក្នុងប្រទេសកម្ពុជាដែលនឹងជួយជម្រុញការអភិវឌ្ឍហេដ្ឋារចនាសម្ព័ន្ធ នគរូបនីយកម្ម និងអភិវឌ្ឍសេដ្ឋកិច្ចជាតិផងដែរ។

ថ្ងៃ...សុក្រ ១៣ រោច......ខែ មិគសិរ...... ឆ្នាំច សំរឹទ្ធិស័ក ព.ស ២៥៦២
រាជធានីភ្នំពេញ ថ្ងៃ......០៨...... ខែ......មករា...... ឆ្នាំ២០១៩

ទេសរដ្ឋមន្ត្រី

រដ្ឋមន្ត្រីក្រសួងសាធារណការ និងដឹកជញ្ជូន

ស៊ុន ចាន់ថុល

Ministerial Foreword

Cambodia has enjoyed strong economic growth over the past decade, which has helped making considerable progress in water and sanitation services, most notably in urban areas. Cambodia's urban areas are home to around 21.7 percent (2018) of its total population and is expected to double by 2030. This rapid increase creates greater demand for public infrastructure and services, and improved infrastructure planning and investments are key to sustaining growth in the urbanization of Cambodia.

Among the crucial sectors which need focus is wastewater management to sustain the development. There are still many significant challenges remaining in this sector, including minimal sewerage coverage and low connection rates, approximately less than 5% (WEPA), to sewerage outside of the core urban areas of Phnom Penh, as well as low technical awareness on wastewater solutions. The general lack of wastewater management plans and facilities is resulting in the direct discharge of wastewater into the environment without being treated, causing pollution and health hazards. Hence, wastewater is considered by the Royal Government of the Kingdom of Cambodia as a high priority as described in the Rectangular Strategies Phase 4 of the Royal Government of Cambodia of the Sixth Legislature of the National Assembly particularly in the Rectangular 4 (Inclusive and Sustainable Development) at the side 3 (Strengthening Urban Planning and Management) point 3 (Formulating an infrastructure master plan for main cities and urban areas to support the development of roads, railways and waterways as wall as electicity networks, clean water networks, espcially **sewage and wastewater treatment systems**.

Developing sanitation systems does not only require infrastructure but also well-established operational processes, community education, technical know-how and regulatory oversight. Additionally, without proper operation and maintenance, infrastructure can rapidly fall into disrepair or not be used to its full potential. This requires operators with the necessary technical skills and training, as well as government officials able to run, repair, monitor and inspect operations and infrastructure when required.

I am pleased that this guideline was developed for this purpose, in Khmer and English, which will enable broad and wide dissemination throughout the country. The guideline is divided into three chapters covering the whole wastewater management chain: the first chapter covers the **sewerage system**, the second chapter focuses on **waste stabilization ponds**, which are usually the most appropriate method of domestic and municipal wastewater treatment. The final chapter is concerned with **monitoring the water quality of effluents** following the treatment stage. The guideline offers detailed technical information on topics such as inspection, cleaning, repairing, monitoring, sampling and testing techniques required for the efficient operation of such systems.

I would like to thank the Sewerage Management and Construction Department under the Guidance of the General Directorate of Public Works of the Ministry of Public Works and Transport, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, and the Global Green Growth Institute (GGGI) for preparing this comprehensive document which I am confident will be a useful guide to anyone involved in wastewater management in Cambodia.

Finally, I would like to acknowledge the **Manual on Sewerage and Sewage Treatment Systems** published by the Ministry of Urban Development of India in cooperation with the Japan International Cooperation Agency, which was used as a basis for the development of this guideline.

Phnom Penh, , 2018

H.E. Sun Chanthol
Senior Minister
Minister of Public Works and Transport

Acknowledgement

The English and Khmer versions of this guideline were developed by the Sewerage Management and Construction Department under the Guidance of the General Directorate of Public Works of the Ministry of Public Works and Transport (MPWT), the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, and the Global Green Growth Institute (GGGI). This guideline is based on the Manual on Sewerage and Sewage Treatment Systems published by the Ministry of Urban Development of India in cooperation with the Japan International Cooperation Agency. Parts of the manual that were the most relevant were selected and adapted to the Cambodian context.
The following people contributed to the development of this document:

Prepared by:

A. Sewerage Management and Construction Department, Ministry of Public Works and Transport

1.	**Mr. Chao Sopheak Phibal**	Director
2.	**Mr. Lim Soktay**	Deputy Director
3.	**Mr. Heng Phoury**	Deputy Director
4.	**Mr. Sok Sam An**	Deputy Director
5.	**Mr. Chheng Sovanndy**	Bureau Chief of Planning and Technical Research
6.	**Mr. Chheav Sokkhim**	Bureau Chief of Operation and Legal Affairs
7.	**Mrs. Dourng Dany**	Bureau Chief of Wastewater Treatment Plant and Solid Waste Management Infrastructure
8.	**Mr. Lun Heng**	Technical Official

B. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)

9.	**Mrs. Eva Ringhof**	Program Coordinator
10.	**Ms. Mia Simpao**	Program Management Officer
11.	**Mr. Thomas Hagedorn**	Capacity Development Advisor
12.	**Mr. Nicholas van Eckert**	Head of Finance and Admin
13.	**Mrs. Bonajean Siarot**	Administrative Officer

Consulted by:

1.	**Dr. Seng Bunrith**	Consultant

Reviewed and Commented by Wastewater Management Working Group

1.	**H.E. Bong Bunhuon**	Under Secretary of State
2.	**H.E. Heng Rathpiseth**	Director General of General Directorate of Public Works
3.	**H.E. Vong Pisith**	Deputy Director General of General Directorate of Public Works
4.	**Mr. Chao Sopheak Phibal**	Director of Sewerage Management and Construction Department

Global Green Growth Institute (GGGI)

1.	**Mrs. Karolien Casaer-Diez**	Country Representative – Cambodia
2.	**Mrs. Kuy Putheary**	Senior Administration Officer
3.	**Mr. Khan Chantharo**	Program Officer
4.	**Dr. Jerome Fakhry**	Advisor

Executive Summary

As wastewater management systems are becoming more widespread in Cambodia, and with many large-scale projects in the pipeline in cities such as Sihanoukville, Battambang or Bavet, it is important that private operators and public authorities responsible for operating and maintaining these systems are equipped with the right tools and knowledge. This document contributes to this purpose by providing technical guidance to Operations and Maintenance (O&M) engineers, operators and inspectors on how to operate, inspect and maintain such systems. Appropriate O&M helps protecting the initial capital investment, prolongs the life on the systems and ensures smooth operations avoiding negative impacts on humans and the environment.

The guideline is divided into three chapters covering the whole wastewater management chain: the sewerage system, the treatment of wastewater and the control of effluent discharge. This guideline is limited in scope and not all technologies and processes are covered. For example, only waste stabilization ponds are described as treatment systems.

The first chapter focuses on the sewerage system which is required for collecting and conveying wastewater to treatment facilities prior to discharge. The sewerage system consists of pipes, conduits, pumping stations, force mains, and all other facilities used to channel wastewater from residential, industrial, and commercial sources to the treatment facilities. Various types of maintenance of a sewerage system – preventive, routine and emergency – are covered, and guidance is provided on how to inspect and examine the sewer, and what techniques and technologies are available. Guidance is then provided on sewer cleaning, including cleaning equipment and procedures, in order to minimize the number of blockages and odor issues.

Even with appropriate maintenance and cleaning, a sewerage system needs rehabilitation from time to time. The guideline covers renewal and repair methods for different components of the sewer system such as burst pipes. Finally, and importantly, safety practices when conducting these operations are detailed.

The second chapter covers the waste water treatment part of the system. While many different types of treatment technologies exist, only Waste Stabilization Ponds (WSP) are covered, which are usually the most appropriate method of municipal wastewater treatment in developing countries, where the climate is most favorable for their operation. WSP are low-cost, low-maintenance, highly efficient, entirely natural and highly sustainable. Generally, WSP have three stages of treatment: a primary anaerobic treatment, secondary facultative treatment, and tertiary aerobic treatment in maturation ponds.

This chapter describes procedures for commissioning and starting up WSP and routine maintenance. It outlines key control indicators to ensure smooth operations of the WSP such as how to care for grasses and plant species used, and controls for potential issues such as erosion, rodents, odors and solid accumulation. Finally, the biggest challenge in the management of pond systems is to identify when a pond requires de-sludging, and to carry it out safely without giving rise to environmental and human health problems. This guideline provides details on how to perform these tasks.

The final chapter is concerned with monitoring of the water quality. Water quality analysis is required to ensure compliance with existing standards prior to release into the environment, to monitor the efficiency of the treatment system, and to check whether upgrades or modifications to an existing treatment system are required. The chapter details the two main sampling methods, where to locate sampling points, precautions for sampling, sample volume, quantity and storage of samples, testing parameters and frequency. This chapter concludes by outlining typical laboratory tests generally required, data analysis and laboratory waste disposal.

Table of contents

List of Figures

List of Tables

1. Sewerage System

1.1 Introduction

Sewerage systems is an integral part of the nation's infrastructure, in particular road infrastructure. It is used to collect wastewater and convey it to wastewater treatment facilities prior to discharge. The system consists of pipelines, conduits, pumping stations, force mains, and all other facilities used to collect wastewater from individual residential, industrial, and commercial sources and convey it to the treatment facilities.

1.1.1 Definition

To ease of understanding and consistence with the definition given in sub-decree #235, the definition of some of the key technical terminologies are adopted from sub-decree #235 on "The management of drainage system and wastewater treatment system" dated on 25 December, 2017.

- **Sewage:** refer to water of which the original characteristics have been changed after usage. This includes wastewater coming out from kitchen, bathroom, laundry, washing, and toilet, including urine and faeces, of household, residential development complex (residential borey), satellite city, business building, commercial and service building, and resort or recreational center.
- **Wastewater:** refer to liquid waste which contains various pollutant substances generating from activities or direct processing of products, businesses or services.
- **Sewerage system:** refer to collection and conveyance systems – conduit connection, manhole and sewerage conduit (combined sewer, separate sewer, main pipeline, secondary pipeline, tertiary pipeline and lateral pipeline).
- **Combined Sewer:** refer to sewer collecting and conveying both wastewater and storm water together.
- **Separate Sewer:** refer to sewer/drain collecting and conveying wastewater and storm water separately.
- **Main pipeline**: refer to network conduit that connects to storage tank, pumping station or sewage treatment plant.
- **Secondary pipeline:** refer to network conduit that connects to main pipeline and receives sewage from tertiary pipeline.
- **Tertiary pipeline:** refer to network conduit that connects to the main pipeline or the secondary pipeline.
- **Lateral pipeline:** refer to network conduit that connects to tertiary pipeline and receives sewage from site or source of producers.
- **Septic tank:** refer to a storage tank which is used to collect sewage from water closet and bathroom. Then, it allows to decompose through bacterial activities prior to drain the effluent to public sewer system.
- **Sludge:** refer to wet mud or waste resulting from the septic tank or sewage treatment plant.
- **Sewage treatment system:** refer to open channel, storage tank, pumping station, main pipeline, secondary pipeline, and sewage treatment plant.
- **Natural reservoir (wetland):** refer to natural reservoir, lake, canal or public pond which is used to store and treat the sewage through natural processes.
- **Central sewage treatment plant:** refer to sewage treatment plant which is used to treat sewage from everywhere in the urban municipality, province, city and district.

1.1.2 Necessity of Maintenance

Maintenance helps to protect the capital investment and ensures an effective and economical expenditure in operating and maintaining the sewerage facilities. It also helps to build up and maintain cordial relations with the public, whose understanding and support are essential for the success of the facility. The Urban Local Bodies (ULBs) must ensure that sewerage systems are given their due importance to improve the sanitation in the country.

1.1.3 Type of Maintenance

There are three types of maintenance of a sewerage system – preventive, routine and emergency.
Preventive or routine maintenance should be carried out to prevent any breakdown of the system and to avoid emergency operations to deal with clogged sewer lines or over flowing manholes or backing up of sewage into a house or structural failure of the system.
Preventive maintenance is more economical and provides for reliability in operations of the sewer facilities.
Emergency repairs, which would be very rare if proper maintenance is carried out well, also, have to be provided forproper inspection and preventive maintenance are necessary.

1.2 Inspection and Examination of Sewer

1.2.1 Importance of Inspection and Examination

Sewer systems are intended to be a reliable method of conveying sewage from individual discharge to sewage treatment plants. Inspection and examination are the techniques used to gather information to develop operation and maintenance programs to ensure that new and existing collection systems serve their intended purposes on a continuing basis. Inspection and testing are necessary to do the following:

- Identify existing or potential problem areas in the collection system,
- Evaluate the seriousness of detected problems,
- Locate the position of problems, and
- Provide clear, concise, and meaningful reports to supervisors regarding problems.

Two major purposes of inspection and examination are to prevent leaks from developing in the sewers and to identify existing leaks so they can be corrected.

A designer's mistake and the failure in construction are directly responsible for many of the sewer failures. Due to age, deterioration of the material of the sewer by attack of hydrogen sulphide or other chemicals, settlement of foundations and leaking joints may result in the structural failure of the sewer. It takes a very long time from the onset of the first initial defect to the collapse of the sewer. A crack or a leaking joint will allow subsoil water and soil mixture to enter the sewer causing cavities around it leading to slow settlement of foundation and the eventual collapse of the sewer.

Very often soil with water is carried away below the bedding along the length of the sewer. The type of failures often gives a clue to the cause. A shear failure due to faulty foundation or movement of earth is a clean vertical break in the pipe. Excessive loading, either internally or externally, causes horizontal breaks. Breaks caused by internal pressure leads to cracks in the sewer while external overload causes the top of the pipe to be crushed. Regular inspection of the sewer can pinpoint the sewer that needs to be attended to before there is a complete failure or collapse. For preventing the above serious instances of damages to the sewer system, the maintenance engineer should establish adequate inspection and examination programs.

1.2.2 Guideline for Inspection and Examination

Documents and data that can give information on the status of sewer facilities are necessary for operation and maintenance of the facilities. However, enormous time and costs are necessary for examining and inspecting the overall information on sewer facilities that extend over a wide area.

It is recommended that a preliminary inspection be implemented to acquire with comparative ease documents and data that can be used to decide the facilities to be examined/inspected and their priority, and then decide the facilities to be finally examined and inspected for effective acquisition of data. The methodology is to first acquire the basic information through preliminary inspection for the examination and inspection of the facilities in a given length or area of the sewers as given below.

The detailed method for each process of inspection is described in the following section:

Preliminary inspection → Inspection & Examination → Judge from inspection results → Decide the necessary measure (Repair, replacement, and modification)

Table 1.1. Preliminary inspection during Defect Liability Period (DLP)

Inspection stages \ Category	Manhole	Sewer	Inverted siphon	Any other sewerage infrastructure
Initial/ first inspection	During the first 3 months of start DLP (to expose any hidden construction deflects)			
Final inspection	During the last 3 months of DLP			
Additions inspections, if DLP is > 4 years	At a frequency of every 2 years after first inspection during DLP			

Note: Defect liability periods is usually 12 months in Cambodia (subject to discuss)

Table 1.2. Preliminary inspection for Manholes & Sewers

Road & Traffic Conditions \ Category	Manhole	Sewer
Roads subjected to heavy & mixed traffic	Once a year	Once in 2 years
Roads 2m to 5m wide subject to mixed traffic	Once in 2 years	Once in 2 years
Road and lanes less than 2m wide	Once in 3 years	Once in 3 years
Demarcated & Kerb /raised footpaths (likely along main road)	Once in 2years	Once in 3 years

Table 1.3. Preliminary inspection period for other facilities

Category	Invert siphon	Force main and their appurtenance
Inspection period	Once a year	Once a year

Note: Remedial measures should be implemented immediately upon finding defects/ distress/ dysfunction in the components of the sewerage system.

1.2.3 Preliminary Inspection

During the preliminary inspection of the sewerage system, subsidence, collapse, and overflows on the roads on which sewers are laid, should be confirmed. Deformation or damage to facilities, and deposits of sand and silt are to be confirmed during observation from the manhole. If damage or possibility of damage to the facility or if any of the abnormalities listed below are confirmed during the preliminary inspection, the facility manager should examine and inspect the relevant locations for the following:

- Corrosion, wear, damage or crack in the facility
- Water infiltration
- Corrosion of steps, wear of covers, deformation of manhole, buried manhole
- Abnormal odors
- Clogging and overflowing

The suggested period of preliminary inspection is based on the best professional judgment prevailing in Cambodia conditions and shall be carried out as in Table 1.1, Table 1.2 and Table 1.3.

1.2.4 Types of Inspection and Examination

In order 988to assess the condition of the sewers inspections and examinations are necessary. There are two basic types of inspection and examination:

- Direct methods
- Indirect methods

a) Direct Inspection and Examination

This means a person walking through a sewer before it is commissioned and physically inspecting the condition visually. This shall never be done once a sewer has been put into service. Even for new sewers, the inside diameter shall be more than 2 m. All safety precautions needed for working in confined spaces shall be taken. Hitting at the sidewall with a hammer or other devise shall be totally prohibited. The only purpose it will serve will be to get a visual idea of whether the pipe joints are made fully. Once a sewer is put into service, this practice is to be banned forever.

b) Indirect Inspection and Examination

This method refers to the technology for helping to inspect instead of the person who walk through a sewer. The technology of indirect inspection and examination of the sewer is mentioned in Table 1.4.

Even though there are so many technologies available, the technology to be chosen will depend on the affordability of the user departments. A simpler and applicable technology compilation is as shown in Table 1.5.

The light and mirror are the oldest of known technologies is shown in Figure 1.1. Two successive manholes are opened and vented sufficiently for about an hour. Thereafter, a long hand-held mirror secured at 45 degrees to the handle is lowered into the bottom of the manhole and a torch light is focused on the mirror from the above so that the light beam is deflected by 90 degrees to travel horizontally through the sewer pipe and the light is seen in the opposite manhole. This is easier at dusk. This can tell whether the bore of the pipe is choked or clear or laid straight.

The closed-circuit camera is propelled through the sewer by a remote-controlled wired power supply from a van and travels through the sewer and relays the picture of the inside to a TV in the van. The sonar system is similar. A robot is sent through the sewer and it emits high frequency sound waves, which impinge on the pipe surfaces and returns to the emitter as a reflection. By knowing the material of construction of the sewer pipe walls, this can be programmed to verify the structural condition of the wall of the sewers.

Table 1.4. Methods of indirect inspection and examination of the sewers(EPA/600/R-09/049 | May 2009)

Technology		Sewer type: Gravity	Sewer type: Force main	Sewer type: Lateral	Pipe material	Pipe diameter (mm)	Defect detected: Internal conduit	Defect detected: Pipe wall	Defect detected: Leakage	Defect detected: Pipe support
Camera	Digital cameras	✓			Any	150 - 1500	✓	✓	✓	
	Zoom camera	✓			Any	> 150	✓	✓	✓	
	Push-camera			✓	Any	≤ 300	✓	✓	✓	
Acoustic	In-line leak detectors	✓	✓		Any	≥100			✓	
	Monitoring systems		✓		PCCP	≥450		✓		
	Sonar/ ultrasonic	✓	✓		Any	≥50	✓	✓		
Electrical/Electro-magnetic	Electrical leak location	✓	✓	✓	Non-ferrous	≥75			✓	
	Remote field eddy current	✓	✓	✓	Ferrous, PCCP	≥50		✓	✓	
	Magnetic flux leakage	✓	✓	✓	Ferrous	50 – 1400		✓		
Electrical/ Electro-magnetic	Laser profiling	✓	✓		Any	100 – 4000	✓	✓		
Innovative technologies	Gamma-gamma logging	✓	✓	✓	Concrete	Not yet define				✓
	Ground penetrating radar	✓	✓	✓	Any	Not yet define			✓	✓
	Infrared thermograph	✓	✓	✓	Any	Not yet define			✓	✓
	Micro-deflection	✓			Brick	Not yet define		✓		✓
	Impact echo / SASW	✓			Brick/ Con-crete	>1800		✓		

** PCCP = Prestressed Concrete Cylinder Pipe, SASW = Spectral Analysis of Surface Waves*

Table 1.5. Sewer system inspection technologies considered applicable to Cambodia condition

NO	Technology	Application		
		Sewer Size	Sewer Material	Sewer Condition
1	Light and Mirror	Up to 300 mm	Any	Empty
2	Closed Circuit Camera	Any size	Any	Empty
3	Sonar Systems	Any size	Any	Fully flowing

Figure 1.1. Mirror test and mirror with rod

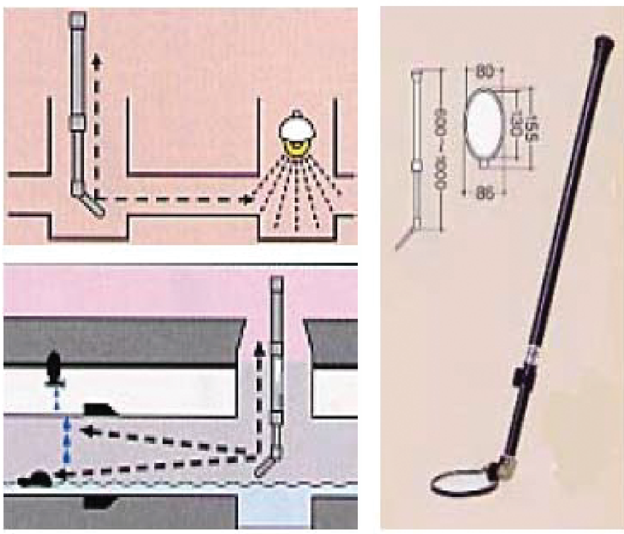


Figure 1.2. Tree roots and sewers

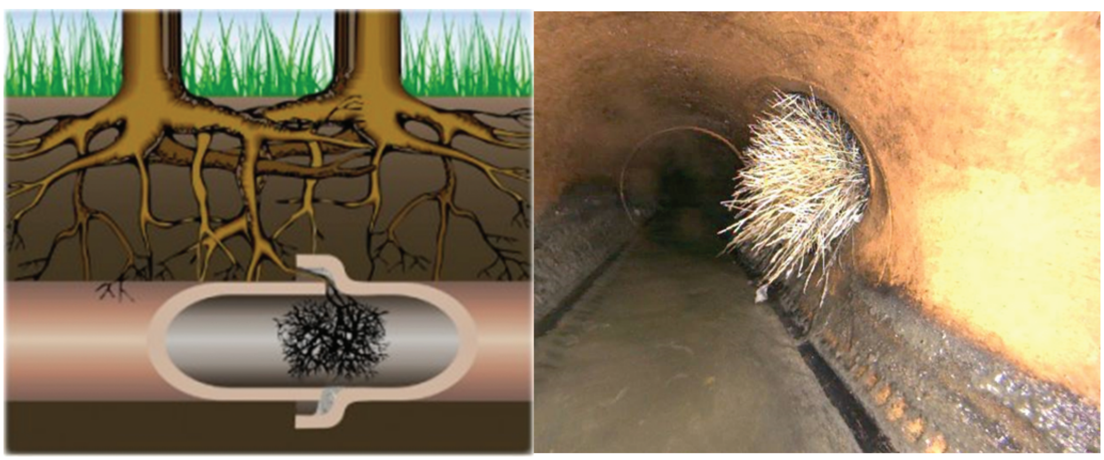
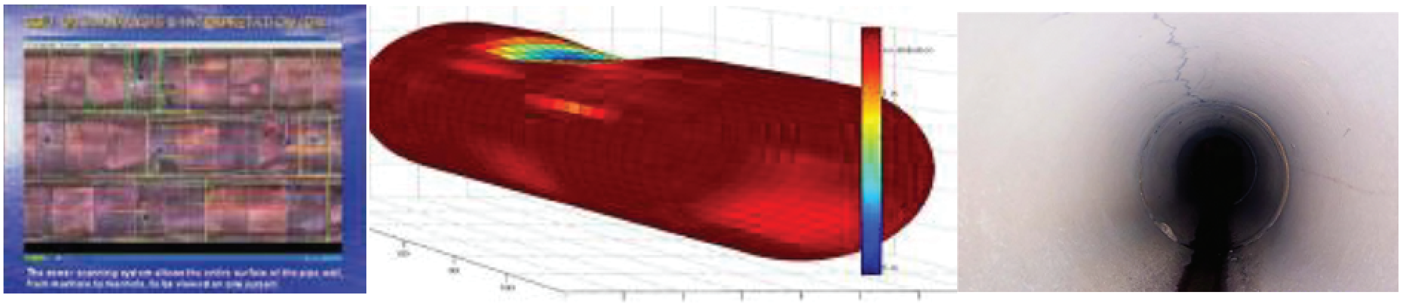


Figure 1.3. Photographs showing Structural Damage and Longitudinal cracked condition of the Sewer



A classical problem encountered in stoneware sewers laid through light forest or heavy garden areas is the roots of trees piercing through the joints and growing inside the sewers. These become like a plug and choke the sewer. This is shown in Figure 1.2. On the right is the photo of the bunch of roots inside the sewer taken by a CCTV camera.

Similarly, the structural condition of old sewers like brick arch sewers and concrete pipes can be ascertained by sonar surveys, which can provide the frontal image of the wall on a 360-degree vertical spiral around the horizontal axis. These images can be analyzed carefully. The system can also provide information on the deflection and sidewall breakages of the sewer as in Figure 1.3.

1.2.5 Sewer and Manhole Inspection and Examination

If an abnormality is detected during preliminary internal inspection or externally noticed from outside, the maintenance engineer should judge the urgency and the content of the abnormality, and then make a proper inspection and study. Most sewer lines and manholes are inspected using one or more of the following techniques:

a) Visual Examination

Visual examination is an inspection through images or by sight to detect an abnormality and includes direct visual inspection, and indirect visual inspection using pole-mounted inspection camera, and closed-circuit TV equipment (CCTV).

- **Manhole visual inspection**

The visual inspection of manhole is performed by visually checking the manhole cover and the environment of the internal parts of the manhole. To inspect the internal parts of the manhole, the inspector should enter the manhole with proper safety. The visual manhole inspection is targeted for the following items:

- Status of internal surface of manhole
- Status of sewer on the upstream and downstream sides viewed from the manhole
- Status of groundwater infiltration

To inspect the internal parts of the sewer from the manhole, either a mirror or a strong light should be used for observation, or a TV camera meant for inspecting conduits should be used.

Features of manhole visual inspection

- Inspection accuracy is high because the inspector actually observes the abnormality personally.
- Economical compared to inspection using a TV camera.
- The inspected results become very useful O&M data.

The procedure for manhole visual inspection is shown in Figure 1.4.

- **Pole-mounted TV inspection camera**

A pole-mounted TV camera consists of an extendable operating rod at the front of which a camera and light are fitted. This arrangement is inserted in the manhole from the ground, and the inspector on the ground observes a monitor and inspects the internal parts of the pipe through the camera. The detail of equipment and operation shown in Figure 1.5.

Figure 1.4. Manhole visual inspection procedure

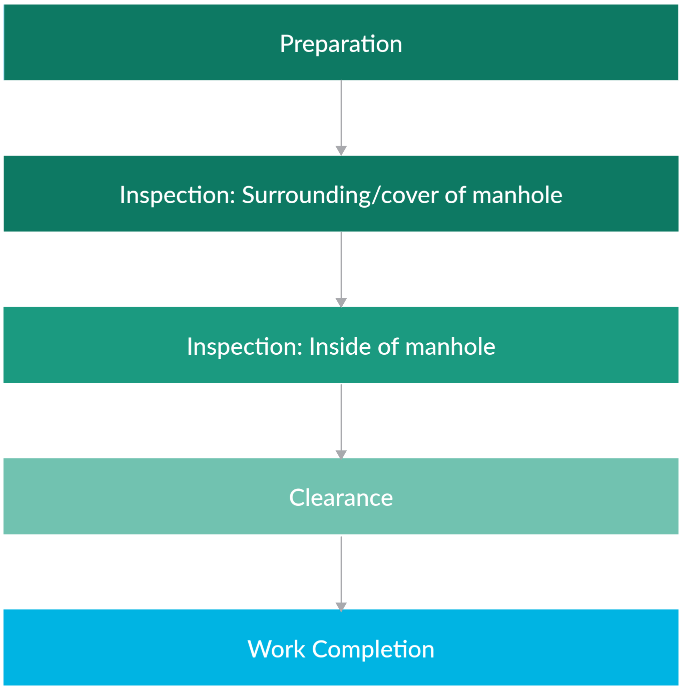


Figure 1.5. Illustration of pole-mounted TV camera inspection

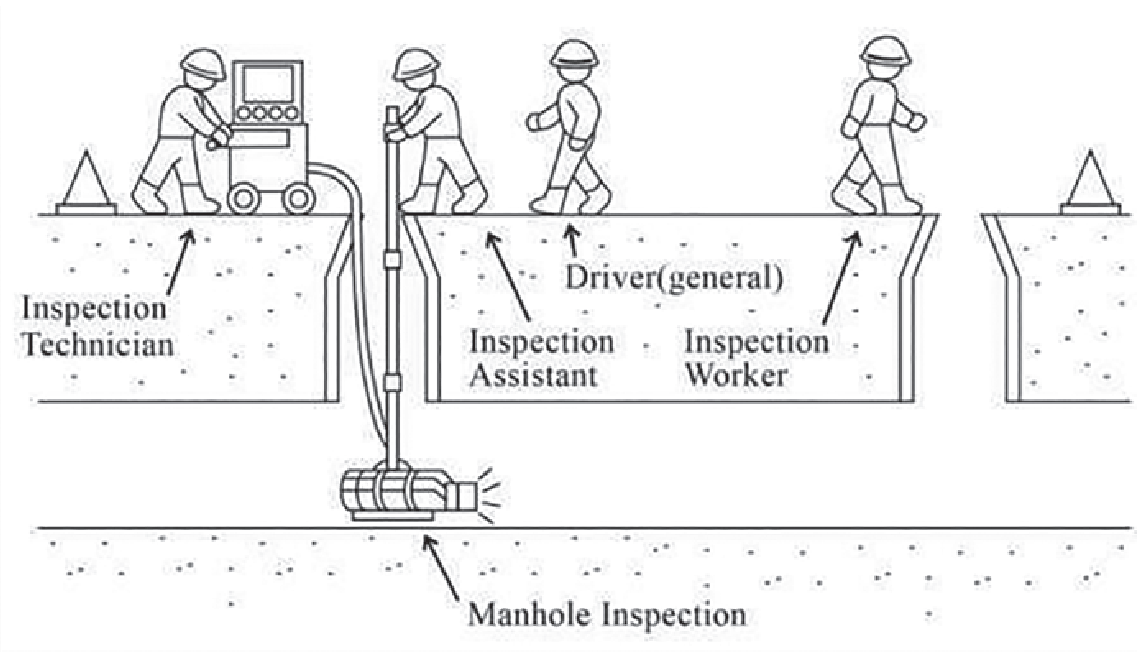


Table 1.6. The advantages and disadvantages between direct visual method and TV camera

Advantages	Disadvantages
The inspection is easy and observations can be made in a short period. Moreover, the data of inspection can be recorded as images.	The scope of inspection is limited to the area around the mouth of the pipe.
Since the inspector works above ground, there is no chance of oxygen deficiency or accidents by fall, and the work is safe.	Offset in the horizontal direction or fine cracks cannot be detected.
	The condition of the side surfaces in the sewer pipe cannot be grasped (sides cannot be viewed).

The features of direct visual inspection are compared with those inspected by TV camera and shown in Table 1.6.

- **Closed-conduit Television inspection (CCTV)**

Television (TV) inspections are the most frequently used, most cost efficient in the long term, and most effective method to inspect the internal condition of a sewer. The closed-circuit TV camera is a type of Television inspection which is propelled through the sewer by a remote-controlled wired power supply from a van and travels through the sewer and relays the picture of the inside to a TV in the van. The CCTV inspections can be operated with sewer lines having diameter range of 150 – 1,200 mm. The larger diameter pipes may also be inspected by CCTV.

Frequently, CCTV inspection can be used for various purposes:

- Require a contractor or construction agency to correct defects observed in the new sewers prior to acceptance.
- Identify or verify exact locations of service connections and other pipe construction points and correct any as built map as needed.
- Establish priorities for corrective work in old pipes on a “as needed” basis.
- Provide for maximum effective and economical use of manpower and equipment for a preventative maintenance program covering an entire collection system.
- Inspect construction of health service connections to the lateral and branch sewers. Determine by observation of those connections if infiltration, roots, debris accumulation and some type of internal inflow are adversely affecting the capacity of sewers.

CCTV system consists of the following components which are normally included in some sort of permanently mounted van or trailer - Television camera, Camera light, Power cable reel and video unit, Television picture monitor, System power control center or module, Portable power source, Camera carrying skids, Camera pulling winch, Camera return winch, Footage counter, Sound power telephone communication system, Float liner pipe stringing line, Television cable reel with slip rings, Video tape recording equipment, and Video footage reel.

The CCTV camera must be assembled to keep the lens as close as possible to the center of the pipe. In larger sewers, the camera and lights are attached to a raft, which is floated through the sewer from one manhole to the next. To see details of the sewer walls, the camera and lights swivel both vertically and horizontally. In smaller sewers, the cable and camera are attached to a sled, to which a parachute or drogue is attached and floated from one manhole to the next. The illustration of the CCTV camera inspection and inspection procedure are presented in Figure 1.6 and Figure 1.7, respectively.

b) Inspecting Infiltration of Water

If infiltration of water is more corresponding to the planned water flow in the sewerage system, the pipelines and treatment facilities will be adversely affected.

This also leads to an increase in the treatment costs of the sewage treatment plant (STP). The cause of infiltration of water is either the pipeline is inadequate or the drainage system is inadequate.

Figure 1.6. Illustration of CCTV camera inspection

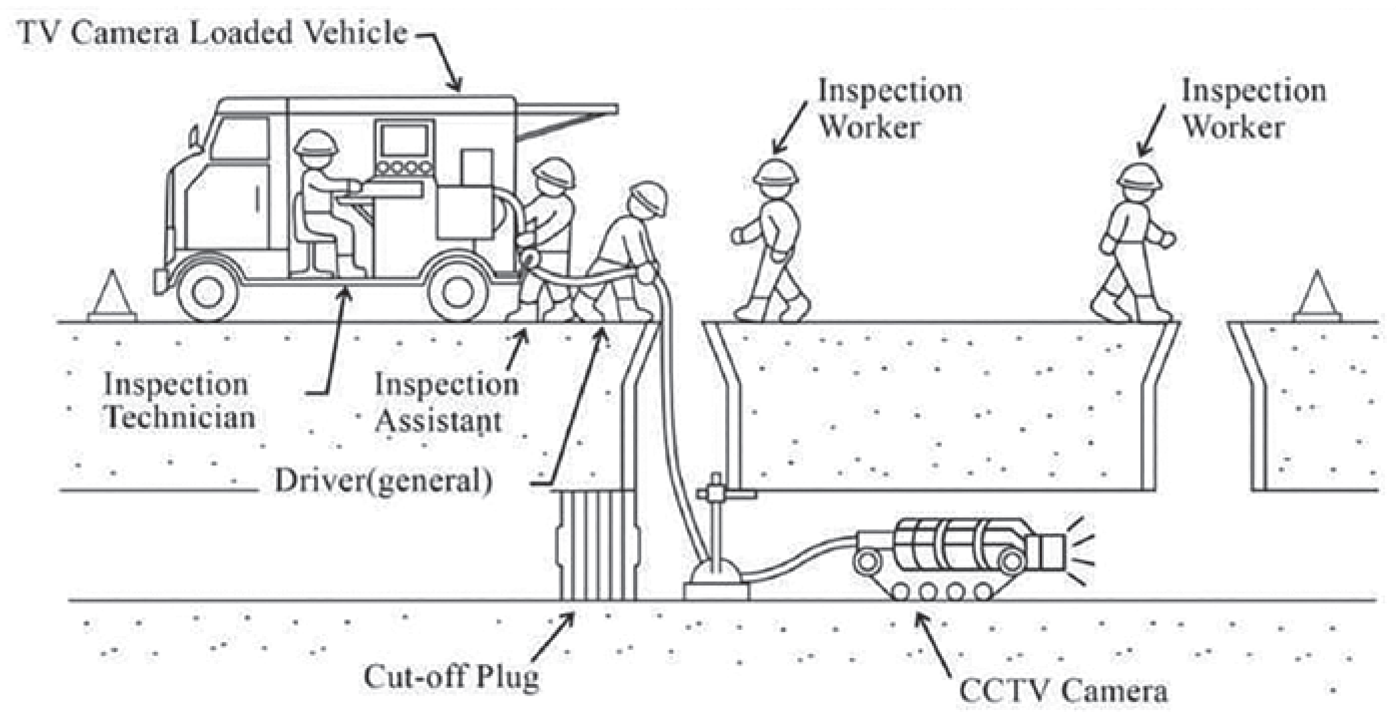
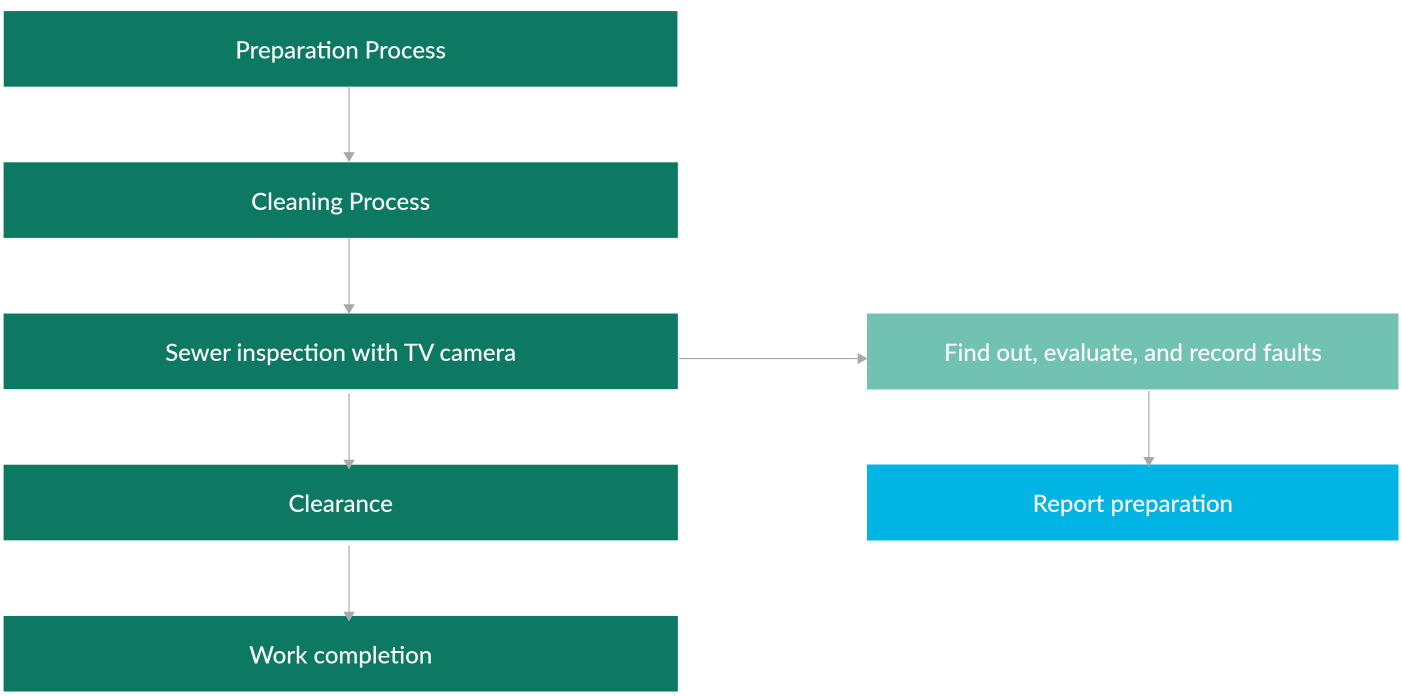


Figure 1.7: Operation procedure for CCTV camera inspection



For this reason, inspection of cross connections, flow-rate inspection and waterproofing inspections need to be combined and the route of water infiltration should be checked. Flow-rate inspections help since useful data for improvements and modifications to the piping facilities can be collected.

- **Inspecting Cross Connections**

Inspection has to be performed to check that storm water equipment is not connected to the sewers in a separate sewer system. The scope of work is from the main pipe of the sewerage works to the house drainage facility.

There are three typical methods for inspecting cross connections such as smoke test, echo sound test and dye test.

- **Smoking Test**

Smoke testing is a simple process that consists of blowing smoke mixed with large volumes of air into the sanitary sewer line usually induced through the manhole. The smoke travels the path of least resistance and quickly shows up at sites that allow surface water inflow. Smoke will identify broken manholes, illegal connections including roof drains, sump pumps and yard drains, uncapped lines and even will show cracked mains and laterals, providing there is a passageway for the smoke to travel to the surface. Smoke testing is a method of inspecting both the main lines and laterals. Smoke travels throughout the system, identifying problems in all connected lines—even sections of line that were not known to exist or thought to be independent or unconnected. Best results are obtained during dry weather, which allows smoke better opportunity to travel to the surface.

The necessary equipment used for smoke testing operation are blower, smoke generator/materials. There are two types of smoke currently available for smoke test: classic smoke candles and smoke fluids. The detail of each equipment shown as following:

- Blower unit which is usually a squirrel cage blower with a gasoline engine and belt drive. The average blower capacity will be over 3,000 m3/hr. and under 5,000 m3/hr. The blower will have a base with rubber gasket underneath the base that permits it to set over and force a blast of air into an open manhole.

- Smoke candles are used by simply placing on the fresh air intake side of the blower. Once ignited, the exiting smoke is drawn in with the fresh air and blown down into the manhole and throughout the system. Smoke candles are available in various sizes that can be used singularly or in combination to meet any need. This type of smoke is formed by a chemical reaction, creating a smoke that contains a high content of atmospheric moisture. It is very visible even at low concentrations and extremely effective at finding leaks.

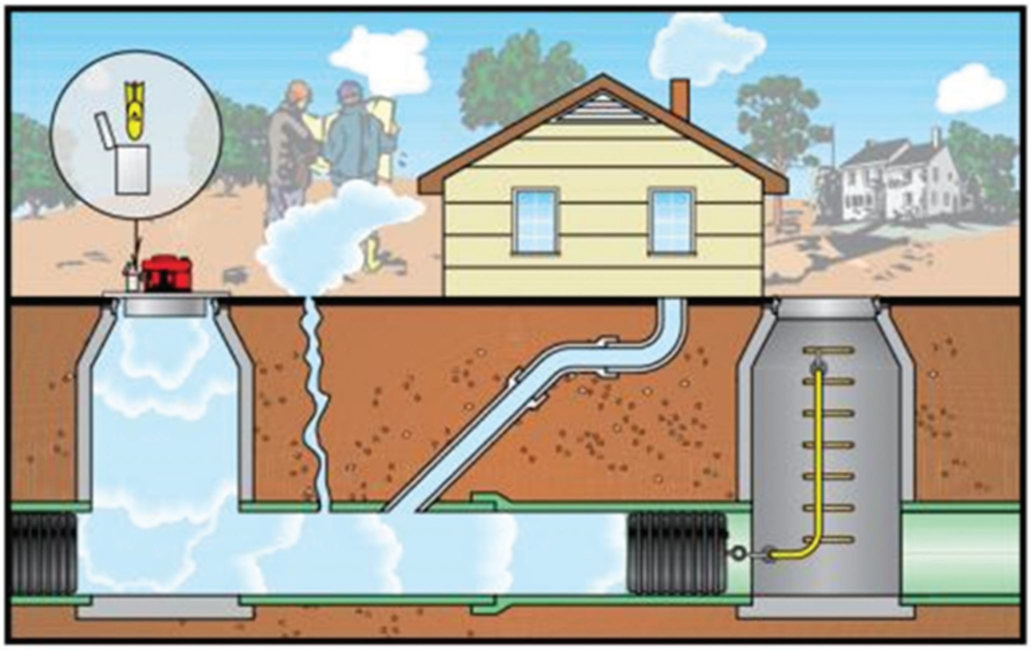
- Another available source of smoke is a smoke fluid system. They certainly can be used effectively, but it is important to understand how they work. This system involves injecting a smoke fluid—usually a petroleum-based product—into the hot exhaust stream of the engine where it is heated within the muffler (or heating chamber) and exhausted into the air intake side of the blower. One gallon of smoke fluid generally is less expensive than 12 smoke candles. However, smoke fluids do not consistently provide the same quality of smoke. When using smoke fluid, it is important to understand that as fluid is injected into the heating chamber (or muffler) it immediately begins to cool the unit. The heating chamber eventually will reach a point where it is not hot enough to completely convert all the fluid to smoke, thus creating thin/wet smoke. This actually can happen quickly depending on the rate of fluid flow. If the smoke has become thin, it can be especially difficult to see at greater distances. Blocking off sections of line usually is a good idea with any type of smoke but becomes almost a necessity when using smoke fluid.

The sketches of smoke testing and the summary work procedure was shown in Figure 1.8 and Figure 1.9, respectively.

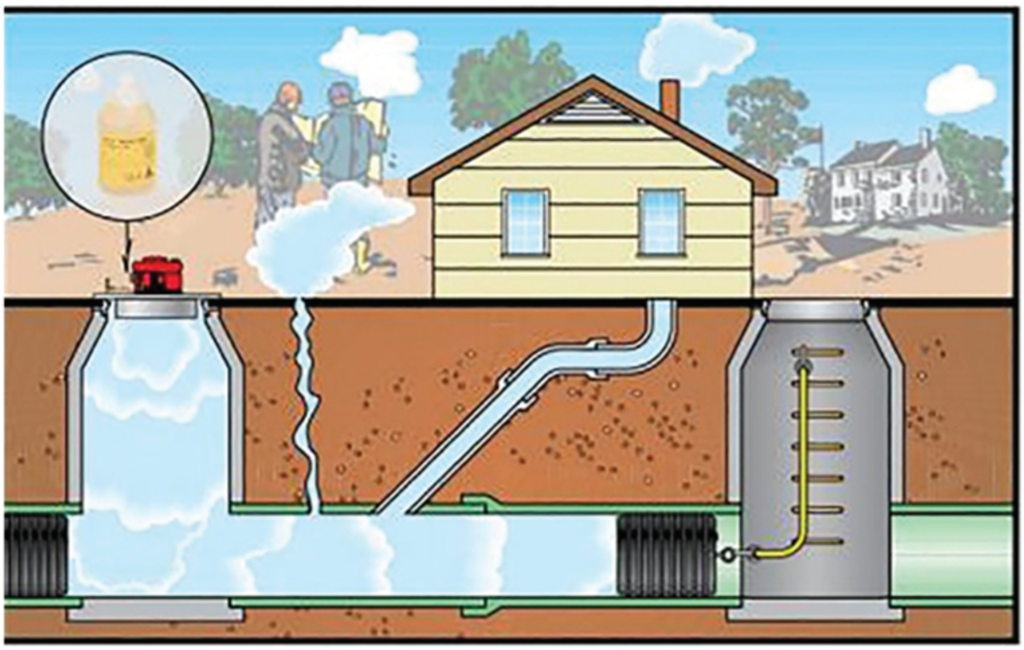
- **Echo sound test**

This is a method for confirming that piping facilities are correctly connected, and is also an effective method for knowing the plumbing systems and the routes of sewers and lateral sewers. Ultrasonic waves are used (transmitter and receiver). The sketch of echo sound test method and work procedure are shown in Figure 1.10 and Figure 1.11, respectively.

Figure 1.8. Illustrative Sketches of Smoke Test



Traditional Smoke Operations



Liquid Smoke Fluid Operations

Figure 1.9. Operation procedure for smoke test

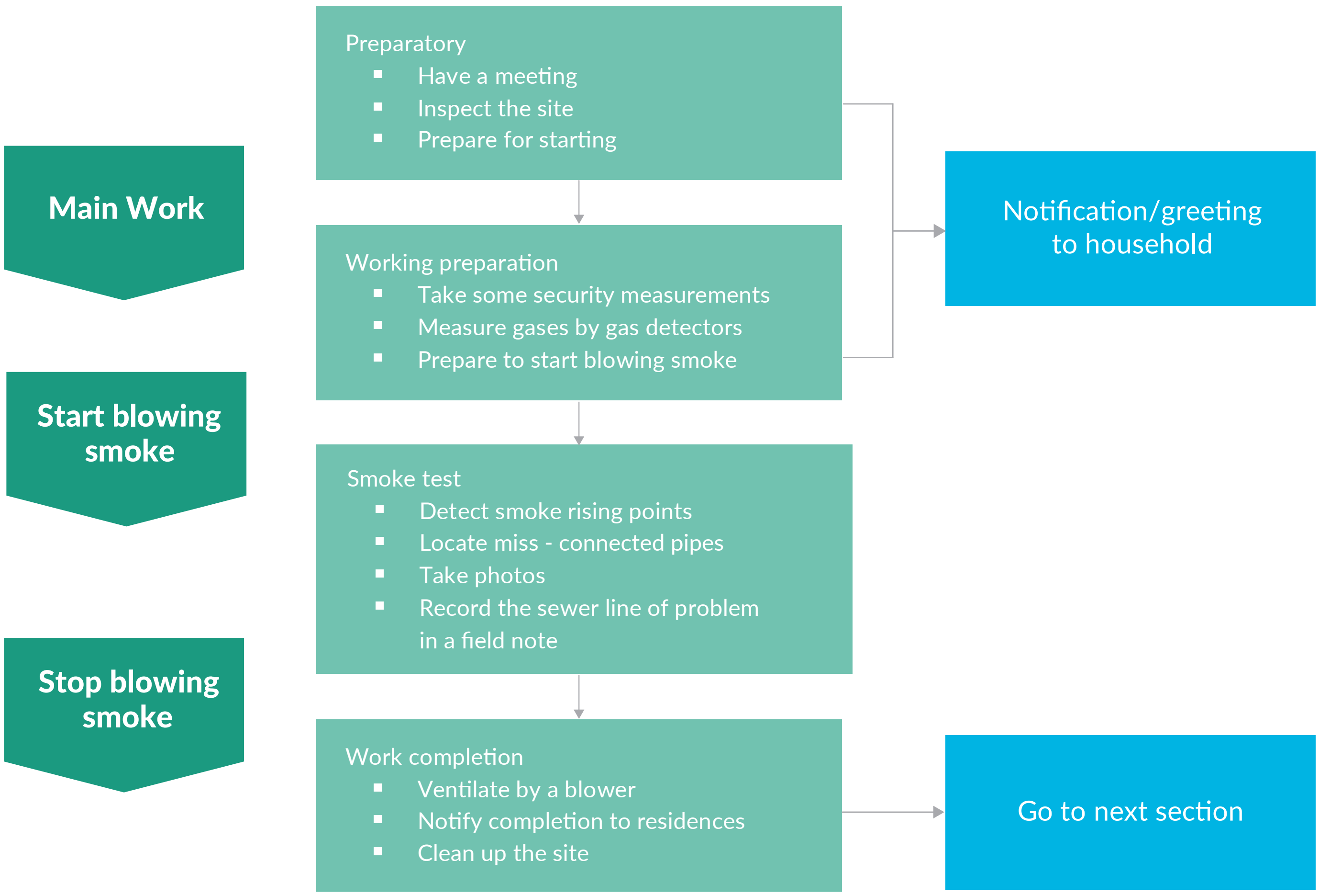


Figure 1.10. Illustration of Echo Sound Test

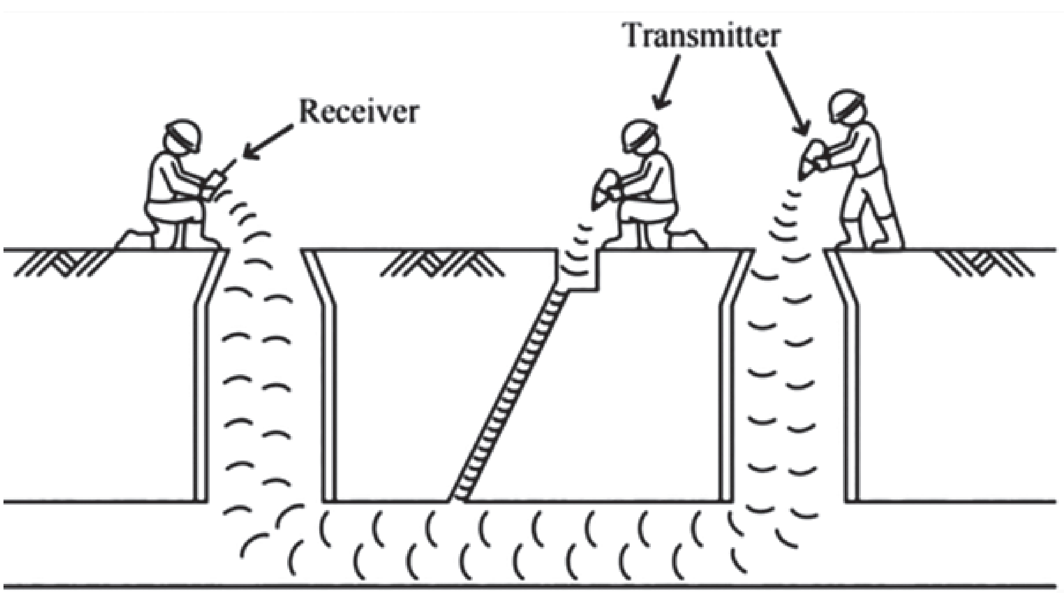
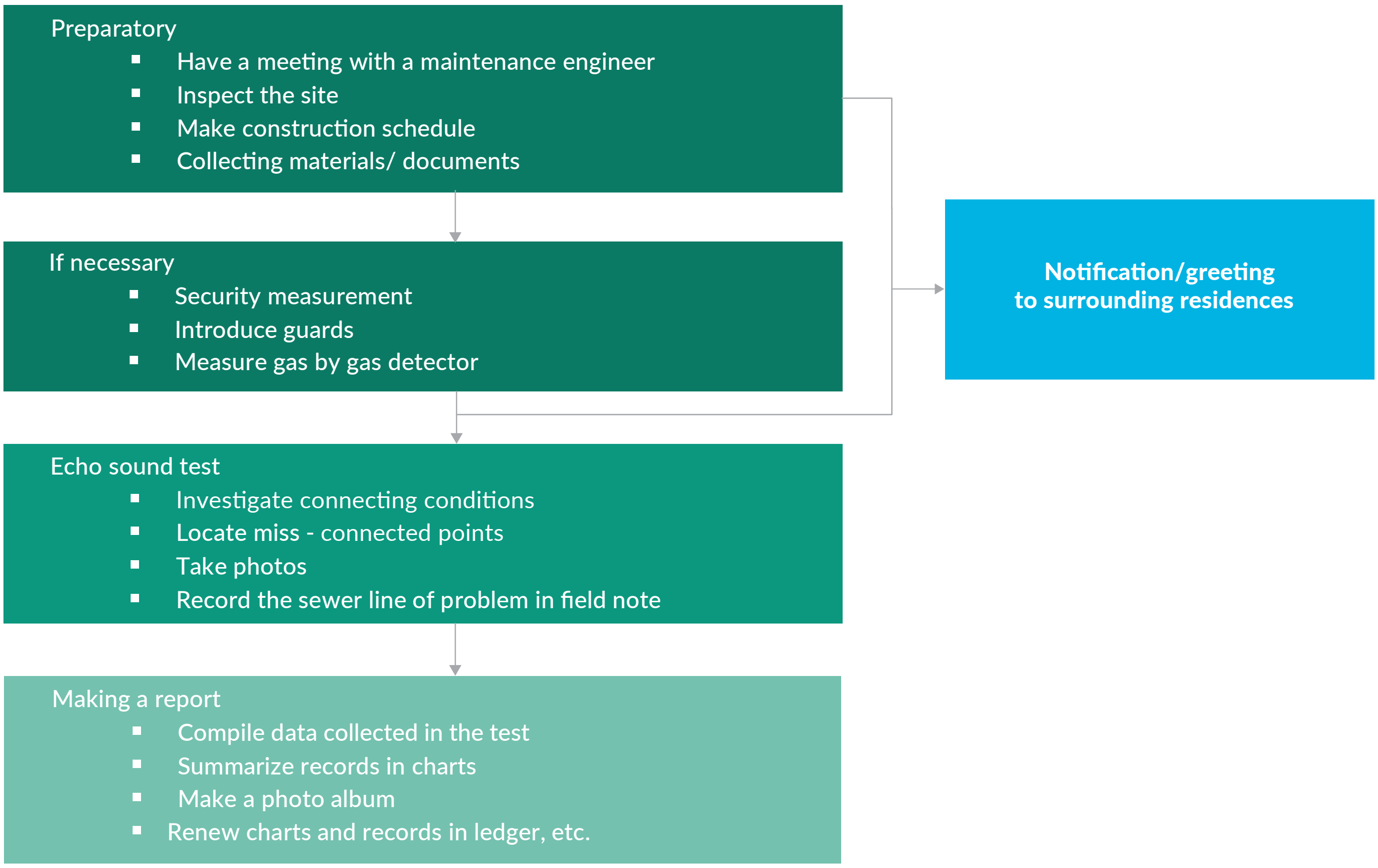


Figure 1.11. Operation procedure for Echo sound test



Features of the echo sound test

- Simple method to confirm that a pipe has been connected or not.
- Effective especially in the connections of lateral sewers.
- Cannot judge clogging or trap.

- **Dye test**

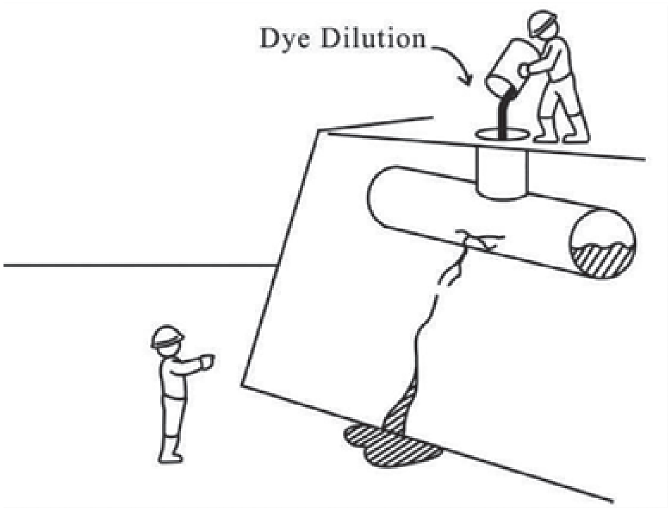
Dye test is being used to identify if certain facilities or fixtures are connected to a wastewater collection system, illegal connections, and overflowed or leaked sewer. Dye test is also used to reveal interconnections between sanitary and storm sewers. Special dye is available for this type of testing.

Examples of typical dye tests include: buildings that may not show smoke at vents during smoke test due to dips or traps in the service connection pipes, yard or storm drain is suspected of being tied to the building sewer or a lateral sewer, and any suspected situation of inflow or surface drainage into the collection pipe.

Other uses of dye testing include estimating the velocity of flow, and testing for infiltration and exfiltration. By pulling a bag of dye up a sewer and stopping at short intervals, an area of extraction can be located that could not be seen on TV inspection such as an open joint that is in line and on grade.

In order to operate dye testing well, while one operator applies the dye to the suspected location, another operator maintains a watch at the next downstream manhole from the location. Where a plumbing fixture is used, such as a closet bowl or basin, the water is turned on and the dye powder or tablet is dropped directly into the drain. Where there is no immediate supply of water, such as a roof gutter or storm drain in dry weather, pouring a bucket of water with dye powder is suggested. The amount of water and dye needed depends on the distance to the next manhole and the existing flow. Based on an assume velocity of flow, an estimate may be made of the expected flow time to the downstream manhole. Allow plenty of time because the dye often takes much longer than expected. When a number of dye tests are to be conducted on the same line or section of sewer system, the dye testing should start the facility farthest downstream and progressively work upstream for the other dye tests. Otherwise, if you dye the facilities upstream first, the flow is then must wait several hours or until the next day to conduct additional tests. The dye testing method is shown in Figure 1.12.

Figure 1.12. Drawing of dye test



c) Inspecting Flow Rate

The flow rate resection should be carried out at locations where possibility of infiltration is high, e.g. where groundwater level is high, at a part of a river crossing, or at a location adjacent to rivers.

- **Flow Rate Measurement**

Flow may be measured on an instantaneous or a continuous basis. A typical continuous system consists of a primary flow device, a flow sensor, transmitter, flow recorder, and totalizer. Instantaneous flow measurements can be obtained by using the primary flow device.
The heart of a typical continuous flow measurement system is the primary flow device. This device is constructed to produce predictable hydraulic responses which are related to the flow rate of water or wastewater through it. Examples of such devices include weirs and flumes which relate water depth (head) to flow, Venturi and orifice type meters which relate differential pressure to flow, and magnetic flow meters which relate induced electric voltage to flow. These standard primary flow devices, if installed and built according to established standards, have proven to be accurate.

A flow sensor is required to measure the particular hydraulic responses of the primary flow measurement device and transmit the responses to the recording system. Typically, sensors include ultra-sonic transmitters, floats, pressure transducers, capacitance probes, differential pressure cells, electromagnetic cells, etc. The sensor signal is generally converted using mechanical, electro mechanical or electronic systems into units of flow which are recorded directly on a chart or transmitted into a data system. Systems which utilize a recorder are generally equipped with a flow totalizer which displays the total flow on a real time basis.

An important consideration for the investigator during wastewater studies is to obtain continuous flow data at a facility where only instantaneous flow data are being taken. If an open channel primary flow device is utilized for making instantaneous measurements, only the installation of a portable field sensor and recorder is necessary

Wastewater flow measurement systems are generally very accurate. Any continuous flow measurement system that cannot measure the wastewater flow within ±10 percent of the actual flow is considered unacceptable for use in measuring wastewater flow.

- **Pumping Test**

This is a method for measuring the flow rate of water that has infiltrated the pipeline. The flow rate of infiltrated water into the space or the system can be known within a short time. However, the flow rate of infiltrated water varies with the variation in groundwater and thereafter, precipitation and weather at the time of measurement should be confirmed.

To drain out household wastewater from the test during inspection of each space, a cut-off plug should be installed. This should preferably be implemented during the night time when the volume of household sewage generated is small. The image of pumping test and the work procedure was shown in Figure 1.13 and Figure 1.14, respectively.

Figure 1.13. Diagram of pumping test

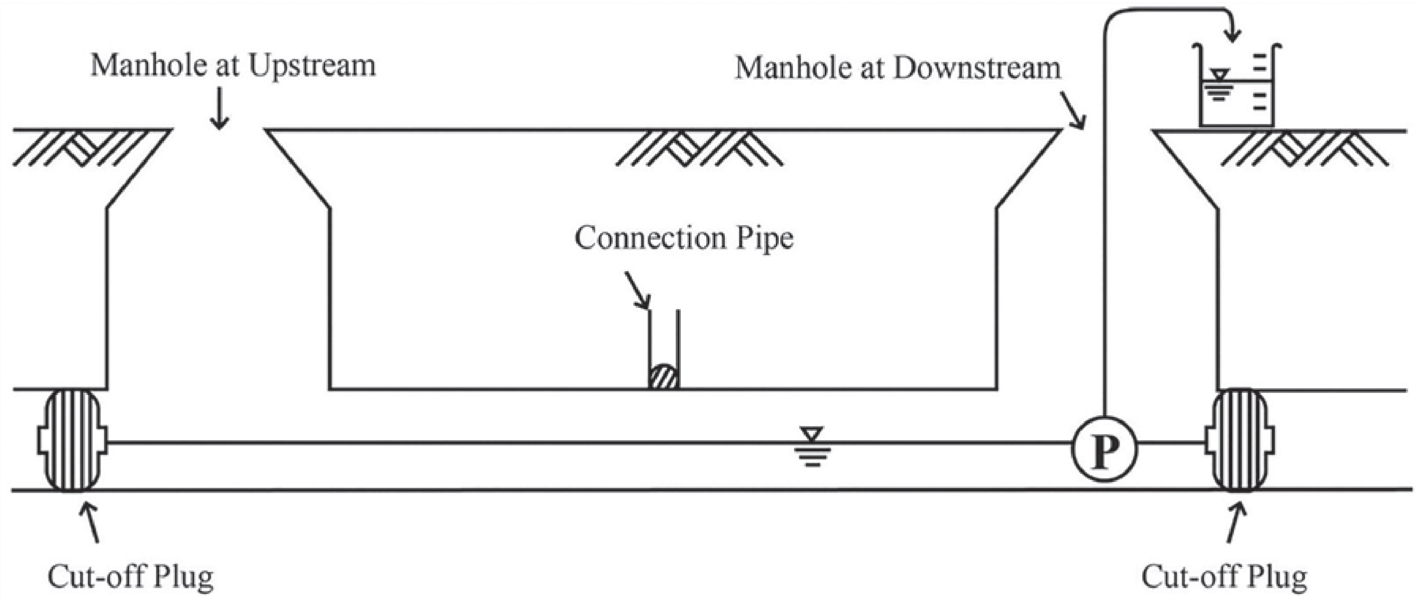


Figure 1.14. Work procedure of pumping test

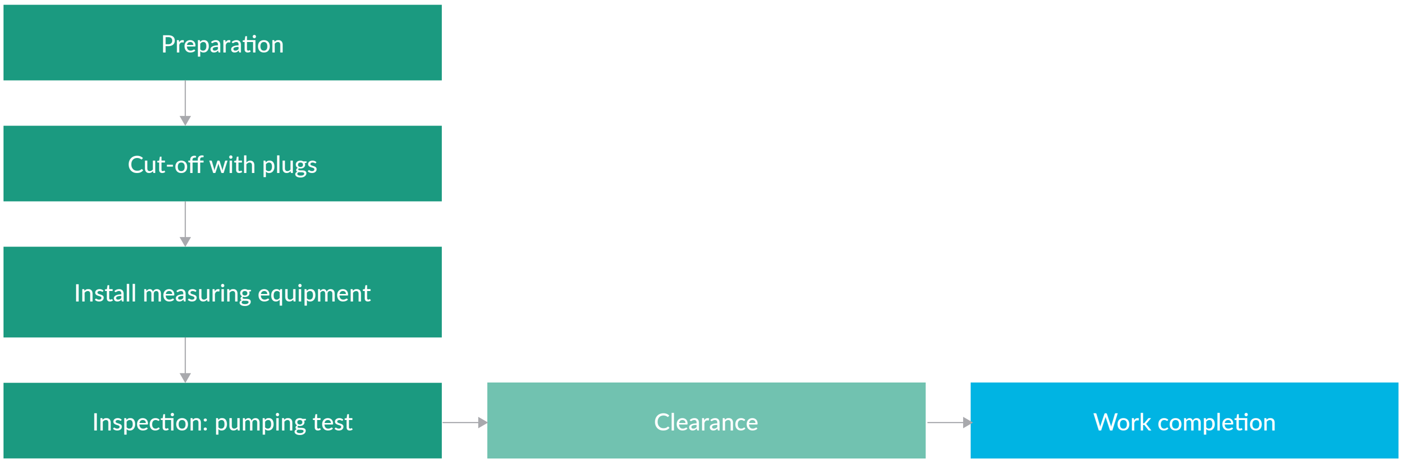


Table 1.7. Gas analysis

Name of Gas	Symbol	Unit
Carbon monoxide	CO	%
Carbon dioxide	CO_2	%
Hydrogen sulphide	H_2S	ppm
Ammonia	NH_3	ppm
Oxygen	O_2	%
Methane	CH_4	ppm
Nitrogen Oxide	NO_x	ppm

Features of measurements during pumping test are

- The flow rate of infiltrated groundwater for each space or system can be measured within a short time.
  The measured values differ widely depending on the variation in the groundwater level.
- During measurements of several spaces or each system, it is difficult to remove household wastewater late at night.

d) Inspecting Corrosion and Deterioration

The status of deterioration or corrosion within the sewer should be judged by TV camera. The materials in the piping facility are of various kinds: concrete pipe, ceramic pipe, hard unplasticized polyvinyl chloride (uPVC), brick, high density polyethylene (HDPE) pipe, ductile pipe, and glass fiber reinforced plastic (GRP) pipe; and hence the corrosion and deterioration conditions vary.

Methods for inspecting corrosion and deterioration conditions of a sewer include the following:

- Inspection by TV camera of the wall surface condition
- Crack inspection
- Neutralization test

The causes of deterioration of structural concrete parts of the piping facilities are the following:

- Crack in concrete due to concentrated loads (live loads)
- Deterioration of structure due to changes with aging
- Deterioration of concrete structures (concrete corrosion) due to sulphuric acid from the generation of hydrogen sulphide

In a facility where sewage resides for a long period, sewage is likely to become anaerobic and dissolved sulphide will be generated, which leads to concrete corrosion because of its formation to sulphuric acid. Locations where concrete corrosion is likely to occur in sewage:

- Piping facilities at the discharge destination of pressure pipe (including manhole pump)
- Upstream and downstream ends of locations where sump discharge occurs
- Upstream and downstream ends of locations where discharges containing sulphide occurs
- Locations downstream of inverted siphon

Table 1.8: Testing criteria for overall sewer span

<table>
<tr><th colspan="2" rowspan="2">Items</th><th colspan="3">Rating</th></tr>
<tr><th>(A)</th><th>(B)</th><th>(C)</th></tr>
<tr><td colspan="2">Corroded pipe</td><td>Reinforcing bars exposed</td><td>Aggregate expose</td><td>Rough surface</td></tr>
<tr><td rowspan="3">Vertically deflected pipe</td><td>ID < 700 mm</td><td>≥ ID</td><td>ID = 1/2 ID</td><td>< 1/2 of ID</td></tr>
<tr><td>ID 700 – 1650 mm</td><td>≥ 1/2 of ID</td><td>1/2 ID - 1/4 ID</td><td>< 1/4 of ID</td></tr>
<tr><td>ID ≥ 1650 mm</td><td>≥ 1/4 of ID</td><td>1/4 ID - 1/8 ID</td><td>< 1/8 of ID</td></tr>
</table>

Table 1.9: Testing criteria for each pipe of sewer

<table>
<tr><th colspan="2" rowspan="2">Items</th><th colspan="5">Rating</th></tr>
<tr><th>(a)</th><th colspan="2">(b)</th><th colspan="2">(c)</th></tr>
<tr><td rowspan="4">Ruptured pipe</td><td rowspan="2">Reinforced concrete pipes, etc.</td><td>Partially missing/ holed pipe</td><td colspan="2" rowspan="2">Axial crack of 2 mm width or more</td><td colspan="2" rowspan="2">Axial crack of less than 2 mm width</td></tr>
<tr><td>Axial crake of 5 mm width or more</td></tr>
<tr><td rowspan="2">Stoneware pipes</td><td>Partially missing/ holed pipe</td><td colspan="2" rowspan="2">Axial crake shorter than 1/2 of the pipe length</td><td colspan="2" rowspan="2"></td></tr>
<tr><td>Axial crake of 1/2 of the pipe length and longer</td></tr>
<tr><td rowspan="2">Cracked pipe</td><td>Reinforced concrete pipes, etc.</td><td>Circumferential crack of 5 mm width more</td><td colspan="2">Circumferential crack of 2 mm width or more</td><td colspan="2">Circumferential crack of less than 2 mm width</td></tr>
<tr><td>Stoneware pipes</td><td>Circumferential crack of 2/3 of the pipe circumference and longer</td><td colspan="2">Circumferential crack shorter than 2/3 of the pipe circumference</td><td colspan="2"></td></tr>
<tr><td colspan="2" rowspan="2">Gap at coupling pipes</td><td rowspan="2">Slip off (Joint displacement)</td><td>Reinforced concrete pipes, etc.</td><td>≥ 70 mm</td><td>Reinforced concrete pipes, etc.</td><td>≥ 70 mm</td></tr>
<tr><td>Stoneware pipes</td><td>≥ 50 mm</td><td>Stoneware pipes</td><td>≥ 50 mm</td></tr>
<tr><td colspan="2">Infiltration</td><td>Splashing in</td><td colspan="2">Flowing in</td><td colspan="2">Soaking</td></tr>
</table>

e) Other Examinations

Special examinations to study in detail the conditions of a facility are as given below. For more details, please refer to relevant documents for each item. Various kinds of information relevant to analysis for studying gas exploration are given.

- Sewer invert elevation examinations: Understanding pipeline conditions and collating with sewerage facility records.
- Sediment examination: Check sediment material, such as sand and silt, which may have entered damaged sewer or through loose joints from outside the sewer. This sand and silt may accumulate around the sewer and form voids.
- Dangerous gas detection examination: Confirming gases generated in the piping facilities. Water quality and gases encountered in a piping facility are closely related. Table 1.7 shows the gas analysis items in a piping facility.

Few of the key gases are very important monitoring parameters to avoid gas-related accidents to the workers of sewer/drainage maintenance team. This include hydrogen sulphide, carbon monoxide and oxygen deficiency.

f) Precautions

Cleaning equipment and machinery for sewers are shown in the following sections:

When entering manholes, safety measures during the work should be to ensure traffic safety, prevent oxygen deficiency, precautions against hydrogen sulphide and so on. For securing workers' safety, manual sewer/septic tank cleaning should be avoided because persons are likely to come in direct contact with sludge and sewage.

Therefore, cleaning machinery and equipment are needed. Furthermore, necessary safety measures before entering manholes for cleaning should be taken.

The contamination of drinking water with sewage may occur when water supply pipe passes through sewer manholes, generally in narrow streets, especially when water supply pipe joints are enclosed in sewer manholes and whenever water supply pipe joints leak, contamination of drinking water supply occurs.

As such, water supply pipelines should never be enclosed in a sewer manhole. If any such situation is observed, water supply pipe be made non-functional immediately by stopping flow of drinking water and affected public be supplied clean drinking water by other temporary means, such as water tankers or laying separate pipe over the ground / road surface and portion of water supply lines lying in sewer manholes be shifted out of manholes.

Special attention should be paid to decentralized sewer system, particularly when small-bore sewer system or shallow sewer system is adopted.

Table 1.10: Testing criteria for sewer

Emergency level	Category	Testing criteria	Criteria for measure
I	Important	(A)s are more or (a)s are more in the testing results	Prompt measure are necessary
II	Medium importance	(A)s are less frequent and (B)s are more, or (a)s are less and (b)s are more in the testing results	Necessary actions may be taken by provisional measures and proper measure will be implemented within 5 years
III	Minor importance	(A)s, (B)s are few, (C)s are many, or (a)s, (b)s are few, and (c)s are many in testing results	Actions may be taken by provision measures, if required

1.2.6 Judgment of Inspection and Examination Results

It is necessary to judge whether urgent repairs or modifications are necessary, or normal operation and maintenance are sufficient to ensure that the functions of piping facilities are maintained when an abnormality is detected by studies and analyses. The facility manager should make the judgment considering material of the pipe, age of the pipe, location where buried, quality of wastewater, status of groundwater, regional environment, and so on.

The criteria given below may be used as judgment criteria:

- Emergency response criteria
- Judgment based on results of inspection or examination
- Testing criteria

a) Emergency Response Criteria

Abnormalities related to piping facilities are generally detected from inspections or from outside reports. Prompt action should be taken when an accident has already occurred. Moreover, when the events below are confirmed, action should be taken immediately.

- Road surface: Irregularity exists that can cause level difference leading to subsidence or obstruction to operation.
- Manhole: Level difference exists that can lead to obstruction of operation.
- Inverted siphon: Water level on the upstream side is excessively high.

b) Judgement based on the Results of Inspection and Examination

Testing of the overall span and by each pipe should be carried out based on the results of visual inspection. Table 1.8 and Table 1.9(overleaf) show about testing criteria.

The testing of the overall span is divided into the three categories (A, B and C)

- Functional degradation
- Deterioration and
- Abnormalities

Clarified by inspection and examination should be assessed as shown in Figure 1.15.

c) Testing Criteria

A maintenance engineer should judge what counter measures are applied for inspected sewers in accordance with Table 1.10, by usual operation and maintenance or by emergency repairs and modifications.

Based on the criteria shown in Table 1.8 and Table 1.9, emergency level I is a state where immediate response is necessary.

Emergency level II indicates that simple response may be adopted and radical measures implemented within the next five years.

Furthermore, emergency level III indicates response adopted by operation and maintenance, and implementation of simple response partially.

1.2.7 Maintenance of Records and Follow up Action

To reflect the inspection and testing results in appropriate O&M of piping facilities, the test results should be recorded and stored in the format shown here.

a) Inspection Sheet

When inspections and examinations are implemented as shown Figure 1.16, an inspection sheet should be prepared and recorded as shown in Figure 1.17.

b) Logbook

Dedicated bound logbooks will be used for field data collection including but not limited to sampling, measurements and observations. Logbook entries should be objective, factual, and free of personal feelings or other terminology which might prove inappropriate. All pertinent field activity information will be recorded contemporaneously when observed or collected to prevent a loss of information.

The logbook should be used to record daily work results, which can be used in the O&M of piping facilities. The format is shown in Figure 1.18 overleaf. Then the daily record should be summarized in monthly reports. The format of the monthly report is shown in Figure 1.19 overleaf.

Figure 1.15. Illustration of testing criteria for sewer

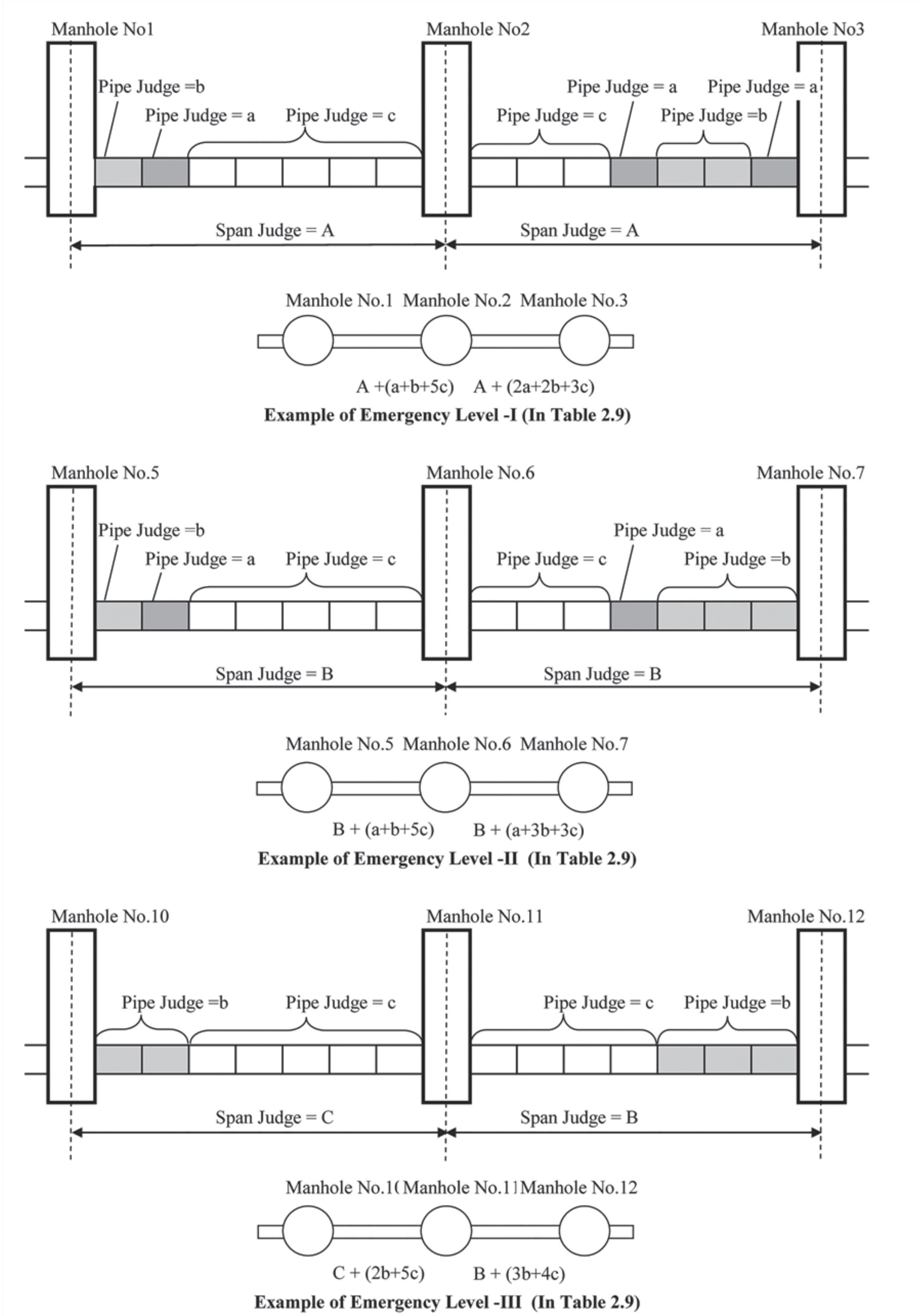


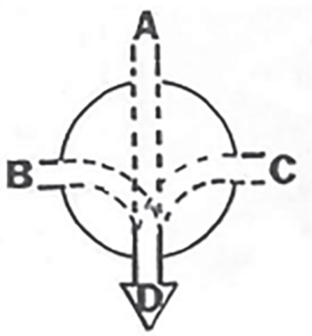
Figure 1.16. Forms of inspection record

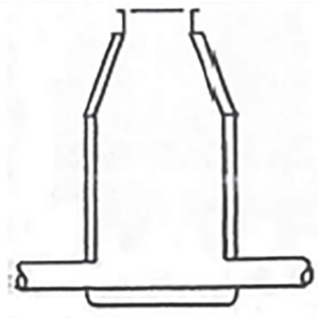
MANHOLE INSPECTION REPORT

MH NO. __________ DATE ____________ TIME _____________INSPECTOR ______

ELEVATION ______________ DEPTH TO INVERT ______________________ CLEANLINESS ________________________

TYPE CONSTRUCTION ________ STREET REFERENCES ___________________________________





DEFECTS:
(Cover, frame, grout, steps, shelf, pipes, or channels)

1.____

2.____

3.____

4.____

5.____

6.____

7.____

8.____

(USE REVERSE SIDE FOR ADDITIONAL DEFECTS TO BE NOTED.)

	PIPE SIZE	LENGTH	TO MH#	EST. FLOW	TYPE FLOW
A-					
B-					
C-					
D-					

REMARKS: (Include need for repairs)

____

Figure 1.17. Inspection sheet

<table>
<tr><td colspan="4">Inspection Sheet</td><td>No.</td></tr>
<tr><td colspan="2">Location
(Manhole No. etc)</td><td colspan="3"></td></tr>
<tr><td colspan="2">Inspection Date</td><td></td><td>Inspector</td><td></td></tr>
<tr><td rowspan="5">Inspection items</td><td>Manhole cover</td><td colspan="3">Abrasion, backlash, difference in level, invaded pavement, damaged, location unknown</td></tr>
<tr><td>Inside of manhole</td><td colspan="3">Corrosion, damage to the floor, infiltration, metal steps corroded, inferior pipe end, rubbish, odour</td></tr>
<tr><td>Pipe</td><td colspan="3">Corrosion, damage, coupling displacement, inadequate inclination, infiltration, roots of trees, earth, sand and mortar, road subsidence</td></tr>
<tr><td>House inlet</td><td colspan="3">Cover (no damage), difference in level, corrosion, damage, damaged invert, earth and sand, location unknown, odour</td></tr>
<tr><td>Lateral</td><td colspan="3">Damage, displacement, earth and sand, road subsidence</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td colspan="2">Inspection Date</td><td></td><td>Inspector</td><td></td></tr>
<tr><td colspan="2">Inspection Result</td><td colspan="3"></td></tr>
<tr><td colspan="2">Follow up actions</td><td>□Necessary
□Not necessary</td><td colspan="2">□Contracted
□ Self</td></tr>
<tr><td colspan="2">Date of order</td><td colspan="3"></td></tr>
<tr><td colspan="2">Date of schedule</td><td colspan="3"></td></tr>
<tr><td colspan="2">Date of completion</td><td colspan="3"></td></tr>
<tr><td colspan="2">Remarks</td><td colspan="3"></td></tr>
<tr><td colspan="2"></td><td colspan="3"></td></tr>
</table>

Figure 1.18. Daily report

Daily Report							Date		Weather
Response to complaint breakdown		Receipt No.	Receipt date	Location: address	Work description	Inspector	Tool Material	Remarks	
	1								
	2								
	3								
	4								
Trunk cleaning	Diameter (mm)							Name of cleaned area District:	Daily total
	Crew A								Person
	Crew B								Person
	Removed sand Volume							System No:	m^3
	Cleaned distance								m
Manhole	Direct works		Name of place repaired		Name of drainage area / System No. / Entrusted works	Name of place repaired	Name of drainage area	System No. / Tool material	Daily total
	Work description				Work description				

Figure 1.19. Monthly report

Monthly Report										Date Weather		
Response to complaint/breakdown	Category	1.Lateral	2.Inlet	3.Manhole	4.Ground Subsidence	5.Odour	6.Others					Total
	Number											
Trunk cleaning	Diameter (mm)											
	Direct crew											
	Entrusted crew											
	Removed sand											
	Cleaned distance											
Manhole repair	Manhole type	1	2	3	4	5	6	7	Special	Direct	Entrusted	Total
	Cover replaced											
	Ring repaired											
	Barrel repaired											
	Noise											

1.3 Sewer Cleaning

To operate and maintain a sewer collection system to function as intended, the maintenance engineer should try to strive towards the following objectives:

- Minimize the number of blockages per unit length of sewer, and
- Minimize the number of odor complaints.

For this purpose, sewer-cleaning using hydraulic or mechanical cleaning methods needs to be done on a scheduled basis to remove accumulated debris in the pipe such as sand, silt, grease, roots and rocks. If debris is allowed to accumulate, it reduces the capacity of the pipe and blockage can eventually occur resulting in overflows from the system onto streets, yards and into surface waters. Roots and corrosion also can cause physical damage to sewers.

1.3.1 Cleaning Equipment and Procedures

There are 3 types of cleaning processes including hydraulic, mechanical, and chemical cleaning techniques. In those mechanical and hydraulic cleaning of sewers is a cost-effective method of removing material that interferes with the proper operation of the sewer. The objective is to remove all material clinging to the interior surface of the pipe so that the sewer pipe can carry full pipe flow without any restrictions that might result in blockages due to reduced pipe capacity.

a) Hydraulic Cleaning

The hydraulically propelled devices take advantage of the force of impounded water to effectively clear sewers. The efficiency depends on the hydraulic principle that an increase in velocity in a moving stream is accompanied by a greatly increased ability to move entrained material. The transporting capacity of water varies as the sixth power of its velocity. Several techniques of hydraulic cleaning such as sewer balls, sewer scooter and flush bags as show in following:

- **Sewer Balls**

These are simple elastic pneumatic type rubber balls, which can be blown up to varying degrees of inflation. They are manufactured in sizes from 150 mm to 750 mm diameter when fully inflated. When used in cleaning a sewer, the ball is first inflated and then wrapped in a canvas cloth, the edges of which are sewed together. A trial line, little longer than the distance between the manholes, is attached securely to the covering. The size of the ball and the covering shall be such as to fit fairly snugly into the sewer. Immediately after the ball is thrust into the sewer, sewage commences to back up in the manhole and continues to rise until such time as its pressure is great enough to force sewage under the ball and move it downstream through the pipe. Acting as a compressible floating plug, it affords enough obstruction, so that a continuous high velocity jet spurts under and to some extent around the ball, thereby sluicing all the movable material ahead to the next manhole. If the ball encounters an obstruction, which is immovable, the ball merely indents to the necessary degree and moves forward. The only fixed obstruction, which will stop the forward progress of the ball is a root mass or some similar obstruction tightly wedged into the pipe.

Bricks, stones, bottles, loose metal parts, broken pieces of pipes, sand, gravel and settled sludge are easily moved ahead. If the ball stops momentarily, a pull on the trial line is usually sufficient to set it in motion again. If the pipe is very dirty, the trial line can be tied to a step in the upper manhole and the ball's progress can be retarded to the required degree as the lower manhole is reached, thus giving time for complete removal of accumulated silt and debris, which has piled up ahead of the ball. Equipment arrangement is shown in Figure 1.20.

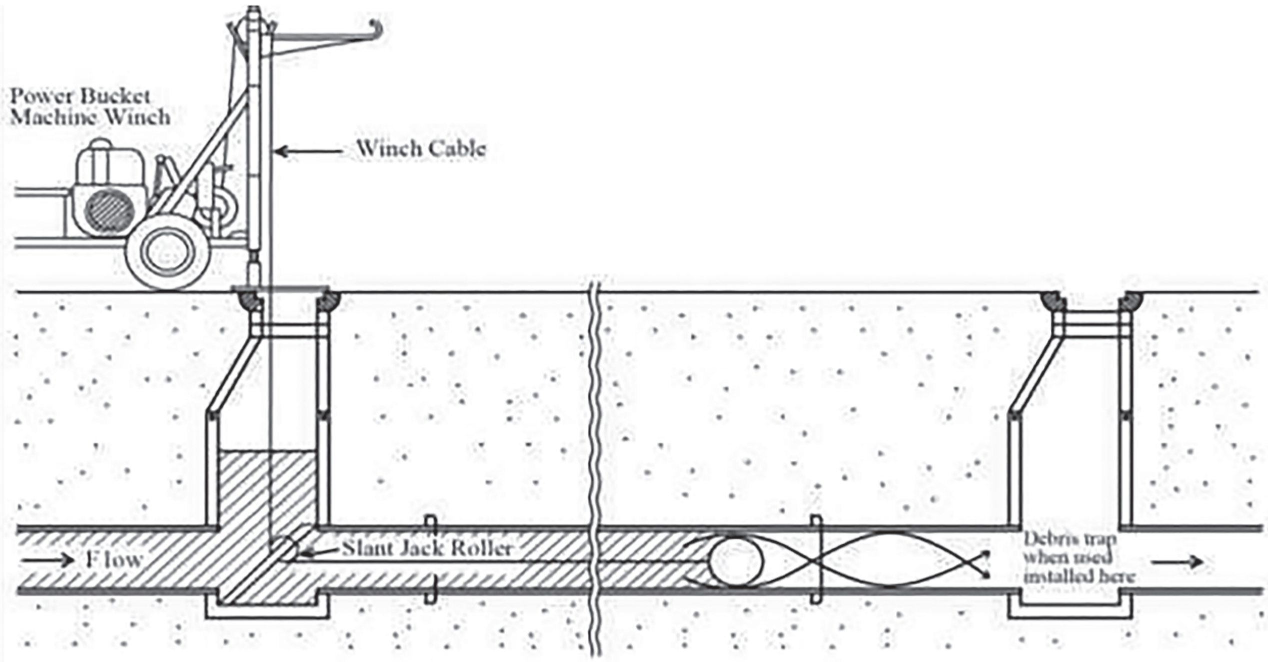
- **Flush Bags**

A very effective tool for cleaning portions of sewers where rods cannot be used is the sewer flusher or flush bag. The flusher is a canvas bag or rubber bag equipped with a fire hose coupler at one end and a reducer at the other end. The flusher is connected to the fire hose and placed in the downstream end, from the point where a choke is located. The bag is allowed to fill up until it expands and seals the sewer. The upstream pressure built up due to this damming effect breaks loose the obstructions.

- **Sewer Scooters**

This arrangement is an improved version of the scraper and consists of two jacks, a controlling rope and the scooter with a tight-fitting shield. In contrast to the scraper, the scooter completely stops any flow of sewage. The scooter, attached to the control rope, is lowered into the manhole and then into the downstream sewer line. The downstream manhole jack is lowered into place from the road and the upper manhole jack set across the top of the manhole. When the scooter is introduced in

Figure 1.20. Typical setup for Hydraulic cleaning using Sewer Ball



the line, it stops the flow of sewage thus building up a head behind the shield. The resulting pressure causes the scooter to move through the sewer until it accumulates enough debris to stop its movement.

The head is then allowed to build up approximately one meter before the control rope is pulled, causing the shield to fold back, thus allowing the accumulated sewage to gush into the sewer downstream, flushing the debris ahead to the next manhole from where it is removed. The control rope is released, clearing the shield against the sewage and causing the scooter to advance again until the debris stops its movement. This process is repeated until the scooter reaches the downstream manhole where it may be removed or allowed to continue through the next section. The operation of the sewer scooter is shown in Figure 1.21.

b) Mechanical Cleaning

The mechanical cleaning also has many technologies such as manila rope and cloth ball, sectional sewer rods, sewer cleaning bucket machine, dredger, rodding machine with flexible sewer rods, scraper, jetting machines, and suction units.

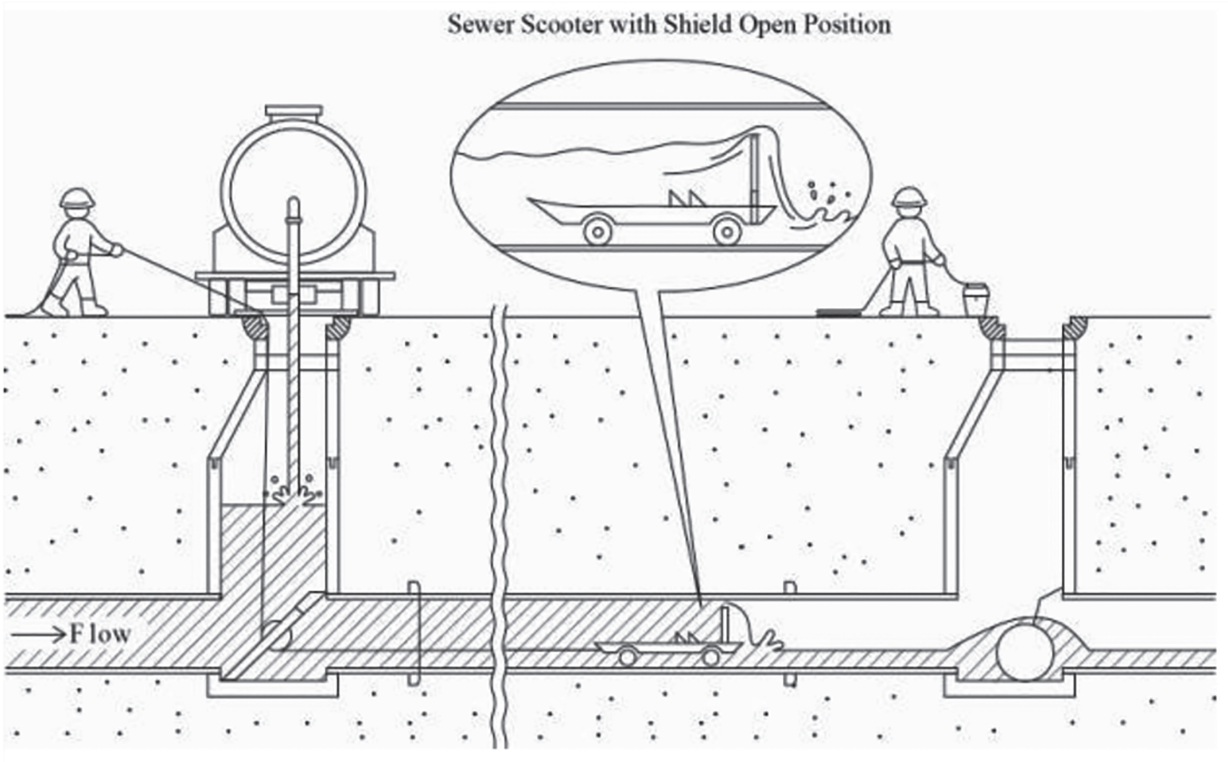
- **Manila Rope and Cloth Ball**

The most common way of cleaning small diameter sewers up to 300mm diameter is by the use of a manila rope and cloth ball. Flexible bamboo strips tied together are inserted in the sewer line by a person on top. If necessary, another person inside the manhole with full safety gears, precautionary measures and safety equipment help in pushing the rod through the sewer line. When the front end of the bamboo strip reaches the next manhole, a thick manila rope, with cloth ball at one end, is tied to the rear end of the bamboo splits. The bamboo splits are then pulled by another person in the downstream manhole and pushed through the sewer line. As the rope is pulled, the ball sweeps the sewer line and the accumulated grit is carried to the next manhole where it is removed out by means of buckets. This operation is repeated between the next manholes until the stretch of sewer line is cleaned. This action requires a careful supervision.

- **Sectional Sewer Rods**

These rods are used for cleaning small sewers. The sewer rods may be of bamboo or teak wood or light metal usually about one meter long at the end of which is a

Figure 1.21. Sewer Scooter operation



coupling, which remains intact in the sewer but can be easily disjointed in the manhole. Sections of the rods are pushed down the sewer. The front or the advancing end of the sewer rod is generally fitted with a brush, a rubber ring for cleaning or a cutting edge to cut and dislodge the obstructions. These rods are also useful to locate the obstruction from either manhole in case a particular portion of the sewer has to be exposed for attending to the problem.

- **Sewer Cleaning Bucket Machine**

Power bucket machines are another type of mechanical cleaning device; they are used to remove debris, roots, grease, or sediments from main line sewers. A bucket machine is equipped with a set of specialized winches that pull a special bucket through a pipe to collect debris. The captured materials are then physically removed from the pipe.

These machines are very powerful and offer the best cleaning product with the least opportunity for operator error that could affect the results. Since a full-size cutter and brush can be pulled through the line, each cleaning should be thorough and no residual debris should be left in the sewer main. Operating bucket machines is a very labor-intensive process; therefore, power buckets are normally used only for specific cleaning purposes, especially removing large amounts of debris from larger sewers.

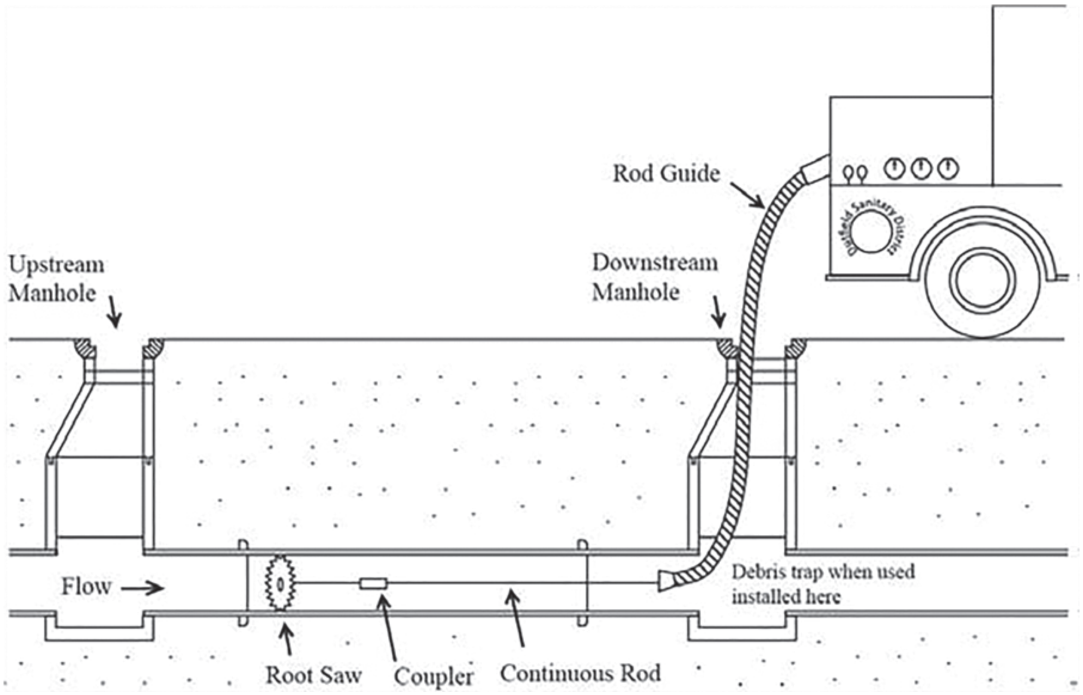
- **Dredger**

It consists of a grab bucket on a wire rope, which is lowered into the manhole in the open condition with the help of a crane and pulley. On reaching the bottom of the manhole, the segments are closed, and the accumulated silt is picked up. The bucket is then raised above ground level where the bucket opens and the silt is automatically dropped into a truck or a trailer. The bucket can be closed by wire ropes or by a pneumatically operated cylinder. The disadvantage in this system is that it cannot clean the corners of the catch pits of manholes. Sometimes the deposits at the corners may become so hard that the same may be required to be chiseled out.

- **Rodding Machine with Flexible Sewer Rods**

This consists of a machine, which rotates a flexible rod to which is attached a cleaning tool such as auger, corkscrew or hedgehog and sand cups (Figure 1.22 overleaf).

Figure 1.22. Power rodding operation

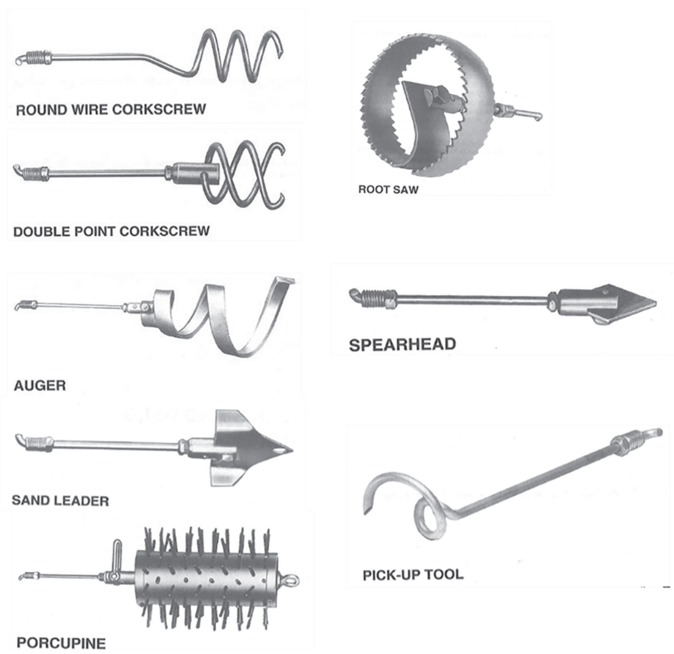


The flexible rod consists of a series of steel rods with screw couplings. It is guided through the manhole by a bent pipe. The machine propels the rod with the tool attached to one end, the other end being fixed to the machine. The rotating rod is thrust into the bent pipe manually with clamps with long handles for holding the rod near the couplings. As the rod is thrust inside, the machine also is drawn towards the manhole. The rod is pulled in and out in quick succession when the tool is engaging the obstruction, so as to dislodge or loosen it. When the obstruction is cleared, the rod is pulled out by means of clamps keeping the rod propelled to facilitate quick and easy removal. The various tools are shown in Figure 1.23.

- **Scraper**

This method is used for sewers of diameter larger than 750 mm. The scraper is an assembly of wooden planks of slightly smaller size than the sewer to be cleaned. If the scraper cannot be lowered through the opening of manhole, it has to be assembled inside the manhole. The scraper chains, attached to a control chain in the manhole into which it is lowered, are then connected to a winch in the next downstream manhole by means of chains.

Figure 1.22. Power rodding operation



The winch is then operated to push the debris ahead of the scraper. The upward flow behind the scraper and the water dropping from the top of the scraper will also assist in pushing it in the forward direction. This ensures that the bottom and the sides of the sewer are cleaned thoroughly. The scraped debris is removed manually. Circular scrapers are used on small sewers below 350 mm diameter for cleaning the body of the line. They are commonly known as discs and these discs are both collapsible and made of metal or a wooden pair separated by about 200 mm by steel rods.

- **Jetting Machines**

The high velocity sewer-cleaner makes use of high velocity water-jets to remove and dislodge obstructions, soluble grease, grit and other materials from sanitary, storm and combined sewerage systems. It combines the functions of a rodding machine and gully emptier machine. It includes a high-pressure hydraulic pump capable of delivering water at variable pressure up to about 8 MPa through a flexible hose to a sewer cleaning nozzle. The nozzle has one forward facing jet and a number of peripheral rearwards facing jets. The high-pressure water coming out of the holes with a high velocity, breaks up, dislodges the obstructions and flushes the materials down the sewer. Moreover, by varying the pressure suitably, the nozzle itself acts as a jack-hammer and breaks up stubborn obstructions. A separate suction pump or airflow device may also be used to suck the dislodged material. The entire equipment is usually mounted on a heavy truck chassis with either a separate prime mover or a power takes off for the suction device. The high-pressure hose reel is also hydraulically driven. The truck carries secondary treated sewage, if available, and if not untreated fresh water for the hydraulic jet. The truck also has a tank for the removed sludge and the various controls grouped together for easy operation during sewer cleaning. The manufacturer's operating and servicing manuals should be carefully followed for best results in the use of the machine.

- **Suction Units**

Suction units create the vacuum required for siphoning of mud, slurry, grit and other materials from sanitary, storm and combined sewerage systems. The vacuum elevated is such as to siphon the materials from the deep manholes catch-pits etc., having depth ranging from 1m to 8m in normal cases with an option to suck an additional 4m with the help of special accessories for the purpose. The unit can be vehicle or trolley mounted.

Silt and heavy particles settled at the bottom can be agitated and loosened by pressurized air with the help of the pump and then sucked in a tank. Once the silt tank is full, the effluent is discharged in the nearby storm water drain or manhole and the operation is repeated until the silt is cleared off the manhole. The silt deposited in the tank is then emptied at the predetermined dumping spot.

c) Chemical Cleaning

Several chemicals and application methods are available to kill and retard the regrowth of roots in the wastewater collection system. Methods of application include foaming, dusting and liquid application. Special equipment is required for all three application methods. If the problem is roots alone, chemical treatment is a very cost-effective method of cleaning. Grease can also be cleaned from sewers by the addition of chemicals or by bioaugmentation (addition of bacteria to speed up the breakdown of grease). Various chemicals are available, such as enzymes, hydroxides, caustics, biocides, and neutralizers, for removing and/or controlling grease buildups. The effectiveness of a particular chemical depends largely on the exact nature of the problem and site-specific circumstances. In most cases, these compounds tend to be an expensive method of treatment if they are applied routinely on an ongoing basis. If the grease is not removed at the source, it can create additional problems downstream at the pumping stations and treatment plants. An effective grease control ordinance is an important part of any service program.

1.3.2 Cleaning Records and their Utilization

Records of all cleaning operations should be entered and filed for future reference. These records should include the data, street name or number, line size, distance and manhole numbers or identification. Also, the kind and amount of materials removed, wastewater flow, and auxiliary water used should be noted. If particular problems were encountered, these too should be noted, especially the exact location of obstructions. A record-form sample is shown in Figure 1.24 overleaf.

If pieces of broken sewer are removed, a TV inspection may be needed and repairs may need to be made on the broken sections of pipe. Recording traffic patterns at a site can be very helpful next time the equipment is set up at the location. Car park (such as over manholes), traffic volume during rush hours, and whether police traffic control should be called for help before going to the site, should be indicated.

Figure 1.24. Sewer Cleaning Work Order Form

Gravity Sewer Maintenance

Work Order Date: ____________________ Work Order #: __________________________

Crew Members: ____

REASON FOR MAINTENANCE: CCTV ☐ PM ☐ Service Call ☐ Other: _____________

US Map Sheet #: _____________ DS Map Sheet #: _____________________

Upstream Manhole: _____________ Downstream Manhole: ____________________

USMH Depth: __________ feet DSMH Depth: __________ feet

Indicated: Length: ___________ feet Size: _______ inches Pipe Material: ___________

Actual: Length: ___________ feet Size: _______ inches Pipe Material: ___________

Nearest Address: ____ (Downstream Structure)

Location Notes: ______________________________________ (e.g. Alley, Easement, Traffic)

Other Notes: ____

Cleaning Results: (Check appropriate box(s))

Type of Material	Clear 1	2	3	4	Heavy 5	Not Rated 0
Debris (sand grit, rock)						
Grease						
Roots						
Vermin						Rat/Roach/Other
Other						

Recommended Maintenance Actions:

Cleaning Frequency: 3 ☐ 6 ☐ 9 ☐ 12 ☐ 18 ☐ 60 ☐ months	
Repair Required? Yes ☐ No ☐	Manhole Inspection Required? Yes ☐ No ☐
Root Control Required? Yes ☐ No ☐	CCTV Required? Yes ☐ No ☐

Comments:

____

Completed by: _________ Date Completed: ____________ Signature: ________

Supervisor Review:	Date:	Data Entry:	Date:

1.4 Sewer rehabilitation

1.4.1 Introduction

Deterioration of sewers proceeds over the surface as a whole, and repair takes considerable time, therefore, it is necessary to implement renewal and repair according to a plan on the basis of the results of inspection and examinations. This practice will prevent accidents.
In older cities, most sewers have already exceeded the service life. In such cities, adequate renewal and repair may resolve urgent problems and help extend the service life of the facilities, reducing O&M expenses. The two terms renewal and repair are clearly segregated as follows. Renewal is not included in O&M duties but in construction because the time of implementation is the starting point of the new service life and changes must be made to fixed assets.

- **Renewal**

This means improvement and replacement of facilities not caused by expansion of drainage area. It includes improvement, which is reconstruction or replacement of the facility that has not yet reached the specified service life and replacement which is reconstruction or replacement of the facility that has reached the specified service life.

- **Repair**

This refers to partial replacement or repair of damage to the facility. Repair provides utility, but not an increase in functions, so it does not contribute to extension of the service life of the facility. Repair simply maintains the capacity and life and does not cause a change in fixed assets.

However, making a clear distinction between O&M and construction duties is often difficult for implementation of renewal and repair according to the plan. In certain cases, it is therefore desirable to plan these duties as one package. Improvement of functions of existing sewers while incorporating elements related to planning and construction projects is generally called rehabilitation. The definition of terms related to rehabilitation is given in Table 1.11.

1.4.2 Rehabilitation Method

Under the traditional method of sewer relief, a replacement is made or additional parallel sewer line is constructed by digging along the entire length of the existing pipeline, while these traditional methods of sewer rehabilitation requires digging and replacing the deficient pipe with (the dig-and-replace method),

Table 1.11. Definition of terms

Terms	Definition	Classification
Rehabilitation, reconstruction	All concepts to improve function of existing sewer pipes.	All measures
Repair	Repair of structural damage or partial renewal of sewer pipes	Structural measurements
Renovation	Functional improvement of a certain section with utilizing the existing pipe structures	
Renewal	Renewal of new pipes, with basic functions and capacities remain equal to original pipes	
Replacement	Replacement with new pipe to reinforce function and capacities	Hydraulic measures
Reinforcement pipes	Installation of new pipes to enhance the flow capacity of the entire system	

trenchless methods of rehabilitation use the existing pipe as a host for a new pipe or liner. Trenchless sewer-rehabilitation techniques correct pipe deficiencies that require less restoration and cause less disturbance and environmental degradation than the traditional dig-and-replace method. Trenchless sewer-rehabilitation methods include:

- Pipe bursting or in-line expansion
- Slip lining
- Cured-in-place pipe
- Modified cross-section liner

a) Pipe bursting or in-line expansion

Pipe bursting or in-line expansion is a method by which the existing pipe is forced outward and opened by a bursting tool. During in-line expansion, the existing pipe is used as a guide for inserting the expansion head (part of the bursting tool). The expansion head, typically pulled by a cable rod and winch, increases the area available for the new pipe by pushing the existing pipe radically outward until it cracks. The bursting device pulls the new pipeline behind itself. The pipe bursting process is illustrated in Figure 1.25.

b) Slip lining

Slip lining is a well-established method of trenchless rehabilitation. During the slip lining process, a new liner of smaller diameter is placed inside the existing pipe. The annular space, or area between the existing pipe and the new pipe, is typically grouted to prevent leaks and

Figure 1.25. Pipe bursting process

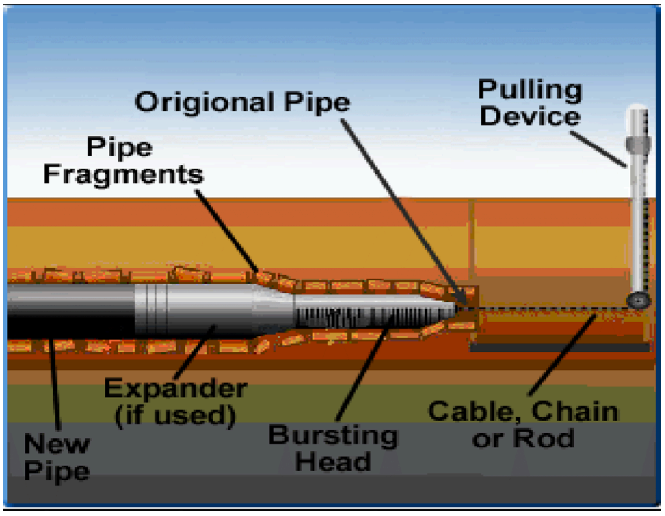
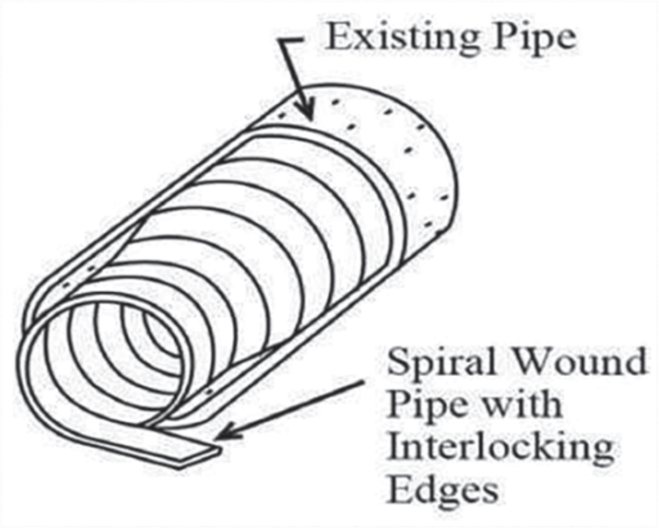
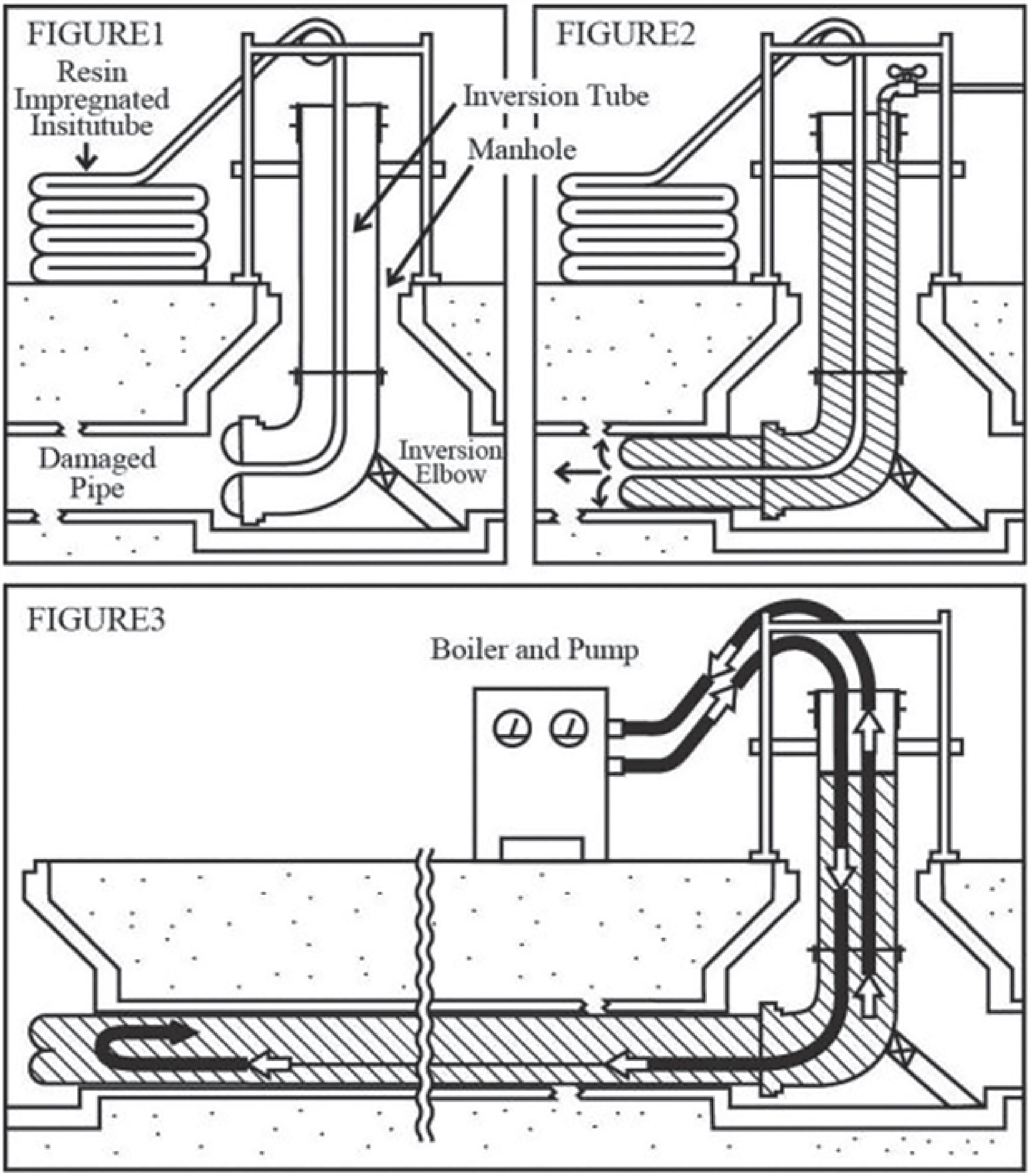


Figure 1.26. Spiral wound Slip Lining Process



to provide structural integrity. If the annulus between the sections is not grouted, the liner is not considered a structural liner. Continuous grouting of the annular space provides the seal. Grouting only the end-of-pipe sections can cause failures and leaks. In most slip lining applications, manholes cannot function as proper access points to perform the rehabilitation. In these situations, an insertion pit must be dug for each pipeline segment. Due to this requirement in most applications, slip lining is not a completely trenchless technique. However, the excavation required is considerably less than that for the traditional dig-and-replace method. System and site conditions will dictate the amount of excavation. Methods of slip lining include continuous, segmental and spiral wound methods. All three methods require laterals to be re-connected by excavation or by a remote cutter. In continuous slip lining, the new pipe, jointed to form a continuous segment, is inserted into the host pipe at strategic locations. The installation access point, such as a manhole or insertion pit, must be able to handle the bending of the continuous pipe section. Installation by the segmental method involves assembling pipe segment at the access point. Slip lining by the segment method can be accomplished without rerouting the existing flow. In many applications, the existing flow reduces frictional resistance and thereby aids in the installation process. Spiral-wound slip lining is performed within a manhole or access point by using interlocking edges on the ends of the pipe segments to connect the segments. The spiral wound pipe is then inserted into the existing pipe as illustrated in Figure 1.26.

Figure 1.27. Cured-in-place pipe installation procedure



c) Cured-in-place pipe

A typical cured-in-place pipe (CIPP) process by the water-inversion method is illustrated in Figure 1.27. During the CIPP renewal process, a flexible fabric liner coated with a thermosetting resin is inserted in the existing pipeline and cured to form into a new liner. The liner is typically inserted in the existing pipe through an existing manhole. The fabric tube holds the resin in place until the tube is inserted in the pipe and ready to be cured. Commonly manufactured resins include unsaturated polyester, vinyl ester, and epoxy, each having distinct chemical resistance to domestic sewage. The CIPP method can be applied to rehabilitate pipelines with defects such as cracks, offset joints and structurally deficient segments.

The thermosetting resin material bonds with the existing pipe materials to form a tighter seal than most other trenchless techniques. The two primary methods of installing CIPP are winch-in-place and invert-in-place. These methods are used during installation to feed the tube through the pipe. The winch-in-place method uses a winch to pull the tube through the existing pipeline. After being pulled through the pipeline, the tube is inflated to push the liner against the existing pipe walls.
The more typically applied inversion-in-place method uses gravity and either water or air pressure to force the tube through the pipe and invert it, or turn the tube inside out. This process of inversion presses the resin-coated tube against the walls of the existing pipe. During both the winch-in-place and invert-in-place methods, heat is then circulated through the tube to cure the resin to form a strong bond between the tube and the existing pipe.

d) Modified cross-section liner

The modified cross-section lining methods include deformed and reformed methods, sewage lining and roll down. These methods either modify the pipes cross-sectional profile or reduce its cross-sectional area so that the liner can be extruded through the existing pipe. The liner is subsequently expanded to conform to the existing pipe's size. During deformed and reformed pipeline renewal, a new flexible pipe is deformed in shape and inserted into the host pipe. While the method of deforming the flexible pipe varies, with many processes referred to as fold and form methods, a typical approach is to fold the new liner into a "U" shape, reducing the pipe's diameter by about 30 %. After the liner is pulled through the existing line, the liner is heated and pressurized to conform to the original pipe shape. Another method of obtaining a close fit between the new lining and existing pipe is to temporally compress the new liner before it is drawn through the existing pipeline.
The sewage lining and roll down processes use chemical and mechanical means, respectively, to reduce the cross-sectional area of the new liner. During sewage lining and a typical draw down process, the new liners are heated and subsequently passed through a reducing die. A chemical reaction between the die and liner material temporarily reduces the liner's diameter by 7 to 15 % and allows the liner to be pulled through the existing pipe. As the new liner cools, it expands to its original diameter. The roll down process uses a series of rollers to reduce the pipe-liner's diameter. As in deform-and-reform methods, heat and pressure are applied to expand the liner to its original pipe diameter after it has been pulled through the existing pipe. Unlike CIPP, the modified cross-section methods do not make use of resins to secure the liner in-place. Lacking resin-coated lining, these methods do not have the curing time requirement of CIPP. A tight fit is obtained when the folded pipe expands to the host pipe's inside diameter under applied heat and pressure. As with the CIPP method, dimples are formed at lateral, junctions and similar methods of reconnecting the laterals can be employed. Materials typically used for modified cross-section linings include Unplasticised Polyvinyl Chloride (UPVC) and High-Density Polyethylene (HDPE).

1.4.3 Maintenance of Machinery and Apparatus for Rehabilitation

Emergency cleaning and a repair are required in case of an emergency response.

Therefore, a maintenance engineer should repair machinery and equipment to the original. In addition, he should have enough maintenance and repair materials required (for example pipes, lid, the mounting tube).
In addition, the maintenance engineer should stock construction materials such as sand, rock crushing and asphalt for the cave-in repair of roads.

The maintenance engineer should ensure that the materials, equipment and facilities, necessary safety equipment are in standby state at all times.

1.5 Protection of Sewer Systems

A sewer may get damaged if other facilities such as water pipe or electric cable work are done beside or at the cross-section of a sewer. Especially, fluctuations due to ground excavation (pile, underground water drops and pile method) may have a serious impact.

To avoid damages of sewer, the maintenance engineer should do the following:

- Collect all related information about the construction activities which are planned around the sewer location,
- Advise appropriate construction methods to minimize impact for sewer, and
- If necessary, request the concerned agencies to adopt the protective measures for sewer prior to the work commencement.

Typical protective measures are as follows:
- Protection for existing sewer (an example is shown in Figure 1.28)
- emporary laying of supported sewer pipe
- Changing sewer material in advance

1.6 Safety Practices

Sewer cleaning is an occupation that has an overall accident frequency rate that is relatively higher than any other industry. The employer has the responsibility of providing the worker with a safe place to work. Nevertheless, the worker has the overall responsibility and must ensure that it is a safe place to work. This can only be done by constantly thinking of safety and working safely.

The worker has the responsibility of protecting not only himself, but also all other plant personnel or visitors by establishing safety procedures for the plant and then ensuring they are followed. He must train himself to analyze jobs, work areas and procedures from a safety standpoint and learn to recognize potentiality hazardous actions or conditions. When he recognizes a hazard, he must take immediate steps to eliminate it through corrective action. If correction is not possible, guard against the hazard by proper use of warning signs and devices / by establishing and maintaining safety procedures. As an individual, the supervisor can be held liable for injuries or property damage, which results from an accident caused by his negligence.

Remember, “accidents don’t happen - they are caused!” Behind every accident, there is a chain of events, which leads to an unsafe act, unsafe condition or a combination of both. Accidents may be prevented by using common sense, applying a few basic safety rules and acquiring a good knowledge of the hazards unique to the job as a plant supervisor.

1.6.1 Safety measures on sewer facilities

a) Traffic Hazzard

- Before starting any job in a street or other traffic area, study the work area and plan your work.
- Traffic may be warned by high-level signs far ahead of the job site.
- Traffic cones, signs, or barricades arranged around the work, or a flagger are applicable to direct traffic.
- Whenever possible place your work vehicle between the working site and the oncoming traffic.
- Use fluorescent jacket while working along roads (Figure 1.29).

Figure 1.28. Protection method for existing sewer

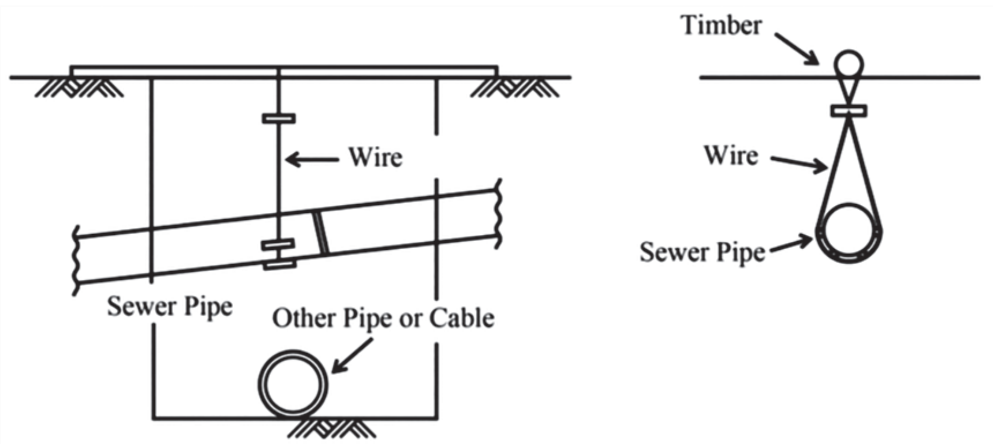


Figure 1.29. Fluorescent jacket

b) Manhole

All workers assigned to enter sewer manholes should be provided with proper safety equipment as recommended here.

1. Approved gas detector (Properly calibrated)
2. Fresh air blower
3. Safety harness, rope and tripod safety system
4. Approved hard hat

Before entering the manhole, following guidelines may be adopted to ensure safety in manhole:

- Oxygen content must be at least 19.5 % in the confined space of the manhole measured at all levels (bottom, middle and top). Safe oxygen level is considered if it ranges between 19.5 % and 21 %. Nobody should enter the manhole if oxygen level is below 19.5 % and more than 21 %.
- Ventilate the sewer line by opening at least two or three manholes on both upstream and downstream where work is to be carried out. This is mandatory where adequate blowers for ventilating sewers are not available. The manholes should be opened at least one hour before the start of operation. The opened manhole must be properly fenced or barricaded to prevent any person, especially children, from accidentally falling into the sewer. Dummy cover with BRC welded fabric or wire-net may be used.
- Fresh air blower ventilation system should be used as far as practicable. It is desirable to operate blowers for at least 30 minutes before start and during the cleaning operation.
- Measure gas inflammability in manholes using detector.
- Presence of toxic gases may be tested before entry of a person in manhole/ sewer line and also in between if the operations are for longer period.
- All workers should use safety harness and lifeline before entering the sewer line. At least one support person at the top must be provided for each person entering the manhole. The person entering the manhole/ sewer line must be monitored using signal/camera /CCTV etc., throughout the operation period.
- Structural safety of manhole rungs or steps must be tested before entering the manhole. Portable aluminum ladder must be available during the work period where necessary. The portable ladder must be properly seated or fixed during use.
- Ensure that no material or tools are located near the edge, which can fall into the manhole and injure the workmen.
- Lower all tools to the workmen in a bucket fixed with rope and pulley.
- Lighting equipment used during sewer cleaning must be explosion-proof and fire-proof.
- Caution signboards must be displayed around open manholes during working period.
- Smoking, lighting open flames or gadgets producing sparks must be prohibited inside the manhole as well as in the immediate vicinity of open manholes.
- All workers entering the manhole must be provided with protective gear and proper equipment. Use of portable gear and equipment must be monitored strictly.
- Gas masks for respiratory protection must be available for use by the workers. The workers must be trained to use the gas masks property.
- When entering a large sewer system, it may be required to use special equipment. The type of equipment might include atmospheric monitoring devices with alarms. In the event of a sudden or unpredictable atmospheric change, an emergency escape breathing apparatus (EEBA) with at least a 10-minute air supply should be worn for escape purposes.

1.6.2 Safety measures on pumping station

Before entering the well, follow all of the procedures required for work in confined spaces which follow in Table 1.12.

- When oxygen concentration is less than 19.5% and hydrogen sulphide concentration is more than 10 ppm, use forced ventilation to ventilate the tank before entering it.

- Do not work on electrical systems or controls unless you are qualified and authorized to do so.
- Guards over couplings and shafts should be provided and should be in place at all times.
- If stairs are installed in a pumping station, they should have hand rails and non-slip treads.
- Fire extinguishers should be provided in the station, properly located and maintained.
- The use of liquid-type fire extinguishers should be avoided. All-purpose A-B-C chemical-type fire extinguishers are recommended.
- Good housekeeping is a necessity in a pumping station to prevent slip and fall accidents.
- Properly secure and lock up an unattended pumping station when you leave so as to prevent injury to a neighborhood child and possible vandalism to the station.

1.6.3 Safety measures on sewage treatment plant

a) Head Works

- Bar screens or racks

- Remove all slime, rags, grease, etc to prevent slip and fall accidents. Never leave rake or other tools on the floor.
- Never lean against safety chains.
- Always turn off, lock out and tag the main circuit breaker before you begin repairs.
- The time and date the unit was turned off should be noted on the tag, as well as the reason it was turned off. No one should turn on the main breaker and start the unit until the tag and lock have been removed by the person who placed them.

- **Pump rooms**

- If the room is below ground level and provided with only forced-air ventilation, be certain the fan is on before entering the area.
- Guards should be installed around all rotating shaft couplings, belt drives, or other moving parts normally accessible.
- Remove all oil and grease, and clean up spills immediately.
- Be sure to provide barricades or posts with safety chains around the opening to prevent falls.
- Until the area has been checked for an explosive atmosphere, no open flames (such as a welding torch), smoking or other sources of ignition should be allowed.
- Do not work on electrical systems or controls unless you are qualified and authorized to do so.

- **Wet pits or sumps**

- Before entering the pits or sumps, follow all of the procedures required for work in confined spaces such as defined in Table 1.12.
- When oxygen concentration is less than 19.5% and hydrogen sulphide concentration is more than 10 ppm, use forced ventilation to ventilate the tank before entering it.
- For access ladders to pit areas, the application of a non-slip coating on ladder rungs is helpful.
- Watch your footing on the floor of pits and sumps; the

Table 1.12. Acceptable entry condition

Substrates	Concentration
Oxygen	19.5% and more
Hydrogen sulphide	Less than 10 ppm
Combustible gases	Less than 10%

floor may be very slippery.
- Tools and equipment should be lowered into a manhole by means of a bucket or a basket.
- Only explosion-proof lights and equipment should be used in these areas.

- **Grit channels**

- Keep walking surfaces free of grit grease, oil, slime, or other material to prevent slip accidents.
- Before working on mechanical or electrical equipment, be certain that it is locked out and properly tagged.
- Install and maintain guards on gears, sprockets, chains, or other moving parts that are normally accessible.
- Before entering the channel, pit or tank, follow all of the procedures required for work in confined spaces such as defined in Table 1.12.
- When oxygen concentration is less than 19.5% and hydrogen sulphide concentration is more than 10 ppm, use forced ventilation to ventilate the tank before entering it.
- Rubber boots with steel safety toes and a non-skid cleat-type sole should be worn.

b) Clarifiers or Sedimentation Basins

- Always turn off, lock out and tag the clarifier breaker before working on the drive unit.
- Maintain a good non-skid surface on all stairs, ladders, and catwalks to prevent slipping.
- When it is necessary to actually climb down into the launder, always wear a harness with a safety line to prevent a fall accident and have someone accompany you.
- Watch your footing on the floor of pits and sumps; the floor may be very slippery.
- Guards should be installed over or around all gears, chains, sprockets, belts, or other moving parts. Keep these in place whenever the unit is in operation.

c) Digesters and Digestion Equipment

- Methane gas produced by anaerobic conditions is explosive when mixed with the proper proportion of air.
- Smoking and open flames should not be allowed in the vicinity of digesters, in digestion control buildings, or in any other areas or structures used in the sludge digestion system.
- All these areas should be posted with signs in a conspicuous place which forbid smoking and open flames.
- All enclosed rooms or galleries in this system should be well ventilated with forced air ventilation. Never enter any enclosed area or pit which is not ventilated.
- Before entering the digester for cleaning or inspection, follow all of the procedures required for work in confined spaces such as defined in Table 1.12.
- When oxygen concentration is less than 19.5% and hydrogen sulphide concentration is more than 10 ppm, use forced ventilation to ventilate the tank before entering it.
- Explosion-proof lights and non-sparking tools and shoes must always be used when working around, on top of, or in a digester.
- When working on equipment such as draft tube mixers, compressors and diffusers, ensure that equipment is properly valve out, locked out and appropriately tagged to prevent the gas from leaking.
- If a heated digester is installed, read and obey the manufacturer's instructions before working on the boiler or heat exchanger because there is a risk of explosion.
- Sludge pump rooms should be well ventilated to remove any gases that might accumulate from leakage, spillage or from a normal pump cleaning.
- Good maintenance of flame arresters will ensure that they will be able to perform their job of preventing a back flash of the flame.

d) Aerators

- An operator should never go into unguarded areas alone.
- Approved life buoys with permanently attached hand-lines should be accessible at strategic locations around the aerator.
- Operators should wear a safety harness with a life line when servicing aerator spray nozzles and other items around an aerator.
- Lower yourself into the aerator with a truck hoist if one is available.
- Be extremely careful when using fixed ladders as they become very slippery.
- Watch your footing on the floor of the aerators: the floor may be very slippery.

e) Sewage Ponds

- Never go out on the pond for sampling or other purposes alone. Someone should be standing by on the bank in case of trouble.
- Always wear an approved life jacket when working from a boat or raft on the surface of the pond.

f) Disinfection Device

- Do not accept containers that have not been pressure tested within five years of the delivery date.
- Do not accept containers not meeting the standards. The most common causes of accidents involving chlorine are leaking pipe connections and excessive dosage rates.
- Bottles or cylinders should be stored in a cool, dry place away from direct sunlight or from heating units.
- Bottles or cylinders should never be dropped or allowed to strike each other with any force. Cylinders should be stored in an upright position and secured by a chain, wire rope, or clamp.
- One of the tanks should be blocked so that they cannot roll.
- Always wear a face shield when changing chlorine containers.
- Connections to cylinders and tanks should be made only with approved clamp adaptors or unions. Always inspect all surfaces and threads of the connector before mixing connection. Check for leaks as soon as the connection is completed. Never wait until you smell chlorine or sulphur dioxide. If you discover even the slightest leak, correct it immediately.
- Like accidents, leaks generally are caused by faulty procedure or carelessness. Obtain from your supplier and post in a conspicuous place (outside the chlorination and sulphonation room) the name and telephone number of the nearest emergency service in case of severe leak.
- Cylinder storage and equipment rooms should be provided with some means of ventilating the room. As chlorine is approximately two and a half times heavier than air, vents should be provided at floor level.
- Normally ventilation from chlorine storage room is discharged to the atmosphere, but when a chlorine leak occurs, the ventilated air containing the chlorine should be routed to a treatment system to remove the chlorine. A caustic scrubbing system can be used to treat air containing chlorine from a leak.
- The IDLH (Immediately Dangerous to Life or Health) for chlorine is 30 ppm.
- Always enter enclosed cylinder storage or equipment rooms with caution. If you smell chlorine or sulphur dioxide when opening the door to the area, immediately close the door; leave ventilation on, and seek assistance.
- Never attempt to enter an atmosphere of chlorine when you are by yourself or without an approved air supply and protective clothing, which will allow a person to enter safely into an atmosphere of chlorine. Remember to use the "buddy system" (system in which two persons work as a single unit) when responding to a leak.

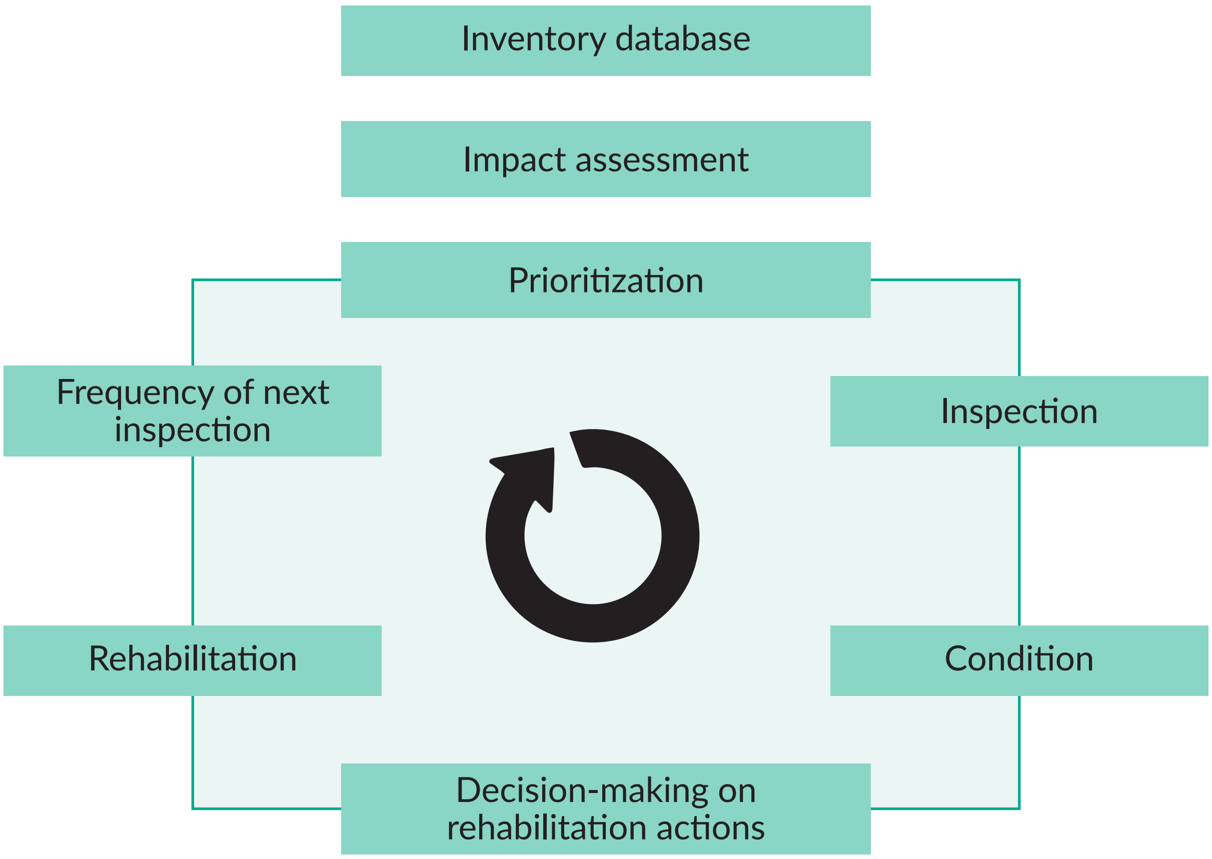
1.7 SUMMARY

The purpose of maintenance of sewerage collection system is to minimize stoppage of functions. The following cycle should be adhered to:

O&M engineers find out problems related to their sewer system based on information obtained from inspections or examinations on the facilities. To solve the problems, they need to make a decision on rehabilitation actions considering prioritization of each facility.
When the facilities are rehabilitated, records of inspections as well as those of rehabilitation should be kept.

The following cycle shown in Figure 1.30 is regarded as essential to achieve the goal of sewer system O&M: “Inspection”, “Condition assessment”, “Decision making on rehabilitation actions”, “Rehabilitation”, and “Next inspection.”

Figure 1.30. O&M cycle



2. Waste Stabilization Ponds

2.1 Introduction of Stabilization Pound

Waste stabilization ponds (WSPs) are usually the most appropriate method of domestic and municipal wastewater treatment in developing countries, where the climate is most favorable for their operation. WSPs are low-cost, low-maintenance, highly efficient, entirely natural and highly sustainable. The only energy they use is direct solar energy, so they do not need any electromechanical equipment, saving expenditure on electricity and more skilled operation. They do require much more land than conventional electromechanical treatment processes such as activated sludge – but land is an asset which increases in value with time, whereas money spent on electricity for the operation of electromechanical systems is gone forever.

WSP systems comprise one or more series of different types of ponds. Usually the first pond in the series is an anaerobic pond, and the second is a facultative pond. These may need to be followed by maturation ponds, but this depends on the required final effluent quality – which in turn depends on what is to be done with the effluent: used for restricted or unrestricted irrigation; used for fish or aquatic vegetable culture; or discharged into surface water or groundwater.

2.2 Stabilization Pond Technology

WSPs are one of the main natural wastewater treatment methods. They are man-made earthen basins or concrete basins, comprising at any location one or more series of anaerobic, facultative and, depending on the effluent quality required, maturation ponds. WSPs are particularly suited to tropical and subtropical countries since sunlight and ambient temperature are key factors in their process performance. Prior to treatment in the WSPs, the wastewater is first subjected to preliminary treatment – screening and grit removal – to remove large and heavy solids. The design of this preliminary treatment stage is the same as that used for conventional electromechanical wastewater treatment plant, but for WSPs the simplest systems are generally used (i.e. manually raked screens and manually cleaned constant-velocity grit channels).

Basically, WSPs have three stages of treatment such as primary treatment is carried out prior to anaerobic ponds, secondary treatment in anaerobic and facultative ponds, and tertiary treatment in maturation ponds. Anaerobic and facultative ponds are for the removal of organic matter (normally expressed as "biochemical oxygen demand" or BOD), Vibrio cholerae and helminth eggs; and maturation ponds for the removal of faecal viruses (especially rotavirus, astrovirus and norovirus), faecal bacteria (for example, Salmonella spp., Shigella spp., Campylobacter spp. and pathogenic strains of Escherichia coli), and nutrients (nitrogen and phosphorus).

a) Anaerobic ponds

Anaerobic ponds are the smallest units in the series. They are sized according to their "volumetric organic loading", which means the quantity of organic matter, expressed in grams of BOD5 per day, applied to each cubic meter of pond volume. Ponds may receive volumetric organic loadings in the range of 100 to 350 g BOD5/m3 day, depending on the design temperature.

These high loadings produce a strict anaerobic environment throughout the pond volume (i.e., there is no dissolved oxygen present and the redox potential is negative). The depth of anaerobic ponds is in the range 2–5 m; the precise value depends on the ground conditions and local excavation costs (which increase with depth) – depths are often 3–4 m.

Anaerobic ponds work extremely well in warm climates: for example, a properly designed pond will achieve around 60 percent BOD5 removal at 20°C and over 70 percent at 25°C and above. Organic matter removal in anaerobic ponds is governed by the same mechanisms that occur in all other anaerobic reactors. A retention time of one day is sufficient for wastewaters with a BOD5 ≤300 mg/l at temperatures above 20°C.

Odor nuisance from anaerobic ponds, typically due to hydrogen sulphide, has always been a concern for design engineers. However, odor is not a problem provided that the anaerobic pond is properly designed and the sulphate concentration in the raw wastewater is less than 500 mg/l.

b) Facultative ponds

These ponds are the second pond in sequence receiving the effluent from anaerobic ponds. The ponds are designed for BOD5 removal based on their "surface organic loading”. The term refers to the quantity of organic matter, expressed in kilograms of BOD5 per day, applied to each hectare of pond surface area; thus, the overall units are kilograms of BOD5 per hectare of facultative pond surface area per day − i.e., kg BOD5/ha d. A relatively low surface organic loading is used (usually in the range of 80−400 kg BOD5/ha d, depending on the design temperature) to allow for the development of an active algal population. The depth of facultative ponds is in the range 1−2 m, with 1.5 m being most common.

The maintenance of a healthy algal population is very important as the algae generate the oxygen needed by bacteria to remove the BOD5. The algae give facultative ponds a dark green color. Ponds may occasionally appear red or pink, due to the presence of anaerobic purple sulphide-oxidizing photosynthetic bacteria. This change in facultative pond ecology occurs due to slight BOD5 overloading, so color changes in facultative ponds are a good qualitative indicator of pond function. The concentration of algae in a well-functioning facultative pond depends on loading and temperature. It is usually in the range 500−1000 µg chlorophyll-a per litter (algal concentrations are best expressed in terms of the concentration of their principal photosynthetic pigment). The photosynthetic activity of the algae results in a diurnal variation of dissolved oxygen (DO) concentration and pH. The DO concentration can rise to more than 20 mg/l (i.e., highly supersaturated conditions) and the pH to more than 9.4 (these are both important factors in the removal of faecal bacteria and viruses).

c) Maturation ponds

Maturation ponds receive the effluent from the facultative ponds and their size and number depends on the required bacteriological quality of the final effluent. They are shallower than facultative ponds with a depth in the range 1−1.5 m, with 1 m being optimal (depths of less than 1 m encourage rooted macrophytes to grow in the pond and so permit mosquitoes to breed). Because of the lower organic loadings received by maturation ponds, they are well oxygenated throughout their depth. The algal populations are much more diverse than that in facultative ponds; algal diversity increases from pond to pond along the series.

Maturation ponds only achieve a small additional removal of BOD5, but they make a significant contribution to nitrogen and phosphorus removal. Total nitrogen removal in a whole WSP system is often above 80 percent and ammonia removal are generally more than 90 percent (these figures depend on the number of maturation ponds included in the WSP system). Phosphorus removal in WSPs is lower (usually about 50 percent). Examples of WSP series (anaerobic ponds + facultative ponds + maturation ponds).

2.3 Start-Up Procedure

Before commissioning a WSP system, any vegetation growing in the empty ponds must be removed.
The facultative ponds and maturation ponds are commissioned before the anaerobic ponds so as to avoid odor release when the anaerobic pond effluent discharges into empty facultative ponds. The facultative ponds and maturation ponds should ideally be filled initially with fresh surface water or groundwater to permit the development of the required algal and heterotrophic bacterial populations. If freshwater is not available, then the facultative pond can be filled with raw wastewater and allowed to rest in batch mode for 3−4 weeks to allow the microbial populations to develop. Some odor release may be expected during this period.

Once the facultative ponds and maturation ponds have been commissioned, the anaerobic ponds are filled with raw wastewater and, if possible, inoculated with active biomass (sludge seed) from another anaerobic bioreactor. The anaerobic ponds are then loaded gradually up to their design load over a period of 2−4 weeks (the time depends on whether the anaerobic pond was inoculated with an active sludge seed or not). The pH of the anaerobic pond has to be maintained at around 7−7.5 during the start-up to allow for the methanogenic archaeal populations to develop. If the pH falls below 7 during this period, lime should be added to correct it.

2.4 Routine Maintenance

Once the ponds have started functioning in steady state, routine maintenance is minimal but essential for good operation. The main routine maintenance activities are:

- Removal of screenings and grit from the preliminary treatment units
- Periodically cutting the grass on the pond embankments
- Removal of scum and floating macrophytes from the surface of facultative ponds and maturation ponds. This is done to maximize the light energy reaching the pond algae, increase surface re-aeration, and prevent fly and mosquito breeding
- If flies are breeding in large numbers on the scum on anaerobic ponds, the scum should be broken up and sunk with a water jet
- Removal of any material blocking the pond inlets and outlets
- Repair of any damage to the embankments caused by rodents or rabbits (or any other burrowing animals)
- Repair of any damage to fences and gates.

As a rough guide one full-time operator is required at WSPs receiving wastewater flows up to about 1,000 m3 /d, two operators for wastewaters flows up to about 2,500 m3 /d and pro rata for higher flows. A foreman/ supervisor is required at sites treating more than 5,000 m3 /d; and should also keep a record of all maintenance activities, measure and record the wastewater flow and carry out routine effluent sampling.

All WSP operators should receive adequate training so that they understand what they have to do and how to do it correctly. If, for example, the pond operators have not been told to remove scum from facultative ponds and maturation ponds, they will not know that it should be removed. As a result, scum can cover a substantial part of the pond, algal photosynthesis becomes impossible, and the pond turns anoxic.

Anaerobic ponds need to be de-sludged when they are around one-third full of sludge. This occurs every 2–5 years, but it is operationally better to remove some sludge every year (as a task to be done every February, for example, has a better chance of being done on time than one which has to be done every few years). The sludge removed from anaerobic ponds can be dewatered on sludge drying beds. Facultative ponds store any sludge for their design life, which is a significant operational advantage.

When the travel time in the sewers is long (more than a day), the wastewater arriving at the WSP site may be highly septic, and that can cause odor from the preliminary treatment works.

2.5 Key Controlling Indicators

2.5.1 Controlling specific plant types

Plants also play important roll to control WSPs. There are many types of plant such as Coontail, Cattails, and Grass cover on disk slopes.

a) Coontail

Coontail is one type of submerged plant that has been shown to be beneficial. It is not deep rooted which has a main stem with branches that have needle-like leaves. The branches and needles look like a raccoon's tail, hence the name. Coontail absorbs nutrients, and therefore limits the excessive growth of algae. Water will typically be very clear when coontail is present. Samples taken from a pond with coontail are usually low in BOD, TSS, and total phosphorus (TP). It is generally best to leave it in the pond. Only when overall growth becomes very dense and interferes with sunlight penetration will you need to remove it. The image of coontail plant is shown in Figure 2.1.

Figure 2.1. Coontail plants

b) Cattails

Cattails easily establish in the shallow water along the dikes, or wherever the water level is below three feet (around 915mm) for an extended period. Cattail's extensive root system can damage the seal. They provide habitat for rodents, reduce circulation and cause short-circuiting. In addition, they may be aesthetically displeasing. The image of cattails plant is shown in Figure 2.2.

You can use several methods to control cattails, however, you must choose a removal method appropriate to the amount of plant growth and the time of year.

Figure 2.2. Cattails plants

- **Pulling**

Pull cattails early in their first year of growth when they are young and before they become established.

- **Cutting and drowning**

Cut off the cattails as close to the bottom as possible. Immediately after cutting, drown them by raising the water level to at least one meter above the top of the cut cattails. If you cannot cut them close to the bottom, cut them at the least one meter below the usual water level. Raising the water level to at least one meter will reduce the amount of sunlight that penetrates the water to the plants. This in turn will hinder the root system from continuing to grow. Cutting and drowning is most effective if done mid-June to mid-July when the cattail flowers are actively growing.

Cattail flowers are developing when you see a dark green and pebbly textured flower on top of the stalk, with a pale green flower just below it.

- **Spraying with an approved herbicide**

Use herbicides only as a last resort, however, if cattails are extensive and dense, using herbicides may be the only practical and effective way to eliminate them. Most herbicides should not apply until the plants are 0.5 meter above the water to ensure adequate leaf surface for chemical contact and allow the use of wetting agent. Successful methods for spraying a pond include high-pressure spraying rigs mounted on dikes or fire trucks and portable spraying rigs mounted on dikes or fire trucks and portable spraying rigs mounted in boats. Although initial cost may be high, using the proper herbicide will likely result in increased saving in time and money overall.

c) Grass cover on the disk slopes

The grass cover on dikes discourages erosion. Frequently mowing dike slopes is the best way to preserve the integrity of the dike system.

Appropriate grasses of use on inner dikes are fast growing, spreading and shallow rooted, however, dense types such as rye, brome, and quack are not acceptable. Use grass with long roots structures, such as alfalfa or reed canary grass, only on the outer dikes. The roots of these plants can alert the compaction of the inner dike and impair the water-holding capacity of the seal, eventually causing structural failure and costly repair.

When planting additional grass on the dike, use netting or mulch material to hold the grass seed and moisture while roots become established.

Move the grass on the dikes at least monthly, twice a month is recommended rate. Frequency cutting promotes a thicker strand of grass and allows the operator to observe developing problems on both sides of the dike slopes.

2.5.2 Controlling erosion

Erosion problems can be more serious on the downwind side of the pond. It can occur while increasing wave action from wind travelling across the pond. Therefore, inspect frequency some area is necessary such as around control structure, in the corner, in area where vegetative cover on the dikes is inadequate, and on the area where dikes were not sufficiently compacted during construction.

Erosion problem greatly reduce the design life of a pond system. Erosion may:

- Wash away the liner cover material or possibly the actual liner
- Created difficult maintenance areas along the dikes
- Increase the potential or muskrat habitat and damage to the dikes

The most practical methods of controlling the erosion is using riprap material. Riprap material, or some other acceptable method of erosion control is required on all inner dikes slopes for new pond system. Before placing riprap on existing pond systems, the first time, you must make sure the seal's integrity is intact. Riprap material is placed from the toe of the dike to the least 0.3 meter above the high-water line. A current design criterion recommends placing the riprap all the way to the top of the dike.

The type of riprap you depend upon what the material is readily available. Riprap materials used for erosion control should include:

- Durable, clean rocks in assorted sizes, such as fieldstone or quarry (angular, crushed bedrock). Most should be between 0.05 – 0.25 meter in diameter and placed a minimum of 0.15 – 0.3 meter deep.
- Materials like snow fences or straw and hey bales may be use as a temporary measure in an emergency situation. They must be replaced by permanent riprap.

2.5.3 Controlling rodents

One critical part of weekly dikes inspections is to look burrowing animals such as muskrats, badgers and gophers that can cause serious damage to the dikes system.

a) Gophers and badgers

Gophers and badgers generally cause problems on the outside of the dikes. They are usually easy to detect because of the dirt mounds they make when they tunnel. Gopher and badgers cause two main problems:

- Their dirt mounds make grass cutting and general dike maintenance difficult
- If their tunnels angle toward the inner dike, the possibility for the tunnel to connect with a muskrat tunnel and a leak greatly increase.

b) Muskrats

Muskrats are the leading troublemakers for pond operators. They often can be eliminated simply by preventive maintenance. Since many types of vegetation are major food source for muskrats, controlling vegetation can help to get rid of them.

Muskrats make their homes by burrowing in dikes to provide an entrance to their den which is above the water line. Tunnels (run) begin below the water line and penetrate the inner dike and liner/seal at an upward angel. A tunnel will end up in a dry chamber (den) above the water line. Because tunnel entrances are underwater, you will need to inspect carefully after a discharge or transfer of water to detect their presence. The entrance to a muskrat den illustrated in Figure 2.3.

Figure 2.3. Entrance to a muskrat den

If riprap is present, locating a muskrat run is difficult. Muskrats have been seen entering very small areas between the riprap. Operators may use several methods to find entrance to muskrat runs and muskrat dens:

- Observe where the muskrat swims to the dike, this is normally close to tunnel entrance
- When the water level is very low, to help locate the tunnel entrance, look for muskrat tunnels below water line
- If you have grass dikes, walk along the dike and look any depression in the dike, tunnels, and dens are often shallow enough that you can find a depression

Discuss with the relevant departments the best way to remove muskrats by shooting, tripping or poisoning. After eliminating the muskrats, carefully repair the damaged areas of the dike, Normally, repair requires removing the riprap and liner, digging open the tunnel, replacing the clay or vinyl liner that was removed, re-compacting the area, and then placing riprap material at the closed tunnel entrance and den.

2.5.4 Control structure

Control structure are essential for controlling water level. An operator must make sure they always function the way they should. Problems with control structures are typically corrosion and leaking.

Reduce corrosion problem by frequently lubricating gate and valves by moving the gates and valves enough to ensure mobility. Another way to reduce corrosion is to increase ventilation by replacing solid manhole covers on the structures with gates covers.

Leak in structures are usually hard to fix. An operator may use gasket material, grout, or sewer plugs to try to stop the leak. However, to get rid of the problem you need to replace gates, slides, or telescoping valves.

2.5.5 Control of odors

Odors may arise from a number of situations. Frequently they are associated with the decay of mats of algae that have been blown to a bank or corner. Chlamydomonas, for example, can grow rapidly, spread over pond surfaces, reduce the penetration of light to the remainder of the pond, and with the assistance of the wind accumulate in the corners where it decomposes and produces vile odors. In other instances, particularly during periods of high-water temperatures in shallow ponds, sludge mats rise from the bottom. These masses of organic debris usually accumulate in corners, and if it is not disturbed the entire mass may become covered with blue-green algae. Usually the bacterial activity is intense and the odors are overpowering.

The solution to the mat problem is immediate dispersal. Agitation of the surface will usually cause the floating mass to break up and settle to the bottom. A jet of water from a garden or fire hose will normally create enough turbulence to achieve this. Another remedy employed by some is to use an outboard motor or an engine-powered paddle wheel to agitate the surface. Such devices have the advantage of flexibility, in that they can be mounted on rafts and moved from place to place

2.5.6 Controlling mosquitoes and insects

Inspects, which naturally occur around water, may discourage the use stabilization ponds. However, in a well-maintained system. Insects usually are not problem.

To control insects, eliminate their breeding habitat. This means controlling vegetation along the dike and the ponds, regularly mowing and removing grass, and breaking up floating materials. Use a chemical or a natural biocide such as bacillus thuringiensis to kill insect larva only in case of service infestation.

2.5.7 Solids accumulation at the inlet pipe

The settleable portion of suspended solids in wastewater tends to accumulate near or in the inlet pipe, particularly when the inlet is a vertical, rather than a horizontal pipe. Because the velocity of incoming wastewater is too low to disperse it, incoming grit and sand will plug the line.

If solids constantly accumulate at the end of the influent line, you must remove them or push them away from the pipe. Removal methods to consider include:

- Pump the excessive grit and sludge from around the inlet
- Break up the island and push the grit away from the inlet

You also need to check the collection system. Cracked collection system piping or possibly an industrial-related problem could be allowing excess grit to enter the collection system. Determine the source of the problem and eliminate it, so the problem dose not reoccur. There should not the vertical inlet coming into the primary pond. The only time this happens is if there is a force main coming directly to the pond system, which is the case in some older pond systems. Beside solids accumulation, another concern with a force main coming into the pond system is a force main break. If that happens, all the water from the primary pond will drain back through the force main and into the groundwater or surface water.

2.6 De-sludging

The biggest challenge to an operator in the management of pond systems is to identify when a pond requires de-sludging, and to carry it out safely without giving rise to environmental problems. These issues are addressed in this section so as to help the operator develop adequate confidence in this task.

When raw sewage without grit removal is admitted to the pond, a general rule of thumb to calculate the grit accumulation is 0.5 meters depth for a ten-year period. Similarly, the accumulation of sludge can be taken as 0.7 meters for a ten-year period. Generally, the pond has to be de-sludge when the combined depth of this grit and sludge exceeds 30 % of the designed liquid depth of the pond. However, the “as constructed drawing” may not be available sometimes. Hence, it becomes necessary to physically measure the total depth of the pond from the top of the bund to the floor, the free board and the depth of accumulated sludge. The procedure will be needed, in general after 10 years or when the BOD removal is getting reduced drastically or when black sludge is constantly overflowing in the treated sewage from the pond.

2.6.1 Preparation for measurement

In order to do the actual measurements in the pond, manual and mechanical methods as also remote instrumentation can be used. In the manual method, the minimum requirements are a clear sunny day with no rains, broad daylight, working between 9 AM and 3 PM only, fire service personnel available at site, minimum of three able bodied persons on a good water tight row boat with a set of extra spare oars, number of people on the boat not to exceed 50 % of the safe carrying capacity of the boat, life vests for all those on board, the boat doubly checked for water tightness, an experienced boatman and oxygen masks for all on board. In the mechanical method, a long arm boom crane which can reach at least one third of the sides from the bund, an apparatus to hold tightly a dip pipe (described later) and an experienced operator. In the instrumentation method, the same crane as above, but equipped with an ultra sound sensor mounted on the end of the boom arm with transmission of the readings by a modem to a personal computer nearby.

a) The Dip Tube

This is a light weight tube of strong aluminum and about 30 mm inner diameter and with striations lightly carved as lines all over its outer length. The length of the tube must be at least the depth of the pond plus a minimum of two meters. A white fluffy “terry” towel is wrapped around the tube three times for a length equal to the depth of the pond plus 0.5 m and securely tied using good nylon thread as a spiral at interval of 30 cm between the windings and finally tied securely in a knot at the top side. At the bottom end, separate thread must be tied and knotted to hold the towel in place. Once this is done, check the towel for tightness before using it.

b) The White towel tests

The test uses the dip tube and is used to understand the depth of the sludge. The dip tube wrapped with the white towel is lowered vertically into the pond until it reaches the pond bottom and held there for about 10 to 15 minutes and it is then slowly withdrawn. The depth of the sludge layer is clearly visible since some of the blackish sludge particles will have been entrapped in the towel material and this can be measured. The length of wetness of the towel will indicate the liquid depth.

The sludge depth should be measured at various points throughout the pond, away from the embankments, and its mean depth calculated. In order to do this test, the boat as described earlier can be used by staying close to the sides of the bund at about 3 to 5 m only. It is not necessary to measure at the pond center because normally, the sludge settles uniformly over the entire plan area of the pond.

Alternatively, if the crane with boom is available, the dip tube can be securely tied to the free end of the boom which can be positioned at chosen locations and the dip tube gently lowered till it comes to rest and the same can be taken out of the bund and measured. This is a type of remote measurement. Do not send any person on the boom arm.

2.6.2 Technique for sludge removal from ponds

The main pond sludge removal technique can be classified as follows:

- Mechanized or non-mechanized
- With interruption or no interruption of pond operation

a) Sludge removal with temporary interruption of pond operation

The temporary deactivation of a pond can be a simple operational measure, if the primary pond stage has been designed in modules, and if there is and idle treatment capacity. However, if this stage consists of single pond, or if the nominal design load has been already reached, the temporary deactivation may put in risk the stability of subsequent treatment stage.

Another important aspect is related to emptying the pond. This operation, necessary for drying the sludge in the pond itself, requires previous planning and consent from the environmental agency. In case of very fast emptying, mainly in aerobic ponds, the impact of aerobic effluent on the receiving body can exceed its self-purification capacity. Fish death, unpleasant odors and protests by the population may arise a consequence.

- **Manual removal**

In this case, the sludge is submitted to drying inside the pond itself, until it is consistent enough to be removed by spades and wheelbarrows (TS>30%)

The disadvantage of this technique is that it requires a long drying period. Considering the periods of time necessary to empty the pond, the drying period, and the period for manual removal the sludge, the pond will certainly remain deactivated for more than 3 months.

However, the sludge volume to be removed under these conditions is much lower than the volume existent prior to the drying. Another aspect is the possible complementary disinfection of the sludge by sunlight-induced pasteurization. This can be a feasible solution for a small sewage treatment plant (<5000 inhabitants).

- **Mechanical removal (by tractors)**

As in the previous technique, the sludge is submitted to dying the pond and removed soon after. In view of the higher yield of the machines in the sludge removal, the pond can start to work again more quickly than in case of the pond, the soil support capacity should be previously verified, so that neither the pond bottom sealing nor the stability of slopes is affected.

The ease of access of the machines into the pond should be evaluated, considering the option for partial rupture of the slopes for further reconstruction. There have been cases of tractors stuck in the sludge in ponds, foe which reason it is recommended that the bottom of the pond should not be accessed while the sludge presents a pasty consistency (20% < TS <30%).

- **Mechanized scraping and pumping of the sludge**

When the pond cannot be deactivated for a very long period of the time, the sludge is partially dried in the air, mechanically scraped, and the pumped. This technique requires the aid of a tractor or another device to convey the sludge still in the liquid state to a lower point from where it will be pumped.

The use of positive displacement pumps (piston, diaphragm, rotating lobes, high-pressure piston, etc.) is recommend due to their capacity to move the sludge mass. Torque pumps (centrifuges) can be used, although they require dilution of the highly concentrated sludge, which results in an increased volume of sludge removed.

b) Sludge removal with the pond in operation

- **Removal by hydraulic sludge discharge pipe**

The hydraulic sludge discharge pipe (bottom drain) is the device more frequently included in the design of anerobic or aerated stabilization ponds. Nevertheless, it is a solution highly criticized by operators.

There are several reports on clogging and loss of function of this device during the operation of the pond. The problem occurs in view of the evolution of solids contents in the sludge over the years, making its consistency change from the liquid to pasty. Should the sludge be discarded with a higher frequency (<5years), which would prevent its thickening at levels higher than 7% on the bottom of the pond, this device could be useful in small sewage treatment plant.

In case this technique for pond sludge removal is adopted, pipe diameters equal to or larger than 200 mm are recommend.

- **Removal by septic tank cleaning truck**

Septic tank cleaning or similar trucks are provided with a vacuum suction system with a flexible pipe that removes the sludge and coveys it to sludge storage compartment in the trucks themselves.

The disadvantage of this solution is that it removes the sludge with a high-water level, once pumping requires the dilution of the sludge layers already in an advanced thickening stage. The results can be the need of many trips to transport the sludge from the sewage treatment plant to the disposal site. However, its great advantage is that it removes and transports the sludge in the same operation. The equipment can also be easily found and rented in medium- and large-size cities.

- **Dredging**

The use of dredges allows the removal of the sludge with TS contents higher than 15%, if the sludge is scraped by mechanical means. For sludge with higher solids levels, this type of removal process is affected due to the consistency of the material.

The dredges can also be provided with a sludge -layer-breaking device, so that the removal is accomplished by pumping. In this case the sludge is removed with water contents higher than those in case, the sludge is removed with water contents higher than those in case of mechanical scraping. Remote control equipment is available.

The dredging may suspend solids at the pond outlet, following the revolvement of the bottom sludge layer. This fact can cause a significant load of solid to the secondary pond, if existent. Another important aspect refers to the stability of the waterproofing seal on the bottom of the pond, which may be damaged by the dredging.

- **Pumping from a raft**

The sludge can be pumped from the bottom of the pond by a motor pump installed on a raft. The use of positive displacement pumps (piston, diaphragm, rotating lobes, high-pressure piston, etc.) is also reconnected. The motor can be propelled by either electricity or fuel. Remote control equipment is available.

The use of centrifugal pumps is only feasible in case in which the sludge still has a liquid consistency (TS contents < 6%), or in case in which the motor pump is provided by with a device for scarifying the sludge on the bottom, the sludge removed by pumping is conveyed outside the pond, where it can be either transported or dewatered in place.

- **Robotic system**

This alternative is not largely used in developing countries yet. It can be considered a promising technology in sludge extraction, and consists a small remote-controlled robotic tractor that move on a crawler. In the front part of the tractor, the sludge layer is broken and aspired, being than removed from the pond by pumping. The process seems to be capable of removing sludge with high concentration of solids (TS > 20%), allowing the pond to be cleaned at longer intervals. Its main disadvantages are the absence of the experience with the equipment in developing countries and the fact that it is imported.

2.6.3 De-sludge procedure

The sludge was followed many steps below:

- Repeat the above depth measurements slowly without hurry. Always do this in clear non-rainy weather. Make sure you have at least four readings, which are fairly close.
- Once the sludge depth is thus measured, consult the chemist for any tendency of efficiency drop in the pond for BOD removal. If the chemist feels that there is a steady decline and efficiency is going down, consult the plant superintendent.

- As a rule of thumb, if the liquid height is less than 1.2 meters in a facultative or anaerobic pond, it is time for de-sludging. Take the decision jointly and never by yourself.
- The best method of de-sludging is to take one pond out of operation during the beginning of summer and pump out the water portion to the other ponds. Thereafter, it normally takes two months for a sludge depth of about 2 meters to dry out.
- Deploy manpower equipped with oxygen mask to gently turn the dried sludge upside down uniformly over the whole area so that drying is hastened. Never use a machine during this operation as methane may get released.
- Once this is completed and the sludge is dried, deploy a suitable earthmoving equipment and evacuate the sludge over the bund and on to the ground on the earth side of the bund.
- The sludge can be heaped into a pile by manual laborer who should wash their hands thoroughly with soap after finishing their work.

2.6.4 Special caution for aerobic and maturation pond

All the points listed earlier in aerated lagoon and facultative ponds apply here also except that the depth of sludge before de-sludging will be according to the original design.

The boat ride to measure the sludge depth shall not be used in these ponds. Instead, the white towel test shall be conducted and a long boom crane shall be used without making any person stand at the end of the boom.

2.7 Maintenance checklist and Record Keeping

2.7.1 Maintenance checklist for WPTs

Routine maintenance such as grass mowing, weeding, trash removal, mulch raking and maintenance, erosion repair, reinforcement plantings, tree and shrub pruning, and sediment removal shall be performed as necessary.

The checklists shall be signed, dated, and maintained at an accessible location with an official representative of the homeowner's association, the individual or company contracted for maintenance, or the owner. All documents were shown in Figure 2.4, Table 2.1, Table 2.2, Table 2.3, and Table 2.4.

2.7.2 Records necessary for Anaerobic Pond

- Daily tests and records will be the flow and SS.
- Monthly tests shall be the BOD after filtering through Whatman 42 filter paper, and pH.

2.7.3 Records necessary for Facultative Pond

- Daily tests and records will be the flow and SS.
- Weekly tests will be identification of organisms as per "Standard Methods" drawings.
- Monthly tests shall be the BOD after filtering through Whatman 42 filter paper, and pH.

2.7.4 Record necessary for Maturation Pond

- Daily tests and records will be the flow and SS.
- Monthly tests shall be the BOD after filtering through Whatman 42 filter paper, and pH.
- Yearly test of faecal and total coliforms at peak rainy season shall be conducted.

Figure 2.4. The maintenance checklist of Waste stabilization pond

WET PONDS PRACTICES: O&M CHECKLIST

Inspection Date………………………………………………………………….

Inspector………………………………………………………………….

Location………………………………………………………………………………

Date BMP Placed in Service…………………………….

Date of Last Inspection…………………………………………….

Owner/Owner's Representative………………………………………………………………………….

Town Project Number………………………………………………

As-Build Plans available: Y/N

Facility Type: Level1……………………………………Level2………………………

During the first 6 months following construction, the pond should be inspected twice after events that exceed 1/2 ince of rainfall. The aquatic benches should be planted with emergent wetland species, consisten with the Wet Pond design specifications. Bare or eroding areas in the CDA or around the pond buffer should be stabilixed immediately with grass cover. Trees planted in the buffer need to be watered every 3 days for the first month, and then weekly during the remainder of the first growing season (April-October), depending on rainfall. Due to typical vegetation survial problems, it is typical to plan and budget for a round of reinforcement planting during the second growing season after construction. Wet Ponds should be inspected and cleaned up annually.

Pond Characteristics and functions: Water quality treatment

❑ Extended detention included ❑ Channel protection ❑ Ties into groundwater ❑ Single cell pond ❑ Multiple-cell pond system ❑ Pond with one or more wetland cells Hydraulic Configuration: ❑ On-line facility ❑ Off-line facility Type of Pre-Treatment Facility: ❑ Sediment forebay (above ground) ❑ Sedimentation chamber ❑ Plunge pool ❑ Stone diaphragm ❑ Grass filter strip ❑ Grass channel ❑ Other: ……………………	Inspection Summary

Note: BMP = Best Management Practice, Y = Yes, N = No

Table 2.1. The inspection and maintenance checklist (1)

Element of BMP	Potential Problem	Problem? Y/N	Investigate? Y/N	Repaired? Y/N	How to Fix Problem	Who Will Address Problem	Comments
Contributing Drainage Area	Adequate vegetation				Supplement as needed	Owner	
	There is excessive trash and debris				Remove immediately	Owner or professional	
	There is evidence of erosion and/or bare or exposed soil				Stabilize immediately	Owner or professional	
	There are excessive landscape waste and yard clippings				Remove immediately and recycle or compost	Owner or professional	
Pre-Treatment	There is adequate access to the pre-treatment facility				Establish adequate access	Professional and, perhaps, the locality	
	There is excessive trash and debris				Remove immediately	Owner or professional	
	There is evidence of erosion and/or exposed soil				Immediately identify and correct the cause of the erosion and stabilize the eroded or bare area	Owner or professional	
	Sediment deposits are 50% or more of forebay capacity				Dredge the sediment to restore the design capacity; sediment should be dredged from forebays at least every 5-7 years, and earlier if performance is being affected.	Professional	
	The sediment marker is not vertical				Adjust the sediment depth marker to a vertical alignment	Professional	
	There is evidence of clogging				Clear blockages of the riser or orifice(s) and make other adjustments needed to meet the approved design specifications	Professional	
	There is dead vegetation				Revegetate, as needed	Owner or professional	

Table 2.2. The inspection and maintenance checklist (2)

Element of BMP	Potential Problem	Problem? Y/N	Investigate? Y/N	Repaired? Y/N	How to Fix Problem	Who Will Address Problem	Comments
Inlet	The inlet provides a stable conveyance into the pond				Stabilize immediately, as needed, and clear blockages.	Owner or professional	
	There is excessive trash, debris, or sediment				Remove immediately	Owner or professional	
	There is evidence of erosion/undercutting at or around the inlet				Repair erosion damage and restabilize	Owner or professional	
	There is cracking bulging, erosion or sloughing of the forebay dam.				Repair and restabilize immediately	professional	
	There is woody growth on the forebay dam.				Remove within 2 weeks of discovery	professional	
	There is evidence of nuisance animals.				Animal burrows must be backfilled and compacted. Burrowing animals should be humanely removed from the area.	professional	
	There is more than 1 inch of settlement				Add fill material and compact the soil to the design grade	Owner or professional	
	The inlet alignment is incorrect.				Correct immediately.	Owner or professional	
Vegetation	Plant composition is consistent with the approved plans.				Determine if existing plant materials are consistent with the general Wet Pond design criteria, and replace inconsistent species	professional	

>>

(Continue)

	Vegetation is dead or reinforcement planting is needed.				Remove and replace dead or dying vegetation.	professional	
	Invasive species are present.				Remove invasive species immediately and replace vegetation as needed.	professional	
	Trees planted in the buffer and on wetland islands and peninsulas need watering during the first growing season				Consider watering every 3 days for first month, and then weekly during first year (April-October), depending on rainfall.	Owner or professional	
	Grass around the facility is overgrown				Mow (at least twice a year) to a height of 4’’-9’’ high and remove grass clipping	Owner or professional	
Permanent Pool and Side Slopes	There is excessive trash and/or debris.				Remove immediately	Owner or professional	
	There is evidence of sparse vegetative cover, erosion or slumping side slopes.				Repair and stabilize physical damage, and reseed or plant additional vegetation.	Owner or professional	
	There is evidence of nuisance animals.				Animal burrows must be backfilled and compacted. Remove burrowing animals humanely from the area.		
	There is significant sediment accumulation				Conduct a bathymetric study to determine the impact to design volume, and dredge if necessary.	professional	

Table 2.3. The inspection and maintenance checklist (3)

Element of BMP	Potential Problem	Problem? Y/N	Investigate? Y/N	Repaired? Y/N	How to Fix Problem	Who Will Address Problem	Comments
Riser/Principle Spillway and Low-Flow Orifice(s)	There is adequate access to the riser for maintenance.				Establish adequate access	Professional and, perhaps, the locality	
	Pieces of the riser are deteriorating, misaligned, broken or missing.				Repair immediately.	Professional	
	Adjustable control valves are accessible and operational.				Repair, as needed.	Professional	
	Reverse-slope pipes and flashboard risers are in good condition.				Repair, as needed.	Professional	
	There is evidence of clogging				Clear blockages of the riser or orifice(s) and make other adjustments needed to meet the approved design specs.	Professional	
	Seepage into conduit				Seal the conduit	Professional	
	There is excessive trash, debris, or other obstructions in the trash rack.				Remove immediately	Owner or profession	
Dam/Embankment and Abutments	There is sparse veg, cover, settlement, cracking, bulging, misalignment, erosion rills deeper than 2 inches, or sloughing of the dam.				Repair and restablilize immediately, especially after major storms	Professional	
	There are soft spots, seepage, boggy areas or sinkholes present.				Reinforce, fill and stabilize immediately.		

(Continue)

	There is evidence of nuisance animals.				Animal burrows must be backfilled and compacted. Burrowing animals should be humanely removed from area.		
	There is woody vegetation on the embankment.				Removal of woody species near or on the embankment and maintenance access areas should be done when discovered, but at least every 2 years.		
Overflow/Emergency Spillway	There is woody growth on the spillway.				Removal of woody species near or on the emergency spillway should be done when discovered, but at least every 2 years.	Owner or professional	
	There is excessive trash, debris, or other obstructions.				Remove immediately.	Owner or professional	
	There is evidence of erosion/back cutting				Repair erosion damage and reseed	Owner or professional	
	There are soft spots, seepage or sinkholes.				Reinforce, fill and stabilize immediately,	Owner or professional	
	Only one layer of stone armoring exists above the native soil.				Reinforce rip-rap or other armoring materials.	professional	

Table 2.4. The inspection and maintenance checklist (4)

Element of BMP	Potential Problem	Problem? Y/N	Investigate? Y/N	Repaired? Y/N	How to Fix Problem	Who Will Address Problem	Comments
Outlet	The outlet provides a stable conveyance from the pond.				Stabilize immediately, as needed, and clear blockages.	Owner or professional	
	There is woody growth within 5 feet of the outlet pipe barrel.				Prune vegetation back to leave a clear discharge area.	Owner or professional	
	There is excessive trash, debris, or other obstructions.				Remove immediately.	Owner or professional	
	There is excessive sediment deposit at the outlet.				Remove sediment.	professional	
	Discharge is causing undercutting, erosion or displaced rip-rap at or around the outlet.				Repair, reinforce or replace rip rap as needed, and restabilize.	professional	
	Access to the facility or its components is adequate.				Establish adequate access. Remove woody vegetation and debris that may block access. Ensure that hardware can be opened and operated.	Professional and, perhaps, the locality	
	Fences are inadequate				Collapsed fences must be restored to an upright position. Jagged edges and damaged fences must be repaired or replaced.	Professional	
	Water levels in one or more cells are abnormally high or low.				Clear blockages of the riser or orifice(s) and make other adjustments needed to meet the approved design specifications.	Professional	
	Complaints from local residents				Correct real problems.	Owner or professional	

(Continue)

	Mosquito proliferation				Eliminate stagnant pools and stock the basin with mosquito fish to provide natural mosquitoes & midge control. Treat for mosquitoes as needed. If spraying, then use mosquito larvicide, (e.g., Bacillus thurendensis or Altoside formulations) only if absolutely necessary.	Owner or professional	
	Encroachment on the pond or easement by buildings or other structures				Inform involved property owners of BMPs status; clearly mark the boundaries of the receiving pervious area, as needed	Owner or professional (and perhaps the locality)	
	Safety signage is not adequate				Provide sufficient, legible safety signage.	Owner or professional	

3.Monitoring the Water Quality of Effluents

3.1 Introduction

Water quality analysis is required mainly for monitoring purposes. The importance of such assessment includes:

- To check whether the water quality is in compliance with the standards, and hence, suitable or not for the designated use.
- To monitor the efficiency of a system, working for water quality maintenance
- To check whether upgradation/change of an existing system is required and to decide what changes should be taken.

Therefore, water quality analysis is crucial to obtain accurate results. The procedure of water quality analysis presented in Figure 3.1 should be followed:

3.2 Sampling

In general, the two categories of samples are to be collected for (a) physical and chemical tests and (b) microbiological tests. In both cases, care should be taken to avoid entry of extraneous materials such as silt, scum and floating matters into sampling bottles.

3.2.1 Sample types

Understanding the principles and practices of sampling to obtain a representative sample is important to get at a truly representative sample instead of random collection leading to misleading results. Laboratory analyses will have little value if representative sampling is not done. Sampling points must be located where homogeneity of the sewage with good mixing is available.

There are two types of sample to be taken, grab sample and composite sample.

a) Grab Sample

Grab samples are collected when frequent changes in character and concentrations are likely to occur and influence the treatment, undesirable constituents are suspected, the quality is not expected to vary or when samples require on the spot analysis for parameters such as DO, pH and fecal coliform. For example, the testing of the suspended solids (SS) in the maturation ponds effluent is an independent sample and it needs to be correlated to the time of sampling because the SS can vary between low flows, average flows and peak flows. Invariably the SS at peak flows of a few hours in the early forenoon may be higher. If the timing is not given, this will give the wrong impression that the entire performance over the 24 hours has got higher SS. Representative samples should be taken with good judgement and should be analysed within 2 – 3 hours of sampling. It is, therefore, a single grab sample does not represent the total waste flow or pond conditions.

b) Composite Sample

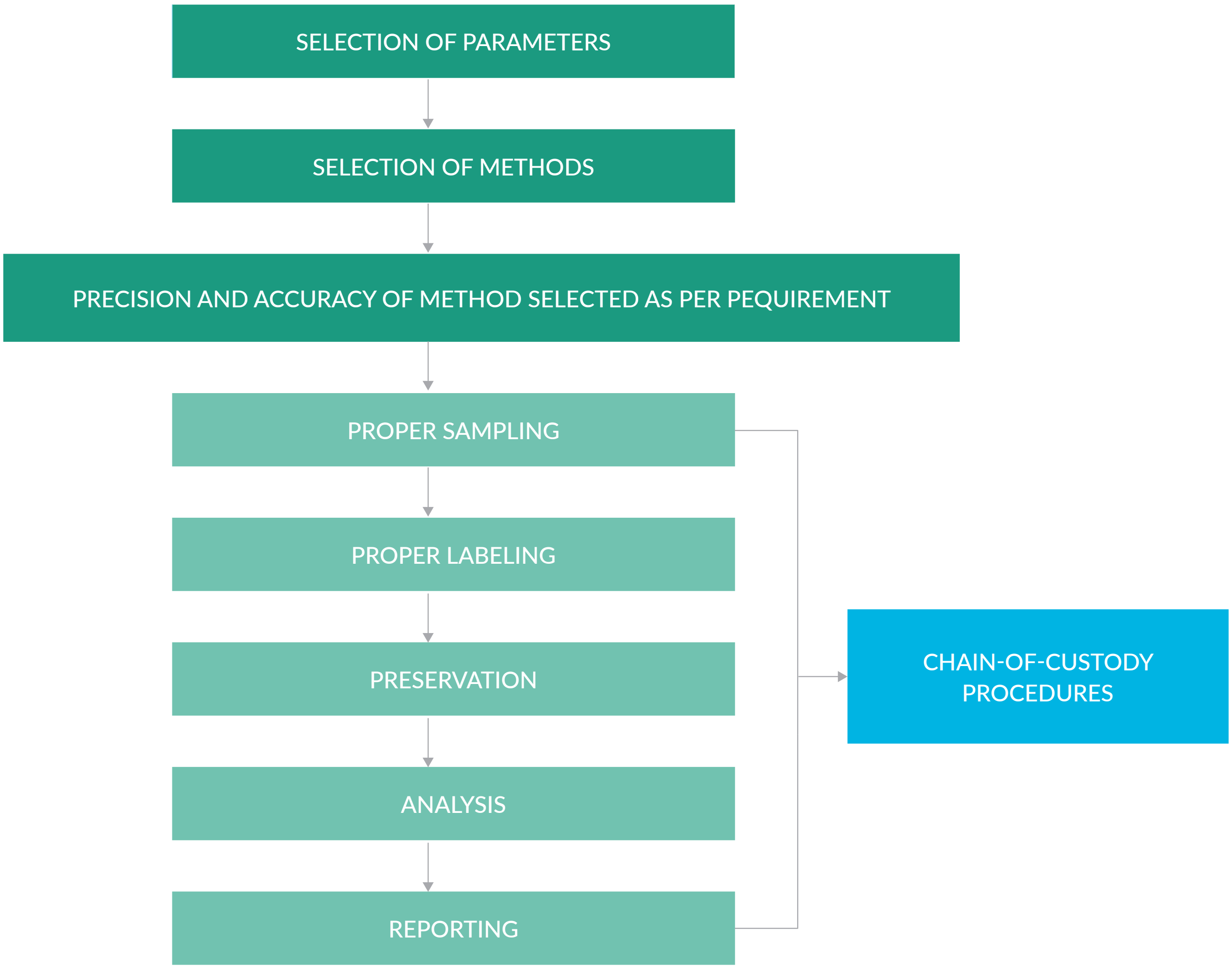
Since the sewage quality changes with time in a day, the best results would be obtained by using some sort of continuous sampler-analyzer.

The continuous analysis if practiced, will leave little time to the operators to pay attention for actual operation of the STP. Hence, for tests, which cannot wait due to rapid chemical and biological change of the sample, such as tests for dissolved oxygen and sulphide, a fair compromise may be reached by taking samples throughout the day at hourly or two-hourly intervals.

When the samples are taken, the containers shall be preserved immediately in a suitable ice box till they are taken to a laboratory and preserved in the refrigerator there till they are taken up for analysis. This is required to avoid anaerobic decomposition which will alter the composition and characteristics of especially the organic portions like BOD, etc. When all the samples have been collected for a 24-hour period, the sample from a specific location should be combined or composite together according to flow to form a single 24-hour composite sample. as under

- The rate of sewage flow must be known, and
- Each grab sample to be taken and in direct proportion to the volume of flow at that time.

Figure 3.1. The flowchat of procedure for water quality analysis



The Table 3.1 illustrates the hourly flow and sample volumes to be measured for a 12-hour sampling.

Large sewage solids should be excluded from a sample, particularly those greater than 6 mm diameter. A composite sample according to the Table 3.1would total 1,140 ml.

The factor (*) mentioned in Table 3.1 is a multiplying factor for flow. The factor is so adjusted or decided so as to arrive at a convenient sample volume. This factor generally remains constant for a particular STP. It also remains constant during composite sampling period so as to maintain proportionality between flow and sample volumes.

During composite sampling and at the exact moment of testing, the collected samples must be remixed so that they are of the same composition. Lack of mixing can cause changes in results samples of solids that settle out rapidly, such as those in activated sludge or raw sewage. Samples must therefore be mixed thoroughly and poured quickly before settling occurs. If this is not done, errors of 25 to 50 % may easily occur.

For example, on the same mixed liquor sample, one person may find 3,000 mg/L SS while another may determine that there are only 2,000 mg/L due to poor mixing. When such a composite sample is tested, a reasonably accurate measurement of the quality of flow can be made.

Table 3.1. Hourly flow pattern during composite sampling

Time	Flow(Mld)	Factor(*)	Sample Volume(ml)	Time	Flow(Mld)	Factor(*)	Sample Volume(ml)
6 AM	0.2	100	20	12 N	1.5	100	150
7 AM	0.4	100	40	1 PM	1.2	100	120
8 AM	0.6	100	60	2 PM	1.0	100	100
9 AM	1.0	100	100	3 PM	1.0	100	100
10 AM	1.2	100	120	4 PM	1.0	100	100
11 AM	1.4	100	140	5 PM	0.9	100	90

3.2.2 Location of sampling points

Theoretically, there is no end to the number of sampling stations that can be used in a treatment plant. But then, it should be remembered that the best monitoring can be possible only when the barest minimum and objectively oriented sampling locations and tests are carried out instead of accumulating all and sundry data that will only confuse the situation. This is because the sewage passes through the treatment plant on a time-deferred scale and if samples are taken all at the same time from inlet to outfall, the chances are that it is not representative of the true performance.

For example, the objective of surveillance is to assess the overall performance of the WSP, the quality of influent water coming into the WSP and of that at the effluent point should be taken and analyzed. Any significant difference between the two implies the treatment performance of the WSP as a whole, but not to the specific functioning of individual pond.

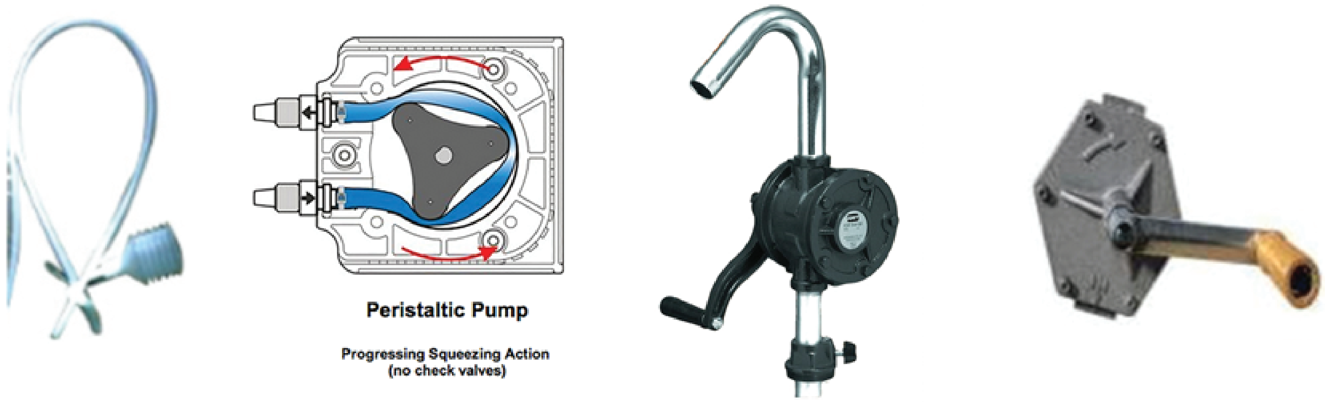
3.2.3 Sampling method and Precaution in Sampling

The sampling procedure is very important and is based on the purpose of sampling and tests to be performed. In general, sewage samples shall not be aerated during collection. Some of the manually operated sampling apparatuses are shown in Figure 3.2. Each has its preference, but the symphonic bellow at A is the easiest to use anywhere.

A-Symphonic tube with bellows; B- Electrically operated peristaltic pump, C- Hand operated rotary with positive displacement, D- Hand operated rotary with circular movement

The use of the symphonic bellows tube involves the dipping of the free end of the tube into the liquid surface and keeping the pump end below the liquid level outside the structure and pumping the bellow, which starts a siphon action. Initially some portion of the sewage is to be discharged freely. If the sample is meant for determining the dissolved oxygen, the free end after bellows shall be extended by rubber tubing with a standard laboratory pinchcock and the free end of the tubing dipped into the BOD bottle to affect a submerged discharge very slowly. A timing of 10 seconds to fill the BOD bottle is considered as optimum. The sample shall be allowed to overflow for 5 seconds before the tube is withdrawn and the bottle is corked with the ground glass cork. This is possible only in the case of tanks with the liquid surface above ground level. If the liquid level is below ground level, a long handle connected scoop can be easily used. In this case, the scoop shall have a minimum of 1,000 ml volume and the above procedure can be done. The electrically operated peristaltic pumps (B) and other hand operated devices (C), (D) are fitted only for the final treated sewage samples. In all cases, the discharge end shall be submerged in the sampling bottle and overflow of samples shall be allowed for about 5 seconds.

Figure 3.2. Typical sampling apparatuses used in sampling of sewage in STPs



A B C D

3.2.4 Sample Volume, Quantity and Storage of Samples

One to two liters of grab sample would be enough to perform all the tests and repeat some tests if required. For composite samples, a total quantity of 1 to 2 liters collected over a 24-hour period is adequate. Fractional sample at intervals of 1 to 2 to 3 hours should be collected in suitable containers, each sample being well mixed and a measured portion proportional to the flow transferred by means of a pipette, measuring cylinder or flask and integrated to form a 1 to 2-liter sample. Hourly records of flow normally available with the Plant Superintendent would facilitate taking representative samples. All samples should be immediately transported to the laboratory for analysis. In case there is any delay in transportation, the preservation time is to be as short as possible and, in any case, not exceeding 24 hours and the ice shall not be found melted on receipt of the sample.

3.3 Testing Parameters and Frequency

3.3.1 Items and Frequency for WSP

In general parameters of testing for diurnal examinations arise only when the treatment process is dependent on solar energy like in the case of ponds. In such cases, the tests will be as follows.

Care, safety and wisdom are paramount in taking samples from ponds especially diurnal samples as chances of vermin and reptiles straying around in wet climates and high summer cannot be ruled out. Proper clothing, safety wear, etc., and the presence of a qualified ambulance person with tool kit is mandatory in the diurnal sampling.

A better way of managing this will be to leave a floating or other pump set erected in the daytime and operate it by remote switch in the night and collect the sample from the outlet hose of the pump set sufficiently far away at a well-lighted and safe and secure location. Table 3.2 mentioned the recommended plant control tests on a monthly basis in a typical WSP.

Table 3.2. Hourly flow pattern during composite sampling

No.	Parameter	Sample Type	Remarks
1.	Flow	-	Both raw sewage and final effluent flows
2.	BOD	C	Unfiltered samples (A)
3.	COD	C	Unfiltered samples (A)
4.	Suspended solids	C	
5.	Ammonia	C	
6.	pH	C	Two samples one set each at 8:00-10:00h & 14:00-16:00h
7.	Temperature	C	
8.	Fecal coliforms	C	Only when effluent being used (or being assessed for use) for crop irrigation. Ca, Mg, and Na are required to calculate the sodium absorption ratio (SAR) (D)
9.	Total nitrogen	C	
10.	Total phosphorus	C	
11.	Chloride	C	
12.	Electrical conductivity	C	
13.	Ca, Mg, Na	C	
14.	Boron	C	
15.	Helminth egg (B)	C	
16.	Dissolved Oxygen	-	At dawn and dusk

C=24-hour-weighted composited sample; G=grab sample,
(A) also, on filtered samples if the discharge requirements are so expressed.
(B) Ascaris lumbricoids, Trichuris trichlura, Ancylostoma duodenale and Necator americanus.
(D) SAR= $(0.044Na)/[0.5(0.050Ca+0.082Mg)]^{0.5}$ where Na, Ca and Mg are mg/L.
Source: Duncan Mara, 1997

3.3.2 Laboratory Testing

The following discussion will allow an operator to become familiar with the basic laboratory test needed by a stabilization pond system. Moreover, some parameters below were stringent by ministry of environment for inspection.

a) pH

The pH of a solution is measured as negative logarithm of hydrogen ion concentration. At a given temperature, the intensity of the acidic or basic character of a solution is indicated by pH or hydrogen ion concentration. pH values from 0 to 7 are diminishing acidic, 7 to 14 increasingly alkaline and 7 is neutral.

Measurement of pH is one of the most important and frequently used tests, as every phase of wastewater treatment and waste quality management is pH dependent.

The pH of natural water usually lies in the range of 4 to 9 and mostly it is slightly basic because of the presence of bicarbonates and carbonates of alkali and alkaline earth metals. pH value is governed largely by the carbon dioxide/ bicarbonate/ carbonate equilibrium. It may be affected by humic substances, by changes in the carbonate equilibriums due to the bioactivity of plants and in some cases by hydrolysable salts. The effect of pH on the chemical and biological properties of liquid makes its determination very important. It is used in several calculations in analytical work and its adjustment to an appropriate value is absolutely necessary in many of analytical procedures.

b) Total suspended solid (TSS)

Domestic wastewater normally contains between 200 and 250 mg/L of suspended solids. The suspended solids in wastewater are solids that are insoluble. Particle size varies. Some particles are large and heavy, they tend to settle readily under quite conditions. Smaller particles may settle slowly under the pull of gravity or not at all.

To test for suspended solids, filter a known quantity of wastewater through a glass fiber filter that has been prepared and weighed. Dry it for an hour and then weigh the amount of material deposited on the filter. Report the finding in mg/L.

c) Total dissolve solid (TDS)

A total dissolved solid (TDS) is a measure of the combined total of organic and inorganic substances contained in a liquid. This includes anything present in water other than the pure H20 molecules. These solids are primarily minerals, salts and organic matter that can be a general indicator of water quality. High TDS generally indicate hard water, which can cause scale build up in pipes and appliances. Scale buildup reduces performance and adds system maintenance costs.

The filterable residue is the material that passes through a standard glass filter disk and remains after evaporation and drying at 180°C.

d) Biochemical Oxygen Demand (BOD)

The Biochemical Oxygen Demand (BOD) is an empirical standardized laboratory test which measures oxygen requirement for aerobic oxidation of decomposable organic matter and certain inorganic materials in water, polluted waters and wastewater under controlled conditions of temperature and incubation period.
The quantity of oxygen required for above oxidation processes is a measure of the test. The test is applied for fresh water sources (rivers, lakes), wastewater (domestic, industrial), polluted receiving water bodies, marine water (estuaries, coastal water) and also for finding out the level of pollution, assimilative capacity of water body and also performance of waste treatment plants.

Since the test is mainly a bio-assay procedure, it is necessary to provide standard conditions of temperature, nutrient supply, pH (6.5-7.5), adequate population of microorganisms and absence of microbial-growth-inhibiting substances. The low solubility of oxygen in water necessitates strong wastes to be diluted to ensure that the demand does not increase the available oxygen. A mixed group of microorganisms should be present in the sample; otherwise, the sample has to be seeded. Generally, temperature is controlled at 20°C and the test is conducted for 5 days, as 70 to 80% of the carbonaceous wastes are oxidized during this period.

e) Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) test determines the oxygen requirement equivalent of organic matter that is susceptible to oxidation with the help of a strong chemical oxidant. It is an important, rapidly measured parameters as a means of measuring organic strength for streams and polluted water bodies. The test can be related empirically to BOD, organic carbon or organic matter in samples from a specific source taking into account its limitations. The test is useful in studying performance evaluation of wastewater treatment plants and monitoring relatively polluted water bodies. COD determination has advantage over BOD determination. COD results can be obtained in 3-4 hrs as compared to 3-5days required for BOD test. Further, the test is relatively easy, precise, and is unaffected by interferences as in the BOD test. The intrinsic limitation of the test lies in its inability to differentiate between the biologically oxidizable and biologically inert material and to find out the system rate constant of aerobic biological stabilization.

The open reflux method is suitable for a wide range of wastes with a large sample size. The dichromate reflux method is preferred over procedures using other oxidants (e.g. potassium permanganate) because of its superior oxidizing ability, applicability to a wide variety of samples and ease of manipulation. Oxidation of most organic compounds is up to 95-100% of the theoretical value. The organic matter gets oxidized completely by potassium dichromate (K2Cr2O7) with silver sulphate as catalyst in the presence of concentrated H2SO4 to produce CO2 and H2O. The excess K2Cr2O7 remaining after the reaction is titrated with ferrous ammonium sulphate [Fe (NH4)2(SO4)2]. The dichromate consumed gives the oxygen (O2) required for oxidation of the organic matter

f) Oil and Grease

Oil and grease are any material recovered as a substance soluble in petroleum ether, hexane or nhexane. It includes other materials extracted by the solvent from an acidified sample such as Sulphur compounds, certain organic dyes and chlorophyll. Oil and grease are defined by the method used for their determination. The oil and grease content of domestic industrial wastes and of sludges, is an important consideration in the handling and treatment of these materials for ultimate disposal. When treated effluents are discharged in water body, it leads to environmental degradation. Hydrocarbons, esters, oils, fats, waxes and high molecular weight fatty acids are the major materials dissolved by hexane. All these materials have a 'greasy feel'. Three methods for oil and grease estimations are (i) the partition-gravimetric method, (ii) the partition infrared method and (iii) the Soxhlet extraction method. Though methods-(i) does not provide the needed precision, it is widely used for routine analysis of samples because of its simplicity and it needs no special instrumentation and (ii) is identical to hydrocarbons. In method (iii) adequate instrumentation allows for the measurement of as little as 0.2mg oil and grease.

g) Total coliform

The coliform group consists of several genera of bacteria belonging to the family Enterobacteriaceae. The historical definition of this group has been based on the method used for detection (lactose fermentation) rather than on the tenets of systematic bacteriology. Accordingly, when the fermentation technique is used, this group is defined as all facultative anaerobic, gram-negative, non-spore-forming, rod-shaped bacteria that ferment lactose with gas and acid formation within 48 h at 35°C.

The standard test for the coliform group may be carried out either by the multiple-tube fermentation technique or presence-absence procedure (through the presumptive-confirmed phases or completed test) described herein, by the membrane filter (MF) technique or by the enzymatic substrate coliform test. Each technique is applicable within the limitations specified and with due consideration of the purpose of the examination.

h) Ammonia (NH3)

Nitrogen, as ammonia, is a critical nutrient in biological wastewater treatment. It is utilized by bacteria to make proteins, including enzymes needed to break down food or BOD as well as in making energy. In both aerated stabilization basins and activated sludge wastewater systems, insufficient nutrient availability will lead to poor biochemical oxygen demand (BOD) removal due to the inability of the bacteria to divide and create more workers.

The two major factors that influence selection of the method to determine ammonia are concentration and presence of interferences. In general, direct manual determination of low concentrations of ammonia are confined to drinking waters, clean surface or groundwater, and good-quality nitrified wastewater effluent. In other instances, and where interferences are present or greater precision is necessary, a preliminary distillation step is required.

In preliminary distillation step, the sample is buffered at pH 9.5 with a borate buffer to decrease hydrolysis of cyanates and organic nitrogen compounds. It is distilled into a solution of boric acid when titration is to be used or into H2SO4 when the phenate method is used. The ammonia in the distillate can be determined either colorimetrically by the phenate method or titrimetrically with standard H2SO4 and a mixed indicator or a pH meter. The choice between the colorimetric and the acidimetric methods depends on the concentration of ammonia. Ammonia in the distillate also can be determined by the ammonia-selective electrode method, using 0.04N H2SO4 to trap the ammonia.

i) Total Nitrogen (TN)

Total Nitrogen (TN) is the sum of nitrate-nitrogen (NO3-N), nitrite-nitrogen (NO2-N), ammonia-nitrogen (NH3-N) and organically bonded nitrogen. Total Nitrogen (TN) should not be confused with TKN (Total Kjeldahl Nitrogen) which is the sum of ammonia-nitrogen plus organically bound nitrogen but does not include nitrate-nitrogen or nitrite-nitrogen.

TN is sometimes regulated as an effluent parameter for municipal and industrial wastewater treatment plants, but it is more common for limits to be placed on an individual nitrogen form, such as ammonia. Treatment plants that have a TN limit will usually need to nitrify and denitrify in order to achieve the TN limit. Because nitrogen in wastewater can be found in four major forms (excluding trace amounts of nitrogen gas), each major form is generally analyzed as a separate component, with Total Nitrogen calculated from the sum of the four forms.

Nitrogen corresponding to total nitrogen nitrite ion and nitrate ion, ammonium ion and organic nitrogen correspond to Nitrogen, total ultraviolet absorption spectrophotometry after changing total nitrogen compounds to nitrate ions, sulfuric hydra A cupium reduction method, a copper / cadmium column reduction method, a pyrolysis method, or a method in which the total nitrogen compound is replaced with nitric acid Ultraviolet absorption spectrophotometry in place of ion and flow analysis method using copper cadmium column reduction method are applied.

j) Total Phosphorus (TP)

Phosphorus is an essential nutrient of plant, animal and human. In water, it exists primarily as orthophosphate (PO43-) or in organic compounds. The parameter total phosphorus (TP) defines the sum of all phosphorus compounds that occur in various forms.

Phosphorus (P) is a nutrient that is vital to human, animal, and plant growth. It's one of the most common substances found in nature. It's found in our water, our food, and our bodies. High levels of phosphorus in nature can create algal blooms causing eutrophication or the premature “aging” of a water body. This process decreases sunlight and oxygen levels (hypoxia) thus affecting fish and other aquatic life.

The total phosphorus as well as the dissolved and suspended phosphorus fractions each may be divided analytically into the three chemical types that have been described: reactive, acid hydrolyzable, and organic phosphorus. As indicated, determinations usually are conducted only on the unfiltered and filtered samples. Suspended fractions generally are determined by difference; however, they may be determined directly by digestion of the material retained on a glass-fiber filter.

k) Detergent

Surfactants enter waters and wastewaters mainly by discharge of aqueous wastes from household and industrial laundering and other cleansing operations. A surfactant combines in a single molecule a strongly hydrophobic group with a strongly hydrophilic one. Such molecules tend to congregate at the interfaces between the aqueous medium and the other phases of the system such as air, oily liquids, and particles, thus imparting properties such as foaming, emulsification, and particle suspension.

The sublation process isolates the surfactant, regardless of type, from dilute aqueous solution, and yields a dried residue relatively free of nonsurfactant substances. It is accomplished by bubbling a stream of nitrogen up through a column containing the sample and an overlying layer of ethyl acetate. The surfactant is adsorbed at the water-gas interfaces of the bubbles and is carried into the ethyl acetate layer. The bubbles escape into the atmosphere leaving behind the surfactant dissolved in ethyl acetate. The solvent is separated, dehydrated, and evaporated, leaving the surfactant as a residue suitable for analysis. This procedure is the same as that used by the Organization for Economic Co-operation and Development

3.4 Data Analysis

All analyses carried out should be properly recorded. Routine daily analysis, periodic analysis and special analysis should be recorded separately. Copies of these reports should be sent to the Plant Superintendent immediately after the analysis is done with explanatory notes to indicate any unsatisfactory conditions or abnormalities.

The Plant Superintendent should study the reports and direct the operating staff for proper corrective measures in the operation schedule. Such measures taken should be reported to the laboratory scientists who should check the efficiency of corrective measures by re-sampling and analysis. Corrective measures followed by sampling and analysis should be repeated till such time as satisfactory results are obtained.

Data collected over a period of time on various parameters of plant control should be analyzed and represented on charts and graphs and displayed in the laboratory for ready reference by the supervisory staff and visitors. These should be included in the weekly, monthly and annual reports of the laboratory.

3.4.1 Processing water quality test data

The analysis of results must be done judiciously. One should not jump to conclusions. Logic of the results should be first verified instead of blindly taking it for granted. Some of the fundamentals to be followed are listed overleaf:

- The outlet BOD of any unit cannot be higher than the outlet BOD of the upstream unit
- The ammonia of final treated sewage cannot be the same or higher than that in raw sewage
- The ortho P of final treated sewage cannot be the same or higher than that in raw sewage
- The SS of final treated sewage cannot be higher than that of raw sewage
- Rotifers, Crustaceans, Protozoans cannot be absent if BOD reduction is at least 75 %
- Follow the final BOD and SS on a graph, which will show any sudden lapses.
- At regular intervals refer the sample confidentially to a recognized laboratory to keep a check on the results of 2 to 5 % samples.
- Whenever visiting a STP, verify DO qualitatively by the Winkler method
- Whenever in the STP, take time to see through the oil immersion microscope for live micro-organisms
- It is most important that analysts alone are not held responsible for plant failures

3.4.2 Accuracy of measured values

In order to make the accuracy of measurement, many steps below should be following:

- If ammonia is reported as nitrified, bicarbonate alkalinity must be reduced 7 times.
- If this is not the case, carry out a repeat test before deriving conclusions.
- Make an "audit" for BOD removed versus kWh spent on aeration system.
- Hypothetical ionic equilibrium may not tally in all the lab results.
- This may be a genuine case as precise chloride estimation is very difficult.
- In such case, it is better to adjust the chloride value to bring the ionic equilibrium.
- The COD reduction in treated sewage Vs. raw sewage cannot be less than BOD reduction.
- If this is the case, the results are suspect.

With the availability of personal computers and software at reasonable cost, the advantages of electronic data processing for storage, retrieval and processing of laboratory test results are obvious. To start with, the analysis results may be entered from the daily records into the computer. A simple programmed can be written for retrieval and presentation of data relating to any particular parameter. This can be in the form of display of data for a fixed period or weekly or monthly averages or the results of analysis carried out on samples collected at a particular time of the day for the period to be studied etc. A slightly more detailed programming can be prepared for the computer to go through the results of specified parameters entered daily and display or print out any figures, which exceed a present value. This can be immediately passed onto the treatment plant staff for investigation and rectification. The computer can also be programmed to display and print out graphs showing the variation in any specified parameters over a period of time.

Analytical instruments are also available for carrying out tests automatically on a large number of samples simultaneously and electronically feed the data directly into the computer using a data logger module.

3.5 Disposal of Laboratory Waste

Any office or other place where a number of people work requires a proper waste disposal system. In the case of a laboratory in a STP, special care has to be taken since the laboratory handles harmful chemicals and the samples themselves are capable for transmitting pathogens.

3.5.1 Solid waste

Solid waste may include filter residues, used cotton plugs, etc. These should be collected and disposed scientifically in an eco-friendly method approved by the local Pollution Control Board.

3.5.2 Liquid wastes

Laboratory liquid wastes are classified into organic and inorganic wastes. Pour liquid wastes into the designated liquid waste container according to textbooks and instructors. Rinse the glassware with the minimum amount of water, and pour into the liquid waste container.

Neutralization of Acidic and Alkaline Wastes:

- Do not pour concentrated acidic or alkaline solutions directly into drains. Neutralize the solutions before disposal.
- Sodium hydrogen carbonate is often used for neutralization because even an excess addition does not make the solution too alkaline. Add it into an acidic solution with stirring until bubbling is ceased.
- Pour the neutralized liquid waste into a drain if it contains no harmful substance.

3.5.3 Radioactive wastes

If radioactive materials are suspected to be present in the waste samples, special precautions will have to be taken to protect the laboratory staff.