Management

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Chapter 11

Operation, Maintenance and Monitoring of Faecal Sludge Treatment Plant

Magalie Bassan and David M. Robbins

Management

Learning Objectives

- Understand the importance and role of operations and maintenance for faecal sludge treatment plants.
- Understand critical operations and maintenance factors to include starting with the design and planning phases.
- Be able to design an effective monitoring and operations and maintenance plan to ensure treatment performance.
- Understand the role of administrative management in the long-term operation of faecal sludge treatment plants.

11.1 INTRODUCTION

Faecal sludge treatment plants (FSTPs) require ongoing and appropriate operation and maintenance (O&M) activities in order to ensure long-term functionality. O&M activities are at the interface of the technical, administrative, and institutional frameworks that enable sustained FSTP function. “Operation” refers to all the activities that are required to ensure that a FSTP delivers treatment services as designed, and ” maintenance” refers to all the activities that ensure long-term operation of equipment and infrastructure (Bräustetter, 2007). Proper O&M of FSTPs requires a number of crucial tasks to be carried out regardless of the size of the plant, and complexity of the technological setup (Figure 11.1). Having skilled workers perform these tasks in a timely manner and in accordance with best practices will maximise the value of the FSTP and ensure its long-term performance.

Figure 11.1 Maintenance worker cleans mechanical screens, a critical activity to be performed each shift to keep the system operational, Dakar, Senegal (photo: Linda Strande).

Many FSTPs fail following construction, regardless of the choice of technology or the quality and robustness of the infrastructure. Reasons for failure are not always investigated, but the most frequent explanations given are low operational capacity (Fernandes *et al.*, 2005; Lennartsson *et al.*, 2009; Koné, 2010; HPCIDBC, 2011), and the lack of financial means to accomplish O&M tasks (Koné, 2002). Lessons learned from these failures are that O&M must be considered as an integral component of the full life cycle costs of a facility, and that ongoing training and capacity building is essential for the operators. In addition, the O&M plan must be incorporated into the design process and receive appropriate review and approvals along with the engineering plans. This helps to ensure that O&M is fully integrated into the facility once construction is complete and operation has begun.

Financial, technical and managerial inputs are needed to ensure the continuous operation of even the simplest of FSTP systems. The procedures that establish how the treatment facility and equipment are utilised, are documented in several O&M plans, monitoring programmes, reports and log books, and health and safety plans, which outline the step-by-step tasks that employees are required to carry out in order to ensure the long-term functioning of the FSTP. While many O&M activities are process-specific, others are common to all facilities and all O&M Plans should therefore include information on:

- the procedures for receiving and off-loading of faecal sludge (FS) at the FSTP;
- the operation of specific technologies such that they function as designed;
- maintenance programmes for plant assets to ensure long-term operation and to minimise breakdowns;
- the monitoring and reporting procedures for the FSTP O&M activities as well as the management of treatment endproducts;
- management of health and safety aspects for protection of the workers and the environment;
- the organisational structure, distribution of and the management of administrative aspects; and
- procedures for the onsite storage of FS and the off-site transportation.

The level of organisation required at any given FSTP is a function of its size and treatment capacity. Small systems that receive a few loads of FS a week may only need one operator, and therefore have relatively simple O&M plans, while large municipal systems that receive FS loads around the clock are more complex and require more staff with different levels of operators and maintenance personnel. This chapter discusses the O&M planning process as well as the specific components of the O&M Plan. It references the procedures and tasks that are common to all FSTP facilities, as well as considerations for technology specific tasks.

11.2 INTEGRATING O&M INTO THE FAECAL SLUDGE TREATMENT PLANT PLANNING PROCESS

There are several important factors that need to be considered when planning FSTPs which will have a direct impact on O&M and monitoring. They encompass both classical engineering aspects of technology integration, as well as other issues concerning the institutional management that defines the FSM programme. Since O&M aspects are important for the overall long-term success of the programme, O&M planning, including the financial provision of funds, should be included in the terms of references for the design of each FSTP (Fernandes *et al.*, 2005; Lüthi, 2011). Furthermore, the O&M plan should be reviewed and approved along with engineering designs and specifications, including the following considerations:

- location of the FSTP and its proximity to residential areas;
- volumes and schedules of FS collection;
- availability of local resources;
- degree of mechanisation of technologies; and
- final enduse or disposal of endproducts.

11.2.1 Location of the faecal sludge treatment plant

The location of a FSTP is a crucial aspect when designing an O&M plan. FSTPs are often associated with nuisances such as odors, flies and mosquitoes, and noise. Facilities located close to residential areas must therefore install preventative controls, all of which have O&M implications. Examples include FSTPs that utilise waste stabilisation ponds located near to residential areas, where mosquito control is an important requirement. For FSTPs located such that access roads cross residential areas, reduction of noise and dust produced by trucks needs to be regulated.

Other site specific factors that might influence O&M activities and costs include:

- soil conditions, such as soil depth and bearing capacity, that might have impact on equipment selection and installation;
- groundwater level and proximity of the FSTP that could result in pollution of water resources or infiltration of groundwater into treatment tanks, directly impacting on the pumping and solids handling equipment; and
- surface waters and flooding risks, which might inhibit site access during rainy seasons, adversely affect or undermine equipment due to scouring or erosion.

11.2.2 Volumes and schedules of faecal sludge delivery

The volume of FS that is collected and delivered to the treatment plant, as well as the operational times of the FSTP will have a significant influence on the O&M costs and requirements. Cultural habits or events can influence the volumes that are discharged at the FSTP at different times of the year. Similarly, seasonal variability of waste volumes will impact O&M staffing requirements. Larger systems that operate on a daily basis have very different staffing requirements to those that operate intermittently.

Figure 11.2 Maintaining the fleet of faecal sludge vacuum trucks in Dumaguete City, Philippines, (photo: David M. Robbins).

The distribution of the FS volume received at the plant throughout the day is critically important in the planning process, as low or high flows that exceed the design of the treatment system can have a significant impact on the operational efficiency. The initial planning phase must therefore ensure that the chosen technology is appropriate for local conditions, and that it is correctly sized to accommodate the expected volumes and related fluctuations. Institutional arrangements that closely coordinate activities between facility owners and those responsible for the FS collection and transportation can help to address these issues.

11.2.3 Availability of local resources

The availability of local resources impacts not only those aspects that determine the cost of construction such as technology selection and building materials but also on the costs of O&M requirements. Local resource issues that must be considered from the O&M perspective include:

- the availability of spare parts and tools;
- the availability of consumables (e.g. chemicals for flocculation);
- the availability and reliability of local utilities including water and power;
- the availability of trained human resources to properly operate the facility;
- the availability of local laboratory resources that may be required for monitoring programs; and
- the availability of local contracting firms to assist with periodic tasks that may be labor intensive, or require very specific skills.

Ideally, equipment that can be maintained and repaired within the country should be used. If no local supplier is available, fast delivery and repair services need to be ensured, or adequate replacement components must be stocked at the plant. For example, the powerful vacuum trucks that are needed to empty settling-thickening tanks require specific maintenance skills, which are often not locally available in mechanical workshops (Figure 11.2). It is therefore recommended that contracts be prepared during the equipment acquisition process whereby conditions for the repair services, for example, the annual maintenance of vacuum trucks, is defined. When designing FSTPs that require the addition of consumables for the treatment process (e.g. lime or chlorine), the costs and availability of these needs to be assessed, as well as the requirements for safe storage. Other aspects that impact on O&M costs include emergency operation procedures during power or water outages, and any shipping or transportation charges for delivery of samples requiring laboratory analysis. The choice of technology should therefore not only be made based on installation costs, but also O&M costs.

11.2.4 Degree of mechanisation of technologies

The degree of mechanisation of the FSTP depends on the availability of spare parts, electrical power and trained operators. Where this is limited, passive technologies such as drying beds and stabilisation ponds might be better technology choices. If power availability is intermittent, technologies that utilise manual systems should be chosen over mechanical ones whenever possible. For example, screenings can be removed manually or by a mechanical rake, dried sludge can be transported with a mechanical shovel or with a wheelbarrow, and small composting piles can be mechanically aerated, while compost heaps need to be turned manually.

11.2.5 Final enduse or disposal of treatment products

The enduse or disposal of the treatment endproducts has an influence on the technologies and processes needed to achieve the required level of treatment (Chapter 10). This in turn, has a significant impact on the costs and skill levels required to operate and maintain equipment. In a simple FSTP where sludge is dried for disposal in a landfill or for enduses such as combustion, both of which do not require high pathogen reduction, less rigorous treatment and lower O&M costs are involved compared to a system that produces endproducts for use on food crops that are directly ingested without cooking (e.g. salad greens). Determining if the value associated with the enduse activities is outweighed by the technology and O&M costs needed to achieve the required levels of treatment is a key driver for FSTP technology design. Understanding the costs associated with the specific O&M and monitoring tasks for identified enduse activities assists in the planning of a FSM programme.

11.3 RECEIVING FAECAL SLUDGE AT THE TREATMENT PLANT

It is important to take the traffic patterns and the management of truck traffic in and out of FSTPs into consideration in order to maximise the efficiency of the receiving and off-loading processes. Receiving FS loads at the FTSP involves:

- traffic control; and
- approving the FS for discharge into the facility.

These aspects are discussed in the following sections.

11.3.1 Traffic control

At facilities which are used infrequently, traffic control is rarely an issue. In most cases, the employees at these facilities is mainly required for discharge approval and direction of trucks in the FSTP. On the other hand, at busy facilities, where vacuum or sludge delivery trucks and other vehicles may be competing to discharge their loads, operational employees can help facilitate rapid unloading by providing direction and assistance to drivers, and thereby avoiding accidents.

Traffic control is simplified through a well-designed facility layout. Access roads that allow vehicles to drive through after discharge rather than turn around are not only more efficient, but also safer. Mechanised unloading stations that record the drivers identification and discharge volume can also reduce O&M costs at busy facilities. The turning radius and weight of the largest trucks that will utilise the facility should be considered when planning roads and driveways. In addition, off-loading and truck parking areas should be level, and access roads should not have more than a 3% gradient.

11.3.2 Approving faecal sludge for discharge

Wastes from different sources can have widely differing characteristics, which may impact upon the operation of the FSTP. Residential FS (e.g. from pit latrines or septic tanks) is often relatively free of toxic chemicals. Restaurant FS, however, may have significant quantities of fats, oil and grease, especially if grease traps or interceptors are absent or not functioning properly. Similarly, FS from auto repair shops, dry cleaning establishments, hospitals, or other commercial or institutional settings may contain toxic materials that are detrimental to the treatment process. In areas with a large number of commercial facilities, it is recommended that FSTP have parallel treatment trains, one that can accommodate residential sludge, and another for commercial wastes.

Depending on the institutional framework, and the arrangement between the stakeholders in charge of the collection, transport and treatment, a manifest system can be utilised to record the origin, volume and special characteristics of FS. A form can be completed at the origin of the FS and signed by the owner (Figure 11.3). Where the trucks frequently contain FS from several onsite technologies, the form should include this information. The manifest is then carried by the driver and presented at the FSTP for review by operations employees prior to off-loading. Once the load is approved, the manifest is then signed by the operator and returned to the driver as proof that the waste load was discharged into the facility.

Manifest Form

Sludge / septage origin

Name (Household unit owner)

Address

Date and time of collection

Source and volume of sludge/septage

Source	Check one	Volume (cubic metre)
Residential		
Commercial / industrial		
Institutional		
Wastewater treatment plant		

Commercial / industrial waste must be sampled and tested before it is offloaded at the treatment facility to ensure that the material will not contaminate the treatment process. Contamination can be caused by grease, oil, metals and chemicals.

Description of commercial / industrial waste:

Excavator / transporter

Operator / company	
Address	
Type of vehicle	
Plate number	
Name of driver	
Signature	
Driver's license number	
Name of other personnel	

Approved by authorised representative

(Name and signature)

Figure 11.3 Manifest form identifying the origin of the load, waste volume and driver's name adapted from the Philippines Department of Health (2007).

Operators of FSTPs should be trained in the physical inspection of sludge samples. If there is any doubt as to the origin of the load, samples should be drawn and inspected for color, odor, and presence of grease or oil. FS from residential sources has a distinct visual appearance, as do loads contaminated with excessive oil and grease. Loads that do not conform to standards that have been established for the treatment process should be rejected if segregation is not possible.

11.4 OPERATION & MAINTENANCE PLANS

The O&M plan provides details on the tasks, materials, equipment, tools, sampling, monitoring and safety procedures which are necessary to keep the plant running properly, all of which have cost implications that must be carefully considered.

11.4.1 Operational procedures

FSTPs require clear operational procedures. Therefore, the O&M plans should include an operation manual, containing the following information:

- the engineering drawings and FSTP specifications;
- the manufacturer's literature and equipment operation guidelines;
- the responsible person for each task;
- the frequency of each activity;
- the operation procedures and tools required to perform the task;
- the safety measures required; and
- the information that is to be monitored and recorded.

If chemicals or other consumables are required for the operation of a specific component, they should also be listed together with the name of the supplier and information on how they are to be used and stored. If some operational activities require the use of external companies, or if a transport company is needed to discharge the endproducts, their contact and description should also be given in the operation manual. The operation manual must also have a special section for emergency or non-routine operations requirements. Procedures should be planned for specific cases such as extreme climatic events, power shortages, overload, degradation of a pump, basin or canal, and other accidents. All procedures provided in the operation manual must be prepared in order to ensure conformance with the local laws and standards.

The treatment technologies described in Chapters 5 to 9 all require the control of the following aspects:

- screenings removal;
- load (quantity, quality and frequency);
- processing (e.g. mixing compost pile, chemical addition for mechanical drying);
- residence time;
- extraction, further treatment or disposal of endproducts;
- collection and further treatment or disposal of liquid endproducts; and
- storage and sale of the endproducts.

The operational procedures should take the climate and the other context-dependent variables into account. The drying time or retention time may vary greatly during intensive rain periods or droughts. Rain events may also increase FS volumes delivered to the FSTP if the onsite sanitation systems were not built adequately, due to runoff or a rise in the groundwater table. The operational activities at the FSTP can then be planned to take these aspects into account. For example, macrophytes of planted drying beds can be weeded during a dry season, when there is potentially less FS to treat, and there is a shorter drying time.

The operational procedure also needs to take the FS characteristics (e.g. viscosity, amount of waste, fresh or partly stabilised sludge), and the required level of treatment into account. The information collected though the monitoring system also needs to be considered in order to improve the operational procedure and planning. For example, the frequency of sludge extraction from a settling-thickening tank or from a waste stabilisation pond can be adjusted based on the observed quantity of sludge accumulated over time.

11.4.2 Maintenance procedures

There are two main types of maintenance activities: preventative maintenance and reactive maintenance. Well-planned preventative maintenance programs can often minimise reactive interventions to emergency situations, which are frequently more costly and complex. Component breakdowns at FSTPs can result in wider system failure, or non-compliance. Therefore, each component at the FSTP has specific preventative maintenance requirements that need to be described in detail in a maintenance plan including the tasks, frequency of actions, and step-by-step procedures for accomplishing the tasks, including inspections. Physical inspections conducted at scheduled intervals are important, where operators look for specific indicators such as cracked wires, broken concrete and discolored and brittle pipes in order to identify preventative maintenance needs.

The maintenance plan should be guided by the local context, the climate, and the asset-specific monitoring information. Coastal FSTPs, for example may require more frequent painting and corrosion control due to the salt air compared to the same plant located inland. The task details include the equipment, tools and supplies needed to accomplish the task and the amount of time it should take to complete. Once completed, the task details should be entered into the equipment maintenance log book or database, along with any difficulties encountered.

Frequent maintenance tasks include:
- corrosion control – scraping rust, painting metal surfaces, and repairing corroded concrete;
- sludge and coarse solids extraction from the basins and canals;
- repacking and exercising valves (i.e. locating and maintaining fully operational valves);
- oiling and greasing mechanical equipment such as pumps, centrifuges or emptying trucks; and
- housekeeping activities including picking up of refuse and vegetation control.

11.5 ASSET MANAGEMENT

Asset management is a holistic approach to FSTP maintenance in order to maximise long-term effectiveness of the facility at the lowest possible cost. Cost items that are included in the full lifecycle costs of an asset include:
- capital cost of purchasing and installation;
- labour required for operation and maintenance;
- spare parts for repairs;
- essential consumables, such as grease or chemicals; and
- replacement costs once the component has reached the end of its useful life.

Integral to the full lifecycle costs are the stocks of tools and supplies that are required for long-term operational needs. These should ideally be available at each FSTP site (Lüthi *et al.*, 2011). If several FSTP rely on the same technology or equipment, centralised stocks can be organised.

Asset management is crucial for large FSTPs and the following aspects should be included in the maintenance plan (USEPA 2012):

- the current state of the assets;
- the required 'sustainable' level of service;
- the assets which are critical to sustained performance;
- the minimum life-cycle costs; and
- the long-term funding strategy.

Without an asset inventory, no comparison can be made on the cost of equipment or the importance of the asset. Components that are crucial for the operation of the FSTP should be highlighted, and once used, replenished immediately. In these cases it is therefore important to have a reputable provider and agreements drawn up to ensure swift service. Case Study 11.1 provides an example of a FSTP failure due to the lack of permanent employees and the pump not being listed as a key component.

Case Study 11.1: Example of treatment plant failure
(Adapted from Bassan, 2009)

A FSTP was constructed with one screening channel, two parallel settling-thickening tanks, nine unplanted drying beds and a pipe conveying the liquid fraction to the waste stabilisation ponds of the wastewater treatment plant located nearby.

In 2009, after less than 5 years of operation the FSTP was out of order for some months, despite the selection of robust technologies. This was partly due to the design process that had resulted in the selection of pumps that were not powerful enough to extract the thickened sludge from the tanks, but also due to insufficient sludge extraction by the vacuum trucks. As a result, the settling-thickening tanks were not emptied for several months, the sludge was not dried on the beds, and the waste stabilisation ponds were saturated with high loads of suspended solids. Additionally, no maintenance was carried out on the beds and the filter media, resulting in degradation of the walls and the valves. Consequently, significant resources were needed to remove the weeds and to once again ensure good treatment performance.

This situation was the result of a weak human resource (HR) strategy, a lack of precise procedures for O&M, and a rigid administrative system. There were no permanent employees at the treatment site, and daily workers were often hired without any training. This mode of recruitment does not encourage accountability which is necessary for careful maintenance, and nor does not allow for continuous operational activities. Additionally, no skilled mechanical technician was hired to repair the pump. Once this information was communicated to the head office, the required repair and maintenance work was carried out, and the FSTP was again able to operate efficiently.

This example demonstrates the extent to which the priority level given to HR operating the FSTP can influence the performance and the long-term viability. It is therefore essential to have sufficient budget in order to hire skilled and permanent employees at a FSTP. It also highlights that the operation of a FSTP requires a flexible internal management process. If the hierarchical procedure is overly time consuming and complex, repairs or improvements are not possible at short notice and may result in the deterioration of the FSTP.

11.6 MONITORING

The maintenance of a FSTP involves a detailed understanding of the treatment processes and performance requirements. This understanding should not only be based on the theoretical information concerning the treatment mechanisms and the design of the technology, but also on a monitoring procedure that requires specific planning, infrastructure (e.g. laboratory), employees, and finance. The monitoring programme should be structured in order to provide the operations employees with adequate information to continuously optimise the plant performance, and to provide control over the effluent quality. Monitoring may include a range of different methods such as:

- visual or sensory inputs: this includes visual observations of plant conditions, such as scum on a treatment lagoon, the color of the sludge, or odours emanating from a pump tank;
- analysis or measurement at source: this includes test strips or kits that can be utilised in the field for measuring pH, dissolved oxygen, or temperature; and
- laboratory testing of samples (either onsite or offsite).

Monitoring is expensive and time consuming. A written monitoring plan is essential and will assist operators in collecting and organising the data that is required, relevant, and accurate. This plan is based on the following aspects:

- why the information are required;
- what information will be obtained;
- how and when the information or samples will be collected in the field; and
- who will collect them.

11.6.1 Monitoring of physical-chemical and microbiological parameters

Planning an efficient laboratory analysis programme provides the data necessary for making operational decisions and reporting findings. The more accurate and timely the information is, the better the operational decisions that can be made. For example, the load and residence time in a waste stabilisation pond or in an anaerobic digester can be adjusted based on the results of the laboratory analysis. If the laboratory analyses reveal biochemical oxygen demand and suspended solids values above the discharge standards, the residence time in the basins can be increased, and the treatment performance improved.

The 'Chain of Custody' form is the mechanism by which the sampler at the FSTP communicates with the laboratory with regards to the samples taken and analytical tests requested. It provides a written record of field sampling conditions, special instructions, and a list of who was responsible for the samples at all times. Specific information includes:

- sample identification;
- data related to the site conditions at the time of sampling;
- instructions to the laboratory as to which analytical tests to perform on each sample; and
- the date, time and signature of each person that maintains custody of the sample.

The parameters that are most often analysed include (HPCIDBC, 2011):

- the solid and suspended matter content: these analyses assist in the evaluation of the settling and solid/liquid separation performances (Figure 11.4);
- the moisture content of the endproducts: this parameter provides an estimation of the drying performances;
- the biological and chemical oxygen demand in the liquid fraction: these parameters monitor the available oxygen which has a direct impact on aquatic life;
- the nutrient content (i.e. nitrogen and phosphorus) which influences the potential for resource recovery in agriculture, as well as the risk of eutrophication of water bodies; and
- the pathogen content: this involves an evaluation of the presence and number of *E Coli*, faecal coliforms or helminthes eggs which allows control of the risks related to waterborne diseases.

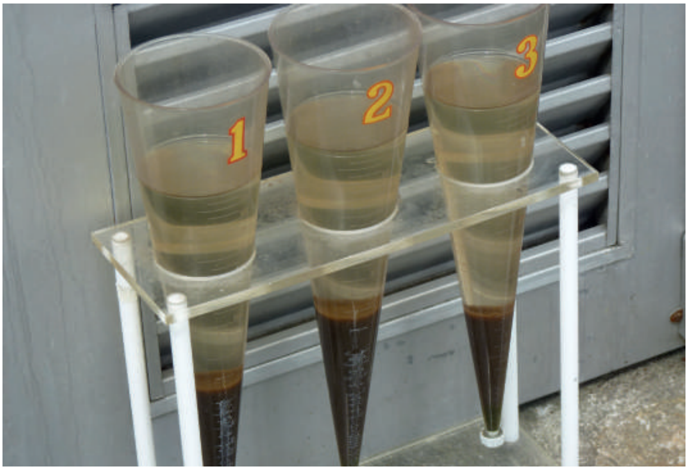

Figure 11.4 Settleability tests performed on site at the Manila Water South Septage Treatment facility in the Philippines (photo: David M. Robbins).

These monitoring parameters can be adjusted depending on the technologies used, on the local effluent discharge standards, and on the enduse objectives (see Chapters 2 and 10). For example, assessment of the pathogen content may not be necessary if the endproducts are to be used as a fuel in a cement kiln, but pH may be a very important factor for loading an anaerobic digester.

Laboratory monitoring requires strict procedures and skilled employees, as well as significant funds to operate and maintain the analytical equipment and infrastructure, and to purchase the required consumables. A specific laboratory budget is therefore required. Some technologies involve more complex laboratory monitoring to ensure an efficient process (e.g. composting, activated sludge, lime treatment), while others only require laboratory analyses to evaluate the treatment performances. Laboratories also require quality assurance and quality control (QA and QC) procedures.

Where specific analyses are required, external laboratories can be contracted to undertake these procedures. Contract laboratories are an important source of information and support to FSTPs operation. If external laboratories are to be used for the monitoring programme a clear definition of sampling techniques, preservation methods for maintaining sample integrity, and procedures for sample analysis are required. FSTPs which make use of contract laboratories may request copies of the QA and/or QC plan in order to review procedures and verify that they will meet the required needs.

11.6.2 Analysis manual

If laboratory analysis is required for a specific FSTP, an analysis manual shall be provided, encompassing the following information:

- the sampling frequency, site and procedure (e.g. grab or composite), and the conditions under which these samples should be transported;
- the storage of the samples and the chemicals (e.g. the type of container, the chemicals required and the temperature);
- the analyses protocol for each parameter; this should be based on standardised methods if possible;
- QA/QC plan for sampling and any onsite analytical activities to ensure the accuracy of the analytical data;

- requirements for split or duplicate samples, or travel blanks; and
- information on the calibration and maintenance of the laboratory and onsite equipment (e.g. probe for oxygen content and pH evaluation).

11.7 RECORDKEEPING

Effective O&M programmes for FSTPs require that accurate records be kept of all O&M activities, monitoring as well of any malfunctions. Operators frequently refer to records in order to identify previous fluctuations in the operation of the facility and operational problems that may recur periodically, review the effectiveness of mitigation measures that may have been used to correct past operating problems, and to optimise the O&M procedures. These records should therefore be easily accessible to FSTP operators.

Some examples of recordkeeping that are useful for FSTPs include:
- information on the operation of the FSTP including daily operating records, the operators log book, manifest reports (an example is provided in Figure 11.5), the treatment unit operating data sheet, and other records related to FS deliveries to the plant;
- disaster response and emergency recovery records;
- preventative and corrective maintenance records including the equipment maintenance log books and store room supply reports;
- compliance reports including field and analytical data, and correspondence from regulatory officials; and
- employee records, such as employee schedules, time sheets and injury reports.

Figure 11.5 Reception reports track the total number of loads delivered, the time, date and driver's name. These records are important to maintain for all faecal sludge treatment plants (photo: David Robbins).

The type of records and the length of time for which they will be retained for a particular facility will be determined by the size of the FSTP, regulatory requirements, and the technologies that are used. Since these records are tools that can be used by employees to assist in the day to day operation of the facility, a summary of the information should be used to optimise the O&M plan, as well as in the planning of any expansion to a FSTP or in the design of new FSTPs. An explanation of some of the key recordkeeping aspects is provided in the following sections.

11.7.1 Operator's log book

The operators log book is perhaps the most important record for a FSTP. This log book provides a means of communication between operators of the plant and a written record of important events. Typical entries include the names of people on duty, weather conditions, any equipment malfunctions, operating problems, important phone messages, security information and actions taken in response to unusual circumstances. An excerpt from a typical operator's log book is provided in Case Study 11.2 from the New Jersey, US Administrative Code on Wastewater Management.

11.7.2 Reception monitoring reports

Reception monitoring reports record the amount of FS received at the plant each day, the discharge fees collected, and any issues reported by drivers or employees. Maintenance of accurate reception monitoring reports is critical as it minimises fraud and assists in guaranteeing that the collected FS was delivered to the FSTP and not discharged elsewhere.

Case Study 11.2: Excerpt from the New Jersey, US administrative code on wastewater management (operator's log book)

The results of all mechanical equipment and related accessoires inspections essential to the proper O&M of the system shall either be recorded in ink and maintained in bound inspection log books or be maintained in secured-access computer databases or files or other equivalent method of recordkeeping. The log books or computer databases, or file or equivalent shall also include:

- time, date and subject of all system inspections;
- a report of all breaks, breakdowns, problems, bypasses, pump failures, occurrences, emergencies, complaints and/or intervening factors within the system that result in or necessitate deviation from the routine O&M procedures; and any situations that have the potential to affect public health, safety, welfare, the environment or have the potential to violate any permits, regulations or laws;
- a record of the remedial or follow up action and protocol taken to correct all of the above issues; and
- the date and time of each entry, and by whom it was entered.

11.7.3 Treatment unit operation sheets

Treatment unit operation sheets are used to record the quantity of FS loaded into each treatment unit, the operational activities performed (e.g. load of FS or extraction of endproducts), the operational variable applied (e.g. mixing ratio of fresh to stabilised sludge, addition of lime), the quantity of endproducts and wastes extracted, and the consumables required. The number of employees required and the relevant skills needed to perform all the activities should also be recorded, together with any difficulties encountered and potential solutions. These sheets therefore provide historical records of the maintenance carried out on each piece of equipment, the failures experienced and the solutions implemented, together with the budget and HR involved. Distinction should be made between preventative and reactive maintenance, and recommendations for optimising the planning process made.

11.7.4 Interpretation and communication of technical data

The data collected in the laboratory and from onsite monitoring (i.e. log books, reports and operation sheets) are used in conjunction with one another in order to optimise treatment performances through the adjustment of O&M procedures. For example, the volumetric load of FS on planted drying beds can be adjusted through a comparison of the laboratory results and with observations on the pollution load and residence time (Koottatep *et al.*, 2005). The optimal operating conditions can then be identified, and the treatment performances improved.

All information collected through the monitoring program and recordkeeping should be analysed, and reports prepared for internal communication. An effective communication system is crucial for the optimisation of the administrative and operational management procedures, and also ensures that all the employees have comprehensive information on the operation of the FSTP. This communication system should therefore also define the frequency of delivering reports and the decision making process that is to be followed.

To ensure that the monitoring data and reports are used, that the correct conclusions are made, and that follow up action is taken, the laboratory analysis reports should be made available to the operating employees, and the operational reports made available to the management. In order that the significance of the laboratory results are understood, both the laboratory technician and the FSTP operating employees need to be suitably trained. If the laboratory analysis data provides results which lie outside of the expected range, the laboratory technician and operating employees need to meet to discuss the necessary adjustments to the operational activities. All data recorded in the O&M monitoring sheets and in the laboratory analysis reports is then captured in a summary report or in a database which provides an overview of the FSTP performance and difficulties over the previous months and years. For example, it is important to know how often a pump fails over a period of one year in order to adjust the maintenance planning programme, and whether to install a better prescreening process or an improved pumping unit. O&M activities are also affected by the seasons and need to be considered in the O&M plan in order to optimise the operational activities under these different conditions.

11.8 PLANT SECURITY AND SAFETY

FSTPs are critical infrastructures and must therefore be secured from unauthorised entry and vandalism by fencing off of facilities and engaging security employees. Managers of FSTPs can also create a culture of security by enacting the following guidelines:

- including security as a topic in employees meetings and discussions;
- appointing a Plant Security Officer or assigning the duties to a responsible employees member;
- enforcing security policies and procedures consistently and equitably; and
- providing security training for all employees.

11.8.1 Health and safety

There are many health and safety hazards associated with the typical tasks required to operate and maintain FSTPs. Health and Safety aspects should therefore form an integral part of the O&M plan but are quite often not given adequate attention.

Figure 11.6 Safety posters and signs are good reminders to follow proper procedures (photo: David M. Robbins).

The "Health and Safety Plan" specifies the procedures, practices and equipment that should be used by employees in order to conduct activities in a safe manner. Health and safety plans are prepared specific to each FSTP but also contain aspects that are common to all FSTPs. Health and safety procedures are strictly enforced by management through the preparation of the safety plan, and also through posters and signs located in areas of risks (e.g. ponds and tanks, electrical device, confined spaces). An example of a safety notice is provided in Figure 11.6. Based on the authors' experience, the following topics should be included in the health and safety plans:

- personal protective equipment (PPE) and safety measures for O&M activities;
- infection control and hygiene measures;
- emergency contact procedures;
- protection against falling and drowning hazards;
- confined space entry protection; and
- electrical safety and the use of the '*Lock-Out Tag-Out*' procedure.

Further details and recommendations can be found on the Occupational Safety and Health Administration (OSHA) website (http://www.osha.gov/), and the following sections explain each of these aspects in more detail.

11.8.2 Personal protective equipment

Personal protective equipment (PPE) is equipment worn in order to minimise exposure to hazardous conditions, and includes:

- hard hats to provide head protection from falling items;
- eye protection such as safety glasses, goggles or face shields to protect against chemical or dust exposure;
- gloves for hand protection from chemicals or abrasion, made from rubber latex or other materials dependent upon the specific hazard;

- breathing safety devices such as respirators, dust masks or self-contained breathing apparatus (SCBA), should certain tasks require them;
- other protective clothing including foot protection, and coveralls; and
- other equipment required for task specific safety.

While the health and safety plan specifies the PPE required for each task, it is the management's responsibility to ensure that appropriate PPE is provided, that employees receives training in the proper use of PPE, and that employees are complying with the requirements regarding PPE usage.

Clear safety procedures are also required for all O&M and monitoring activities at the FSTP, including the receiving and movement of trucks; the discharge of FS, the O&M of equipment, the use, storage and disposal of chemicals, the sampling of various processes and the processing and removal of endproducts. For example, safety requirements for the receiving of trucks and FS discharge include the use of chocking wheels during off-loading or when trucks are parked, wearing personal protective clothing, and the prohibition of smoking.

11.8.3 Infection control

FS, by its nature is infectious material. It often carries disease-causing bacteria, viruses or other pathogens. Workers should have proper immunisations (e.g. hepatitis A, tetanus), and follow hygienic procedures at all times when handling equipment that might have come into contact with fecal materials. Showers and areas to wash hands should be available for workers, as well as a locker room where workers can store clothes. Infection control procedures include:
- use of appropriate PPE to protect skin from contact with faecal material;
- washing hands prior to eating or after coming in contact with faecal material;
- no eating or drinking in areas where FS or chemicals are stored or processed;
- reporting illness to plant supervisors immediately; and
- prohibition against smoking, an activity that can transmit pathogens via the fecal oral route of entry.

11.8.4 Emergency contact procedures

Emergency contact procedures provide current telephone numbers and contact information that can be used by employees in the case of an emergency. The contact list should be posted in a common area that is accessible to all employees and which has access to an operational telephone. For all FSTPs, but especially those in remote areas, first aid materials, supplies and equipment must be provided. A typical emergency procedure consists of the following actions:
- contacting the appropriate emergency personnel;
- depending on the situation (e.g. explosion, fire or chemical spill), evacuating the employees;
- contacting the plant manager if not already on site; and
- providing support to affected personnel until emergency personnel arrive and take control of the emergency situation.

Emergencies must be documented on an emergency report form that is then sent to management for investigation. All emergencies must also be fully detailed in the operators log book.

11.8.5 Protection against falling and drowning hazards

FSTPs that utilise lagoons or waste stabilisation ponds, or even large reactor tanks need to have a drowning prevention programme in place that provides safety equipment, signage and training. Plants with large lagoon cells often have boats from which O&M tasks are accomplished. In these situations, workers must make use of floatation devices, work in pairs, and be trained in proper procedures to minimise the hazard of drowning. At all FSTPs, measures should be taken to avoid slip hazards such as preventing the spilling of FS, as well as ensuring that manholes are closed in order to avoid falls.

11.8.6 Confined spaces

A confined space is defined as any place in a FSTP that is enclosed and has limited access, such as tanks and dry wells. They are potentially hazardous as the breathable atmosphere may become compromised, either by a depletion of oxygen or the presence of chemical gasses, such as chlorine or hydrogen sulphide. In order to prevent confined space accidents, a "Confined Space Entry Permit" programme is utilised at FSTPs.

The first step in this programme is for senior management to identify all confined spaces in the plant. When maintenance is required inside these areas, certain procedures can be defined in order to protect the worker. These typically include the following:

- a confined space entry permit is prepared by the worker and signed by the supervisor;
- prior to entry, the atmosphere is tested with an oxygen meter or, in the case of manholes, with a hydrogen sulphide meter; and
- the work is conducted using the buddy system, with one person entering the confined space secured with a harness attached to a safety rope, and one person located outside of the confined space ready to provide assistance if needed. When the work is completed, the permit is returned to the supervisor for signature indicating the completion of the task.

11.8.7 Electrical safety

FSTPs with electrical equipment must enact specific procedures to keep workers safe when performing O&M activities on powered devices. An example of such a safety procedure is the *Lock-out Tag-out* procedure which ensures that the breaker to the power source for the equipment that is to be repaired is turned off and locked in the off position. A tag which specifies the work to be carried out, the person doing the work, and the date and time the work will be conducted, is attached to the locked out breaker. This tag must be signed by the plant or shift supervisor and the electrician doing the work. When the task is completed, the tag is removed by the supervisor and electrician, and the lock removed. Only then can the equipment be powered up.

11.9 ADMINISTRATIVE MANAGEMENT

Effective management of a FSTP requires a well-defined management strategy specific to each FSTP. If not incorporated in the management strategy, aspects such as employees coordination, planning, supervision, and capacity strengthening, it can result in reduced treatment performances. This can be due to poor operational skills of the employees, misunderstanding of the technical priorities by the administrative employees, poor communication, or poor financial management (see Case Study 11.1). The procedures for the O&M, and monitoring of the plant, as well as the communication requirements should be strategically defined by the decision makers, and tie up with the financial and HR of the company. These aspects are described in more detail in the following sections.

11.9.1 Financial procedures

It is recommended that financial procedures are defined based on operational needs. Therefore, the operating costs should be monitored, and the budget adjusted based on the actual expenses. The various types of costs that can be incurred are discussed in Chapter 13. Special provision and administrative mechanisms should be in place in case of breakdown of equipment that is crucial for the operation of the FSTP, as well as for the replacement of old equipment. The procedures for the acquisition of tools, other stock items, and safety equipment must be rapid, and special funds should be available for small repair work in order to ensure continuous operation (e.g. repairs to a screening grid or a valve). For example, if a valve or a pump is broken, the funds need to be available immediately for the repair, not after three or six months of budget approval process.

11.9.2 Human resource management

HR management refers to the way in which employees are managed and trained, including the definition of job descriptions, chain of authority, and policies and procedures for work place activities.

While HR management can be considered as a key aspect for the successful operation of any treatment plant, very often, no financial mechanisms are defined in order to ensure that sufficient and appropriate HR is available to operate the FSTP. HR requirements can be defined based on the specifications of the design consultants, and the operational requirements observed during the startup period. In some cases, where O&M activities may involve very specific skills or resources (e.g. mechanical skills to repair centrifuge or vacuum trucks) which are not available in-house, external services can be hired. Specific provisions are then needed to ensure that the required level of service is provided (see Case Study 11.3).In this case, the service and frequency must be well defined to allow continuous operation of the FSTP.

Case Study 11.3: Outsourcing of maintenance services for treatment plants

The National Operator for Water and Sanitation in Morocco (ONEP) has the responsibility for managing the operation of several wastewater treatment plants countrywide. Due to the wide territory covered, ONEP cannot afford the equipment and employees for specific maintenance activities for all the treatment plants (e.g. mechanical repair of pumps). Private companies are therefore hired on a 5 year contract basis to provide maintenance of the treatment equipment. Each company covers one region, answers to quality standards defined by ONEP, and the employees is trained at the ONEP training center. This type of organisational structure results in optimisation of the equipment and operational costs as well as ensuring a maintenance plan for the treatment plants

Such dependency on external services must be well managed. Long-term collaboration should be encouraged, and quality standards well defined. If this external service includes the maintenance of key equipment, and cannot be planned precisely, the service must be available at short notice at any treatment site.

Irrespective of the size of the FSTP, employees should have defined roles and responsibilities in order to ensure complete understanding of specific job requirements. HR aspects of FSTPs therefore include:
- description of the lines of communication indicating who the employee reports to;
- outline of the level of authority required for making operational decisions; and
- appropriate and ongoing training to ensure that employees can carry out their responsibilities.

11.9.3 Staffing, roles and responsibilities

FSTPs can have a broad range of staffing requirements depending on the size of the plant, the treatment volume and the required level of skill.

An organisational chart that clearly specifies the roles and responsibilities of each employees member, as well as the lines of communications is a useful management and training tool which should be defined during the design and planning phase. Employees are recruited through HR management systems as described above, complete with job descriptions for each employee classification.

Smaller FSTPs may combine various job titles such as plant superintendent, safety officer, and maintenance technician into one job description. The following sections outline the key employees requirements and the respective responsibilities which are crucial for the long-term operation of FSTPs.

Plant superintendent

The FSTP superintendent forms part of the management team and is responsible for the day to day management of the FSTP. The superintendent defines the goals, objectives, policies and priorities, concerning the O&M, and is responsible for:

- all paperwork and correspondence, grounds and equipment maintenance, and supervision of personnel;
- participating in the development and implementation of goals, objectives, policies, and priorities;
- coordinating the organisation, staffing, and operational activities including assuming responsibility for critical decisions regarding operational changes, process control, maintenance priorities, scheduling, and compliance;
- identifying opportunities for improving O&M, monitoring and safety methods and procedures;
- directing, coordinating, and reviewing the work plan for O&M functions;
- directing the testing of various treatment phases, interpreting tests to determine necessary changes in treatment parameters;
- directing the adjustment and repair of equipment such as pumps, chlorinators, metering devices, electrical control panels, and treated or digested sludge dewatering;
- serving as a team member on construction project teams with construction management companies and contractors;
- selecting, training, motivating, and evaluating assigned personnel;
- overseeing safety programs for assigned sections and work groups and assisting with action planning for safety programs; and
- participating in the development and administration of assigned programme budget.

Figure 11. 7 Sludge removal from drying beds at the Bugolobi Treatment Plant in Kampala, Uganda (photo: Linda Strande).

Plant engineer

The FSTP engineer serves as the chief technical employees member. Typical roles and responsibilities include:

- ensuring the overall efficiency of the plant and optimisation of the treatment process;
- controlling operating expenses;
- organising and coordinating the work carried out by subordinate teams (e.g. sludge removal from drying beds as shown in Figure 11.7);
- recommending technical solutions to problems that may be encountered;
- contributing to the monitoring and reporting on the performance of equipment and processes; and
- managing technical subcontractors and suppliers.

Plant operator

The FSTP operator is responsible for carrying out the day-to-day technical aspects of plant operations in order to ensure that equipment is operating properly and in compliance with all requirements. Typical duties include:

- performing equipment inspections, monitoring operations, and collecting samples in order to verify system performance in collaboration with laboratory employees;
- operating trucks, pumps, blowers, generators, compressors, and other machinery/equipment;
- testing, calibrating, repairing, and operating control and instrumentation systems under general supervision;
- keeping records of operational activities, degradations and failures;
- preparing field and office reports summarising the records and providing recommendations for optimising the system; and
- assisting in site environmental investigations, field surveys, and cleanups as required.

Plant maintenance technician

The FSTP maintenance technician performs routine and emergency maintenance and repairs on plant facilities, pumps, engines, motors, filters, bar screens, valves, pipes, and other equipment at the FSTP. Typical responsibilities include:

- checking, adjusting and maintaining mechanical equipment including greasing of moving parts, changing oil, and performing other routine maintenance activities;
- maintaining buildings, roads and grounds;
- performing janitorial work;
- replacing worn parts and performing routine and emergency service and repairs including replacing motors, bearings, flanges, seals and other equipment components;
- inspecting mechanical and hydraulic equipment being installed under contracts to ensure compliance with contract requirements;
- monitoring facilities and equipment in order to identify and repair leaks or other malfunctions; and
- keeping records through the logging of maintenance activities and repairs, and preparing reports summarising the main activities, malfunctions and recommendations.

11.10 COORDINATION

Communication should be encouraged between the O&M and monitoring employees of different FSTPs in the same jurisdiction, as well as with the decision makers. An effective vertical communication ensures that the administrative employees understands the constraints and needs of the O&M employees, and results in rapid acquisition of parts or repairs in order to ensure continuous operation of the FSTP. Horizontal communication between the different FSTPs allows the exchange of experiences and therefore assists in the optimisation of the procedures. Frequent (weekly or monthly) meetings should be held in order to facilitate discussions between the operating, monitoring and administrative employees on the difficulties experienced and possible solutions. If the operating company is in charge of several FSTPs, one person can be designated to ensure quality control and harmonisation of the O&M procedures over all the facilities. This would result in the adjustment of procedures and guidelines based on experiences, the standardisation of these for all similar FSTPs, and would ensure the uniform implementation of safety rules and O&M procedures.

11.11 STARTUP PERIOD

For newly built FSTPs, a transition period is necessary at the beginning of operation in order to evaluate the preliminary procedures. This allows definition of the frequency, safety measures and communication lines for the operation, maintenance and monitoring activities. During this startup period, there should be frequent communication between the operating and administrative employees in order to discuss any problems. The final procedures and documents (i.e. operation manual, information sheets, monitoring sheets, logbooks etc.) will be prepared based on the information collected during this startup period.

For some treatment technologies, the startup period may involve specific procedures. For example, biogas digesters need to be started up slowly to allow for the development of the appropriate anaerobic microorganism community, and planted drying beds need to be progressively loaded to allow the acclimatisation of plants. Even though the infrastructure and equipment may be operational within a relatively short time period (e.g. unplanted drying beds, settling-thickening tanks), the following operational aspects should be assessed and optimised during the startup period:

- quantities of FS discharged in the FSTP;
- truck circulation in and around the FSTP;
- removal frequency, and quantities of screened wastes;
- loading of the treatment unit(s);
- organisation of the activities required for the treatment process (e.g. turning the heaps in co-composting plants or in solar sludge driers);
- removal frequency, and quantity of the endproducts from the treatment unit(s);
- time and conditions required for efficient stabilisation and pathogen removal depending on the enduse goals;
- frequency and type of routine maintenance activities; and
- frequency and interpretation of the monitoring analysis and observations.

The time required for the startup period may differ depending on the technology used. For example, the acclimatisation of macrophytes on planted drying beds or lagoons (Figure 11.8) may require between 3 and 6 months until the nominal treatment efficiency is reached. For some technologies, it is also important to plan the startup period given the seasonal climatic variations, as these influence the operational activities and performance. For example, the time needed for FS to dry at the surface of unplanted drying beds may differ greatly during dry and rainy seasons in arid climates. The quantities of FS produced may also vary based on the rainfall patterns. Therefore, an assessment of the ideal loads and retention times during dry and rainy seasons, or warm and cold seasons is useful, and it is recommended that the startup period covers at least two seasons.

To ensure a successful startup period, the entire employees should be trained in order that they understand all the necessary procedures before the commissioning of the FSTP. Therefore, site visits to similar treatment plants should be organised, and basic information on the treatment mechanisms provided. During the startup period, the operator may need technical and managerial assistance from experts in the field.

Figure 11.8 Starting up period of faecal sludge lagoon system, San Fernando City, Philippines. In this case, lagoon basins were seeded with activated sludge from a nearby wastewater treatment plant (photo: David M. Robbins).

The operating hours of the FSTP and the procedures for FS discharge (e.g.. FS characteristics and discharge fees) should be monitored over several months and discussed with the collection and transport stakeholders. Similarly, the treatment efficiency of the plant, and the quantity and quality of endproducts needs to be assessed, and the enduse or disposal procedures defined and agreed upon with the relevant stakeholders.

At the end of the startup period, all the administrative, operational, maintenance, monitoring and communication procedures should be defined and well understood by the entire employees. Final versions of tools such the O&M plans and manuals, laboratory reports, monitoring sheets, and health and safety plans should be developed validated and enforced.

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End of Chapter Study Questions

1. What are important operations and maintenance factors that should be taken into consideration when planning FS treatment plants, and why are they important?
2. List three site-specific factors that could have an impact on the operation and maintenance of FSTPs.
3. Give four examples of types of records that need to be collected in the operation and of FSTPs.
4. Explain why monitoring is critical in the ongoing operation of FSTPs.