Manual for Sludge Management in Bangladesh Textile Sector

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Foreword

This manual is intended to be a practical instruction and information guide for the Management of Wastewater treatment plants in Textile Industry, primarily the Effluent treatment plant (ETP) managers.

It is a compilation of relevant information adapted from the Bangladesh Standards and Guidelines for Sludge Management published in 2015 by Department of Environment, Ministry of Environment and Forests, Government of Bangladesh. Any information provided herein is for explanatory/illustration purpose only and is not intended to supersede any provisos in the said standard.

It is hoped that this manual shall enable the ETP managers to evaluate the type of sludge from their own ETP through simpler measures and help them to make every effort to reduce the pollutant concentration in the sludge to prevent it from getting categorized as more hazardous in nature. It is expected that this manual will also motivate them to find out disposal/reuse options of sludge without any adverse environmental impact.

Readers are encouraged to obtain more information in this regard by obtaining copies of the DoE Standards and Guidelines published in English and/or Bangla and they can also attend the different ETP/Wastewater training courses.

Abbreviation

BAT	Best Available Technologies
CETP	Common/Central Effluent Treatment Plant
DoE	Department of Environment
ETP	Effluent Treatment Plant
GIZ	Gesellschaft für Internationale Zusammenarbeit, (German International Co-operation)
GoB	Government of Bangladesh
I-TEQ	International-Toxicity Equivalent
MoEF	Ministry of Environment & Forests
SOP	Standard Operating Procedure
PCDD	Polychlorinated dibenzodioxins
PCDF	Polychlorinated dibenzofurans
PSES	Promotion of Social and Environmental Standards in the Industry
SOP	Standard Operating Procedure
TOC	Total Organic Carbon
USEPA	United States Environmental Protection Agency
WDF	Washing/Dyeing/Finishing

Contents

1. Introduction

This manual summarises a practical application of 'Bangladesh Standards and Guidelines for Sludge Management', particularly for the sludge generated from Textile wastewater/effluent treatment plants (ETPs). The purpose is to provide an overview of the sludge management through categorization of sludge, sampling of sludge to test certain parameters and identifying options for disposal.

What is Sludge?

Sludge is the residual, semi-solid material left/generated from industrial and municipal wastewater treatment processes.

Current Practices of Sludge Disposal in Bangladesh

The current practice of sludge disposal in Bangladesh is not very organized and environmentally sound. Commonly, the sludge generated is stored onsite for a certain period and then dumped into the adjacent low lands. When these piles of dumped sludge come in contact with rain or flood water, substances in the sludge may leach into soil and water. The efforts of reducing the adverse environmental impacts of wastewater through proper treatment will be in vain if/when concentrated pollutants in the sludge eventually get released into the environment. The producer of the sludge is responsible for the proper handling and management of this concentrated waste as part of the overall solid waste management.

Why the focus on Sludge Management?

With increasing production volumes of textile washing/dyeing/finishing (WDF) and the growing number of treatment plants, the volume of sludge from industrial waste treatment plants also increases. The main priority of sludge management in Bangladesh is to ensure that the environment and its inhabitants are fully protected from any negative impacts of the sludge.

The factories which run their ETP continuously or intending to run it continuously in compliance with the national wastewater discharge standards, need to address the challenges of sludge handling and disposal as part of their end-of-pipe waste management efforts. The type and concentration of the constituents present in the sludge will determine which disposal option will be appropriate to the factory. Efficient sludge management implies proper and systematic planning, proper sampling from appropriate location and transport, analysis and implementation of suitable disposal measures based on the test results.

Standards and Guidelines for Sludge Management in Bangladesh

According to the Bangladesh Environment Conservation Act, 1995 (Amendment 2010) proper management of sludge is mandatory. In order to further detail the requirements in this regard, the Department of Environment (DOE), Ministry of Environment and Forests, with the technical support from the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH prepared and published 'Bangladesh Standards and Guidelines for Sludge Management' in February 2015.' These guideline outlines, (i) General requirements for classification and management, (ii) Classification of sludge, and (iii) Sludge management options.

2. Understanding the basics of sludge management

What are the categories of Sludge?

Sludge can be classified based on its origin and compositions. According to the Bangladesh Standards and Guidelines for Sludge Management, sludge is classified into three categories:

Category A	*Municipal sludge including comparable sludge*	Sludge produced in a sewage treatment plant treating only domestic or urban wastewater or comparable to that
Category B	*Sludge from industry including sludge from CETP*	Neither *Category A* nor *Category C*
Category C	*Sludge from industry including sludge from CETP belonging to the category of hazardous waste*.	Sludge or the wastewater generated from any hazardous labelled industry or contain any chemical recognized as hazardous. These sludges exhibit one or more hazardous characteristics such as high flammability, explosive property, oxidizing property, toxicity, infectious etc.

Sludge under *Category A* is generally considered to be safer compared to *Category B*, and the sludge under *Category C* is considered to be the most hazardous. In case of a sludge mixture containing more than one category of sludge, the combined sludge category is generally considered to be the next level of hazardous category (*e.g.* for a mixture of *Categories A* and *B*, the combined sludge is considered to be of *Category B*)

Where the Textile industry does falls in Sludge Guideline?

The textile wet processing industry uses a wide variety of chemical products. The pre-treatment processes (desizing, scouring, bleaching etc.) of fabrics and yarns uses detergent and other surface active agents such as antifoaming, demineralizing agents as well as halogenated solvents (usually tetrachloroethylene). Including acid and alkali (for pH adjustment) and other finishing chemicals to impart water repellency, fire retardancy, durable press or insect repellency may leave residues which will eventually end up in the waste stream.

Bangladesh Standards and Guidelines for sludge management shown in Table 1 (from Annex 2B) for textile industry allows to determine whether the sludge is hazardous or not according by looking at the waste generating process.

04 Wastes from the leather, fur and textile industries

04 02 wastes from the textile industry

Table 1 - Different wastes from textile industries according to European waste category

04 02	wastes from the textile industry	Hazardous
04 02 09	wastes from composite materials (impregnated textile, elastomer, plastomer)	
04 02 10	organic matter from natural products (for example grease, wax)	
04 02 14*	wastes from finishing containing organic solvents	x
04 02 15	wastes from finishing other than those mentioned in 04 02 14	
04 02 16*	dyestuffs and pigments containing dangerous substances	x
04 02 17	dyestuffs and pigments other than those mentioned in 04 02 16	
04 02 19*	sludges from on-site effluent treatment containing dangerous substances	x
04 02 20	sludges from on-site effluent treatment other than those mentioned in 04 02 19	
04 02 21	wastes from unprocessed textile fibres	
04 02 22	wastes from processed textile fibres	
04 02 99	wastes not otherwise specified	

In the lists 04 02 14, 04 02 16 and 04 02 19 are marked as hazardous. However, if these wastes do not include organic solvents they should be classified as non-hazardous under 04 02 15. Solvent containing wastes should be considered under H3B; H4 to H7 (carcinogenic at $\geq$ 1%) and H10, and additionally under H8 and H11 if acid, alkali or heavy metal contamination is present. Dyestuffs and pigments, and sludges from effluent treatment, can contain a range of organic and inorganic substances, including heavy metals. These wastes should be considered under H3B; H4 to H8 and H10 to H12. The code of hazardous characteristics is given in Table 2.

Table 2 Hazardous code and associated characteristics

Code	List of Hazardous Characteristics
H1	Explosive
H3	Flammable liquids
H4	Flammable Solids
H5	Oxidising/Organic peroxide
H6	Poisonous (acute)/Infectious substances
H7	Carcinogenic
H8	Corrosive
H10	Liberation of toxic gases in contact with air and water
H11	Toxic (delayed or chronic)
H12	Ecotoxic

Types and quantities of sludge generated in an ETP

Textile manufacturing industry particularly those requiring large amounts of water as input for production processes and subsequently generates wastewater need to be treated in the plants' own individual ETP or a common effluent treatment plant (CETP).

In a study by GIZ[1] it was found that 60% of the ETPs are of physico-chemical nature in Bangladesh. The capacity of the ETPs varied from 5 - 350 m^3/hr and with an average capacity of 50 m^3/hr. It was estimated that in 2007, the total amount of sludge from textile sector generated was 113,720 tons/year which was projected to rise up to 2.81 million tons/year in 2012[2]. It was calculated that 1 m^3 effluent generated approximately 1.14 Kg dry sludge in 2007.

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[1] W.A. Schimpf, Testing Co-Incineration of Textile Sludge in Bangladesh, GIZ, 2014

[2] DoE, Waste Concern and ADB 2008

3. How to treat the sludge

The following steps describe how to proceed with the sludge once it has been generated in the effluent treatment plant

Step 1 - Sludge pre-treatment

Sludge pre-treatment are measures to make handling and further utilization of the sludge easier. There are multiple options for each of the stages and selection of these processes depends on the cost and suitability of the initial sludge. Pre-treatment mainly includes

- Sludge thickening and/or conditioning to reduce the volume of sludge – this can be done physically and/or chemically in a sludge thickener tank.
- Dewatering the sludge to reduce the water content- this can be done in a sludge drying bed or by various types of mechanical means for example vacuum filters, filter press, or centrifuge.

Step 2 - Evaluation of the physical properties of sludge

Depending on the pre-treatment measure applied, the physical properties of the sludge can vary, for example, appearing like thick slurry or solid cake. Figure 1 shows sludge produced from ETPs of different textile industries.

Figure 1 Semi-dry sludge from different ETPs of textile industries.

Even dewatered sludge produced from the ETP normally contains high amount of moisture, which is very difficult to handle and transport. When sludge is kept under shade/cover, it loses moisture over time and become dry. Figure 2 shows the differences between the fresh dewatered and older sludge (kept for ~ 3 months or longer).

Figure 2 Views of fresh and older sludge

It is therefore recommended to store the sludge under a shade for sufficient time before disposal. The present stipulation is to keep it for a minimum period of six months to ensure maximum drying and stabilisation before disposal. Sludge does not dry at the same rate during the different seasons in Bangladesh, so it is difficult to predict an optimum storage time suitable for all seasons. Also, it is better to limit the storage for some disposal/reuse options. Accordingly, it is recommended that sludge should be stored onsite for at least 3 months but not more than 6 months before being disposed of, except when the disposal options could be such that sludges less than 3 months old would be needed, for example, production of biogas would require slurry of sludge. Accordingly, space for storage of such quantities should be made available.

Step 3 - Evaluation of the chemical properties of sludge

As mentioned before, the sludge category needs to be determined in order to decide on the possible disposal options. Only *Category A* sludge is permitted for land deposition. All other categories of sludge need to be properly disposed or recycled in other way.

To decide whether the sludge generated follows under *Category B* or *C*, the composition of the sludge should be analysed as per the criteria specified in Bangladesh Standards and Guidelines for Sludge Management 2015.

Textile Industry in Bangladesh is predominantly cotton based textile wet processing which usually do not use organic solvents like halogenated solvents (e.g. perchloroethylene) mainly used in wool scouring, therefore option for 04 02 14 is generally not applicable. However, since dyestuffs and pigment may contain heavy metals, which eventually will go into sludge, therefore most common waste category for textile industry could be 04 02 16 and 04 02 19 within the threshold limit.

Therefore, analysis of the detailed chemical properties of the sludge will determine the waste category and will assist in identifying suitability of certain sludge for any specific disposal option. The analysis should be done through proper sampling and laboratory tests. It is recommended that the testing should be done quarterly as in line with DoE wastewater testing existing guideline. This could go for first 2 years to establish the nature of sludge generated by any particular factory and accordingly, associated trends of sludge production. Sludge testing, then can be continued bi-annually.

Step 4 - Selecting Sludge disposal options

Industrial sludge usually comes under *Category B* or *Category C*. The sludge contains different inorganic compounds and heavy metals, and other compounds which have been added during the production process or have been generated as part of the production process and reactions. Direct land disposal of this categories of sludge is not permitted as per guideline.

4. Overview of common disposal options

The commonly available disposal/reuse options for sludge has been discussed here. It should be explicitly understood that some of the options discussed here such as Agricultural use or land application is not applicable for sludge from textile ETPs and is included here for information only.

Agricultural use

The main purpose of using sludge in agriculture is to utilize nutrients such as phosphorus and nitrogen and organic substances in the sludge for soil improvement. However, the sludge must meet the criteria to be suitable for this application, as mentioned in Table 3. There is also a limit of the total amount of sludge that can be applied on specific land area for a given period of time. At present, the Bangladesh standards and guideline for sludge management (adopted from German Sewage Sludge Ordinance) suggests less than 3 ton dry substance sewage sludge (similar to *Category A*) or less than 10 ton compost per hector land area in 3 years [1].

Table 3 - Parameter limits of sludge for use as compost/fertilizer[2]

Parameter	in sludge mg/kg dry substance	in soil* mg/kg dry substance
Pb (Lead)	900	100
Cd (Cadmium)	10	1.5
Cr (Chromium)	900	100
Cu (Copper)	800	60
Ni (Nickel)	200	50
Hg (Mercury)	8	1
Zn (Zinc)	2500	200

Composting

Composting is another option that aims at biologically stabilizing sludges while controlling pollution risks and exploiting the nutrient or organic value of sludges as fertilizer. To obtain a suitable compost, carbon-rich material is required, with an optimized Carbon:Nitrogen (C:N) ratio between 25:1 to 30:1. Since all sludge may not have such kind of C:N ratio co-composting material such as green waste, sawdust, woodchip, rice and straw may need to be added.

Experience in India with non-hazardous ETP sludge indicated that windrow type aerobic composting of sludge with green biomass could produce compost with nutrient value comparable to farm yard manure in about 80-110 days. While large (common) compost units used artificial aeration system, the smaller units adopted composting in heaps with manual turning over (whenever the heap temperature started falling down) with satisfactory results.

The moisture level of 60 – 65% was essential to aid effective composting. The temperature of the heap rises to above 700°C within the first 10 to 20 days which also ensures complete destruction of pathogens. Thereafter temperature would remain >40°C, which gradually falls to reach the ambient temperature, when the composting process is completed.

Figure 3 Compost heaps of sludge with admixtures in India

Composting is not permitted for hazardous waste

(*Category B* or *C*). It is only permitted for non-hazardous waste from *Category A*.

Production of Biogas

The term biogas typically refers to gas produced during anaerobic digestion of waste making its harmful components less hazardous. During the anaerobic digestion process microorganisms break down biodegradable material in the absence of oxygen. Moisture content and the total organic content are two very important factors for biogas generation.

One of the advantages of this method is that industries can utilize high-moisture containing sludge and therefore may not need to store sludge in their premises for several months as recommended.

Biogas generated might need stripping of H_2S content (commonly done through adsorption in Iron based media). The gas could be used for power generation or can be used directly in boilers.

The organic residues after the biogas generation should be as low as possible to prevent uncontrolled biodegradation leading to emissions and leachate.

Figure 4 A sludge digester in Massachusetts, USA[3]

Anaerobic digestion is not permissible for *Category C* sludge from hazardous industries and/or CETP in view of high risk of toxic

[3] http://blog.mass.gov/energy/green-business/anaerobic-digestion-turning-waste-into-renewable-energy/

emissions that may be harmful to human health and the environment.

Brick manufacturing and in Construction

The use of sludge in construction industry can contribute to the sustainability of limited natural resources and hence this is also environment friendly. The application of sludge in construction industry, mostly in the production of bricks, and to some extent in the ceramic and glass production has been explored and suggested by various researchers.

- Sludge can be used in a mixture of clay for brick production to discourage the brick industries from using topsoil. For several years this method is being promoted in countries such as India, China, Taiwan, and Egypt.
- Sludge from physico-chemical ETPs is more suitable for such application than the same from biological ETPs due to the lower organic content.
- Sludge with decent heating/calorific value (8-10MJ/kg) and with lower moisture content (30 to 40% of sludge) should consume less energy during brick making process.

Since some heavy metals might remain inside the brick, leachate study should determine the optimum level of sludge mixing.

<u>Emission levels from the brick kiln must comply with the national air quality standard.</u>

Land application

Land application refers to a wide variety of uses such as filling material for flood prevention, material/ substrate for re-cultivation of mining sites or covering landfill sites. <u>Land application does not include agricultural use.</u>

It can be assumed that sludge suitable for agricultural use is also suitable for land application. But when large amounts of sludge is used, nutrient contents must be taken into consideration for minimizing impact of leaching. For any specific land application of sludge, prior permission has to be obtained from the Soil Resource Development Institute (SRDI) and the Department of Environment (DOE).

Incineration

Incineration of sludge can reduce the sludge volume and potentially produce energy depending on the calorific value of the sludge. However, conventional incineration process generally consumes more energy than it produces, mainly because of high moisture content and lower calorific value of the sludge. If there is no recycling option available, incineration could be considered and it is being practiced in different countries such as India and China to reduce the waste volume. There are several gaseous and particulate pollutants that emit from the exhaust of the incineration system. Besides furans, dioxins and a number of other flue gas components about 5 to 10 % of the total chromium is converted from chromium (Cr^{+3}) to the carcinogenic chromium (Cr^{+6}). Some of these can have severe impact on the human health and the environment. To address the pollution problem, installation of expensive pollutant filters are highly recommended. Scrubbers can be used to capture significant fraction of the pollutants from the exhaust gas. In case of sulphur containing waste incineration, for example, sludge generated from Washing industry using sulphur dyes, Flue Gas Desulferization (FGD) unit is used in developed countries. Moreover, in case of co-incineration in existing plants these filter system need to be installed as well.

Depending on the dry matter content in the sludge, a range of incineration chamber can be chosen. It is expected that after at least 3 months of storage onsite, the sludge will be dried (>50% dry solid) and therefore, sludge can be mixed with waste or fed together into the incineration chamber. However, studies have shown that if the sludge ratio is too high (e.g. >10 %.), high fly ash content or unburnt material in bottom ash may occur.

The requirements incineration of textile sludge are:

- The moisture content of should be as low as possible
- Incineration should be carried out with an industrial incinerator (e.g. Figure 4) with proper emission control system
- It is recommended that the incineration temperature be sufficiently high to avoid generation of toxic chemicals such as dioxin and furan.
- The temperature of incineration chamber should be at least 800°C to avoid noxious smell
- Emission criteria such as SO_2, CO, TOC, HF, NO_x, Dioxins and Furans, chromium (Cr^{+6}) should be met as per the National emission standard for this kind of industries.

Figure 5 A industrial sludge incinerator in Antwerp, Belgium by Waterleau

As the incineration is an energy intensive (thus expensive) process, co-firing of sludges with other high calorific wastes could reduce the energy consumption. Another useful modification of sludge incineration can be introducing heat recovery system. As sludge drying is a heat consuming process and sludge incineration produces heat, integrated sludge treatment can be designed where the heat required for drying can be recovered from the heat released by the sludge incineration. In addition, it is also possible to produce electricity from the heat generated from incineration using boiler-turbine combination. The combination of heat and power recovery is known as Cogeneration system. In this process, a waste incinerator produces steam by a steam boiler and the steam goes to a back pressure turbine and produces electrical power. Moreover, the exhaust steam from turbine still contains enough heat to dry the wet sludge to some extent. Adopting any of these approaches can make the incineration process relatively cost effective.

Co-incineration/co-processing in Cement Industry

Co-incineration of sludge in the cement industry is very popular option all over the world as hazardous sludge can be mixed as fly ash. Toxic component will be destroyed in view of the high temperature of around 1400°C and longer residence time. Incinerating sludge alone can be expensive.

Furthermore in case of low temperature incineration operation, it may contribute to generation of harmful air emissions such as toxic Dioxins (PCDD) and Furans (PCDF)._However, a recent sludge co-incineration study (June 2014)[4] in Berger carried out by GIZ PSES I showed that the Dioxins and Furans concentrations in the stack gases are far below (<0.01 ng/TEQ/Nm^3) the international recommended standard (0.1 ng PCDDs/PCDFs /I-TEQ/Nm^3).

[4] I-TEQ - International-Toxicity Equivalent (I-TEQ). Toxic Equivalents, or TEQs, are used to report the *toxicity-weighted masses* of mixtures of dioxins

Various researches show the successful application of sludge in the cement production and mixing component in concrete production. India has adopted this method in 2010. In 2016, 22 cement manufacturing units in various Indian states have started co-processing sludge. The number of cement plants in Bangladesh with a cement kiln is rather limited.

The requirements for co-processing sludge are similar to those in brick making:

- Sludge needs to be dry.
- Dust emission needs to meet the particulate matter emission standards during co-processing.
- Other emission criteria such as SO_2, CO, TOC, HF, NO_x, Dioxins and Furans, heavy metals and their compounds should be met as per the National emission standard for this kind of industries.

Controlled Landfill

<u>Landfilling should be considered as the last option for the disposal of sludge, if no other alternative options are available or feasible.</u>

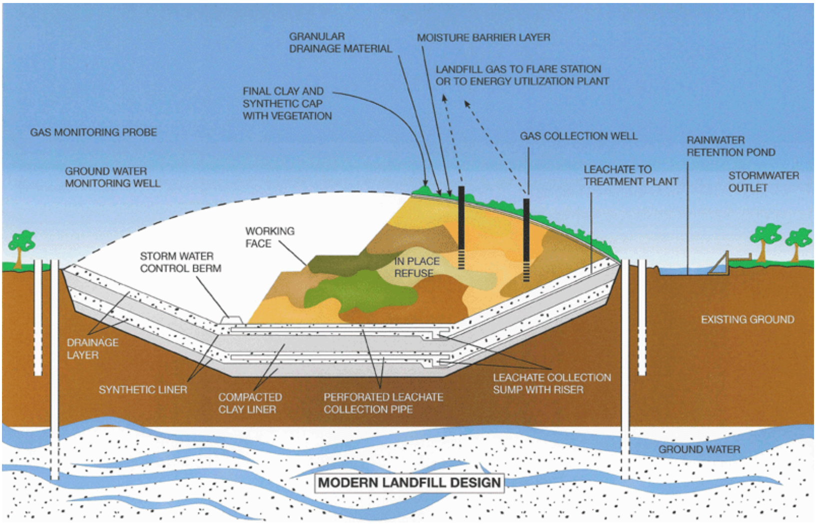
Even though controlled landfilling is isolated from the surroundings, some degree of subsurface pollution might occur despite most careful setting and proper operation.

Basic Requirements for the location of a landfill site

- The over flooding level should be of the > 2.0 m of the maximum expected water level of the surrounding water bodies
- > 500 m distance to populated areas
- No construction in protected areas
- No construction in flood plains and areas with a high risk of natural disasters
- The underground has to resist mechanical stresses, has to hold back or prevent leachate and pollutants
- Water impermeability
- Buoyancy safety has to be considered

Construction of a landfill site must be done according to acceptable specifications and standards such as EPA guidelines. The details of landfill design can be found in US EPA guideline https://www.epa.ie/pubs/advice/waste/waste/EPA_landfill_site_design_guide.pdf. An example of modern landfill design is given in Figure 6.

Figure 6 A modern landfill design in Newton County, Gerogia, USA[5]



To establish a controlled landfill site, it is necessary to obtain prior approval from the DOE, which is responsible for granting an environmental clearance certificate. Some major points to be considered during the design and construction of a landfill site are listed below.

[5] http://green-hillp3.com/

Major points for Design and Construction of a landfill site

- Proper leachate barrier system including suitable lining, ground barrier and leachate collection system.
- Suitable leachate storage, treatment and disposal system near the landfill site.
- Adequate monitoring system to assess leachate water quality and gas emission levels.
- Ground water and surface water near the landfilled facility should be tested on a regular basis to detect any failure of the landfill leak protection facilities.
- Emission of nuisance dust and other particulate matter beyond the landfill boundaries must be minimised.
- The landfill must not adversely affect local amenity, in terms of offensive odour, noise etc.
- Landfilled waste must be covered to minimise odour, dust, litter, the presence of scavengers and vermin, the risk of fire, rainwater infiltration into the waste and the emission of landfill gas. The cover material can be natural material like organic or inert waste in the form of soil with a minimum cover depth of 150 mm. However, specialty manufactured covers such as plastic sheets, tarps, foams and fabricated metal landfill lids can also be used unless there is any apparent environmental risk.
- The landfill must continue to be non-polluting and not cause environmental harm after site closure.
- It can take many years after closure for the waste to become physically, chemically and biologically stable, therefore, development on or near closed landfills should be avoided.

5. Sampling and transportation of sludge

As mentioned in section 2, the analysis of the chemical properties of sludge is required to ascertain the sludge category. Special attentions need to be paid to the specific and accurate identification of sludge sample collection points and application of correct sampling methods.

Selecting sludge sampling points

The sludge sampling points should be chosen to produce a representative sample of the sludge source. While selecting sampling locations several factors should be considered such as type of process (batch or continuous), accessibility and safety of personnel involved.

Type of Process

- Sampling sludge from **batch** process (e.g. lagoon, tank, plate and frame filter) requires collect a number of grab samples (minimum 8) from different areas throughout the sludge volume at random points to produce a composite sludge.
- For **continuous** processes multiple grab samples (minimum 8) are collected from a single location within the process over time. For example, to sample from a belt filter press, a predetermined number of grab samples are typically collected from the first accessible or the most convenient location after the sludge has passed completely through the press.

Accessibility

- At some times, the best sampling point may not be readily accessible. In such cases sampling should be performed at the next best point of accessibility.
- If there is a risk of injury inherent to a particular sampling location, then a safer alternative should be considered.

- Once a sampling location is selected, the potential risks associated with that location need to be identified. Appropriate safety precautions and protective equipment are to be considered as well.

Based on Recycle and disposal options

The representative samples of sludge need to be collected based on what best meets the stated goals of the sampling plan. The sludge sample to be used

- for **compliance** purposes, sludge should be collected at the end of the sludge treatment process, in the form in which it will be recycled or disposed.
- to observe changes in sludge **quality** or track the fate of a specific pollutant during sludge processing, then samples before sludge pre-treatment and completely processed sludge should be collected.

Sampling procedures

Proper sampling is an integral part of monitoring the quality of sludge which is to be removed for use or disposal. Four key aspects include:

- **Consistency** involves the assurance that samples are taken the same way from the same location every sampling event.
- **Communication** involves making sure the lab understands the proper methods to run, types of the sample and key details regarding the facility.
- Proper sampling activity **documentation** includes proper sample labelling, sampling method and deviation from protocol, if any and a log book of sampling activities.
- **Data handling** involves proper reviewing of the collected information before the data gets submitted.

Sample handling and preservation

When the analysis of the sludge sample is to be performed away from the sampling site, samples must be packaged, transported and preserved properly. Sample containers must be packaged in such a way to protect them and reduce the risk of leakage. Preservation of sludge sample is important since during storage several phenomena may occur such as development of odours due to anaerobic processes, mineralization of organic matter leading to loss of constituents in the form of gases such as ammonia, change of biological properties as a consequence of pathogens reduction etc.

Sludge samples are to be generally preserved by cooling and storing at 4°C, if possible. Table 4 provides an overview of recommended maximum storage time under preservation for specific analysis.

Table 4 - Maximum allowable sample preservation time before testing

Parameters to be tested	Maximum storage time before analysis
Most metals And Heavy metals: Al, As, Cd, Cr, Cu, Pb, Ni, Zn	6 Months
Mercury, Nitrogen compounds, Phosphorus Chloride, Sulphur compound, Organic Carbon	28 Days
Volatile organic compounds	14 Days
Total solid and volatile solids	7 Days
Biological parameters such as coliform, pathogen	24 Hours

Transport procedures to laboratories

Apart from proper sampling, packaging and preservation during transport of samples contributes to accurate results of sample analysis.

Packaging of sludge:

Samples can be packaged following the method mentioned below.

- Put two large plastic trash bags into a cooler or large insulated container to create a double liner. Immediately before packing the cooler, put two plastic bags filled with ice. These bags should be inside another bag to prevent leakage.
- Each individual sample container needs to be packed into plastic bag and sealed properly before putting into the cooler.
- The cooler lid should be properly closed and the horizontal joints need to be sealed with duct or packing tape before transportation.
- Label the container properly with the sufficient details of sampling procedure, name of the relevant personnel etc.

Cooler is recommended mainly for freshly generated sludge, however, it is expected that 3 months older sludge stored onsite should be sufficiently dry and therefore, may not needed cooler or plastic bag with ice.

Transport of sludge

Samples are generally hand delivered once the proper sampling and documentations are done. Transportation by truck is the most convenient method for handling larger sample. This method requires relatively low investment cost and offers a high degree of flexibility. It is also easier to arrange rerouting and alteration of collection points. However, transporting with truck might cause leakage and emission problem.

Preservation of sludge during transport:

- Exposure to extreme temperatures during transport may compromise the collected sludges samples. The testing results may not accurately reflect the true conditions.
- Exposure of sludge samples to high temperatures and freezing are not recommended as they can encourage growth of

bacteria followed by degradation of the organic components in a sample and cause sample containers to break, respectively.
- Sample containers must be packaged properly in order to protect them and to reduce the risk of leakage.

6. Parameters to be tested

Sludges exhibit wide variations in their properties depending on origin and previous treatment, and therefore need to be characterized before planning to disposal method and/or potential applications.

The parameters for conventional characterization of sludge can be grouped into physical, chemical and biological.

- Physical parameters which give general information on sludge in terms of ease of processing and handling.
- Chemical parameters are relevant to the presence of nutrients and toxic/dangerous compounds to identify the disposal options such as in agriculture and brick manufacturing.
- Testing of biological parameters provide information on microbial activity and organic matter/pathogens presence, thus allowing the safety of use to be evaluated.

However, the testing of all these parameters is expensive and time consuming. Therefore, it may be necessary to decide on a few important (key) parameters which allow for quick and convenient determination of sludge properties. There are few parameters which are extremely important irrespective of the potential application. These parameters must be evaluated for sludge before any application.

Table 5 lists the parameters relevant for various sludge utilization/disposal methods.

Table 5 - Parameters need to be tested before deciding on any sludge disposal application

Priority	Parameters
Primary Parameters	Total Organic Carbon (TOC) Moisture Content Calorific Value Heavy metals: Cr, Cd, As, Pb, Cu, Ni, Hg, Zn Sulphur Content
Secondary Parameters	Organohalogen Polychlorinated biphenyl (PCB) Polychlorinated dibenzodioxin (PCDD) Polychlorinated dibenzofuran (PCDF)

Some additional parameters should also be tested based on the specific disposal route. For example, Salmonella, Helminth ova, Phosphorous and Nitrogen are important for agricultural application, whereas Chloride is important for high temperature applications. Table 6 shows some additional parameters recommended to be tested relevant to specific application.

Table 6 Additional parameters relevant to specific sludge disposal options

Option	Parameters to be tested*
Agriculture	Salmonella, Helminth ova, Nitrogen and Phosphorus
Construction material/Brick	Benzene, Halogen
Biogas	Moisture content in a slurry
Incineration	Halogen, Benzene
Landfill	Benzol, Toluol, Ethylbenzol and ortho-xylol, Petroleum-derived hydrocarbon, Polychlorinated biphenyl, Polycyclic aromatic hydrocarbons Chloride

7. Proposed Limit for Different Categories of Sludge

To simplify the classification approach, an acceptable limit for the major sludge quality parameters have been proposed in Table 7. The threshold mainly differentiates between *Categories A, B* and *C*. Limits for *Category A* is suggested based on the Sludge Management Guideline limits adopted from German Sewage Sludge Ordinance, July 2002. The limits to distinguish between *Category B* and *C* have been adopted from the US EPA limits recommended for sludge disposal. Only *Category B* sludge is recommended for textile sludge disposal options as mentioned before. *Category C* sludge are too hazardous for these application and must be landfilled following proper procedure.

Table 7 Limits of heavy metal concentration in textile sludge for different sludge Category

Parameter	Unit	*Category A**	*Category B#*	*Category C*
As	mg/kg	≤ 40	41-75	> 75
Cd	mg/kg	≤ 10	11-85	> 85
Cr	mg/kg	<600**	<600	> 600
Cu	mg/kg	≤ 800	801- 4,300	> 4,300
Pb	mg/kg	<840**	<840	> 840
Ni	mg/kg	≤ 200	201-420	> 420
Zn	mg/kg	≤ 2500	2,501-7,500	> 7,500
Hg	mg/kg	≤ 8	9- 57	> 57

* According to the limits imposed in Bangladesh standard and guidelines for sludge managements of sludge for use as compost/fertilizer
#U.S. EPA Standards for the Use or Disposal of Sewage Sludge (40 CFR Part 503)
**As the present limits for these parameters are slightly higher than the US EPA values considered for *Category B* and *C*, US EPA limits are considered for consistency.

Based on this proposed limit the classification of textile sludge can be carried out according to Figure 7 and corresponding sludge management options are given in Table 8.

Figure 7 Decision Tree for Classification of Textile Sludge

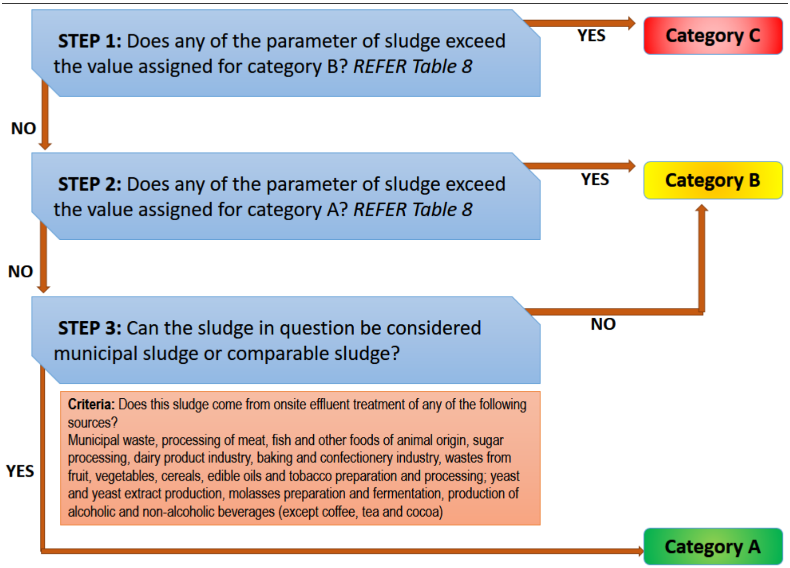


Table 8 Generalized guide for selecting suitable sludge disposal option

Disposal Options	**Sludge *Category***			**Bangladesh Scenario**
	A	*B*	*C*	
Anaerobic digestion (co-fermentation)	X*	X*	X¥	Pilot Trial
Aerobic digestion (composting)	X*			Need to be tested before application
Agricultural use	X			Need to be tested before application
Controlled landfill[Ψ]	X	X	X	Not yet started but easily implementable
Thermal incineration	X*	X*	X*	Pilot Trial
Land application	X	X#	X¥	Commonly practiced
Recycling in brick, cement or asphalt	X	X§	X¥	Formal and informal brick trial, pilot trial to make Compressed

making				Stabilized Earth Blocks (CSEB).

* Residues will remain that have to be disposed of, fulfilling the requirements applicable to the *Category*, on an alternative route e.g. by landfill.
\# Inert material (low organic matter required)
§ Availability and capacity limited by local conditions. Accepted sludge volume limited due to a loss of compressibility of the product
Ψ Requirements for the landfill class vary depending on *Category* of the sludge.
¥ The producer may provide evidence that sludge categorised as *Category C* sludge according to Annex 1A or 1B of Standards and Guidelines for Sludge management does not possess any hazardous characteristics; in this case it may be categorised as *Category B* sludge and the management options anaerobic digestion (co-fermentation), land application (filling material e.g. for flood prevention), recycling in brick, cement or asphalt making are permissible.

8. Sludge management plan

The producer of the sludge is responsible for preparing a sludge management plan that comply with the relevant standards and guidelines. Therefore, the producer of the sludge is required to submit a sludge management plan to the DoE as part of the environmental clearance information required for ETP or in case of any modification from the existing condition.

Factories should have their sludge tested in a reputable laboratory and their sludge management plan, to be agreed with the DoE, can propose disposal of their sludge as Category *A, B* or *C* depending on the results of the analysis, which enables their sludge category to be determined.

In any case, direct land application of sludge from textile ETPs or using it for agricultural purpose is not permitted. Other options relevant to *Category A* may be considered based on strict verification and duly obtained permission from DoE.

A sample requirement of the plan is given in Annex A.

Annex A: SLUDGE MANAGEMENT PLAN

(Applicable for all Textile industries with ETP that generates any amount of sludge)

1.	Name of The Company	:	
	a. Name of the Entrepreneur	:	
	b. Address	:	
2.	a. Name of The Industry	:	
	b. Address	:	
3.	Is the wastewater generated in the same facilities? If NO, then address of the Wastewater generation site	:	☐ YES ☐ NO
4.	The expected amount of sludge	:	t DM/yr
5.	The amount of sludge generated	:	t DM/yr
6.	The origin of the wastewater classified based on waste processes (Refer Annex 2B of Bangladesh Standards and Guidelines for Sludge Management, 2015)	:	
7.	The class of Sludge from the ETP		☐ *CATEGORY A* ☐ *CATEGORY B* ☐ *CATEGORY C*
8.	Storage duration of sludge	:	months
9.	Capacity of sludge storage tank	:	tons
10.	Storage Tank size: Area m^2 height/depth: m		

11.	Planned option for safe disposal or use	: ☐ Composting ☐ Brick ☐ Constructions (other than bricks) ☐ Co-incineration ☐ Bio-gas ☐ Co-generation ☐ Controlled landfill ☐ Others
12.	Is the Documentation on fulfilment of requirements relevant for this option complete?	☐ YES ☐ NO
	If YES, then Please attach copies of the documents with the form.	
13.	Company and address of further parties involved in sludge management including collection, transport, recovery and disposal of sludge, including the supervision of such operations and after-care of disposal sites (ATTACH A SEPARATE SHEET WITH THESE INFORMATION)	
14.	Discuss and attach Documentation on suitability of recovery or disposal plant or site:	
15.	Company and address of the laboratory accredited by the appropriate authority commissioned to conduct any analysis, if applicable:	